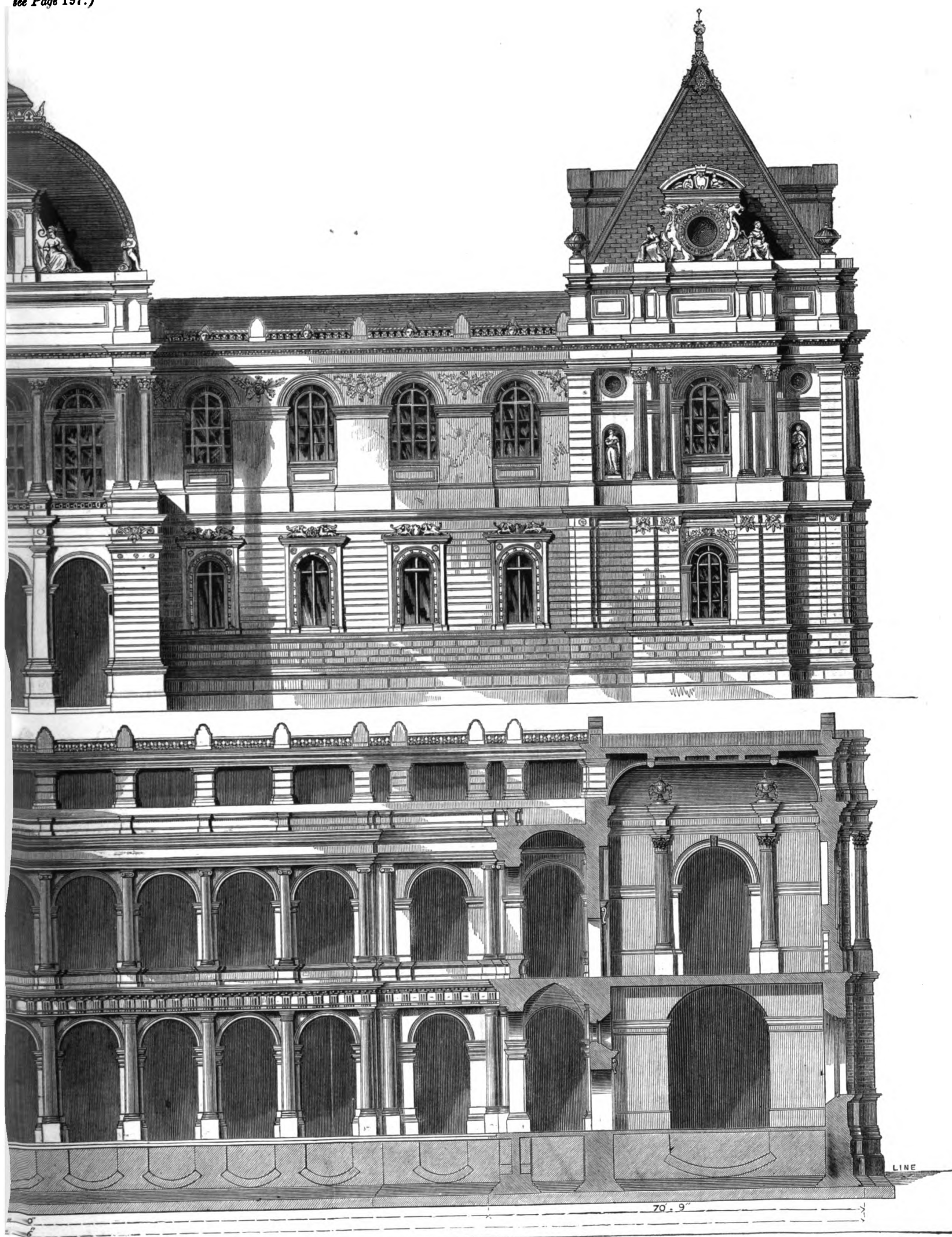


MUSEUM AT CALCUTTA.
(LLE, ARCHITECT.
see Page 197.)



NEW MUSEUM AT CALCUTTA.

It is now some four or five years ago since the Indian Government determined on erecting a set of public buildings in Calcutta, which should be worthy of the capital of so vast an empire, and amongst these are to be buildings for the post-office and telegraph departments, the mint, accommodation for the several departments of the executive, and a new imperial museum.

The two-page engraving which we give this week illustrates the design that has been approved for the last of the above-named buildings, which will contain the Geological Survey offices, the Geological Museum, and the Asiatic Society's Museum, in addition to the necessary libraries, reading-rooms, &c., &c.

The site selected for the building is at the corner, enclosed by the junction of Chowringhee-road and Sudder-street, and it will have a frontage of 319 ft. in length on the former, and 255 ft. 6 in. on the latter street. The building is to be in two stories, and of a total height of 84 ft. to the spring of the raised roofs. The designs are by Mr. W. L. Granville, architect to the Government of Bengal, and the total estimated cost is 66,000*l*.

THE ENGINE TRIALS AT BILLANCOURT.

TO THE EDITOR OF ENGINEERING.

SIR,—In your publication of August 80th, page 176, you give a limited report of the Paris Exhibition engine trials, at Billancourt, and fall into an error respecting ourselves. It is stated "the English competitors were Ransome and Sims, Marshall and Sons, and Tuxford with the Allen engine." You then give a minute description, embracing certain scientific terms and explanations of the brake employed by Messrs. Ransomes. You next remark, "The brake used by Messrs. Marshall and by Messrs. Tuxford was defective in principle," and finish your report with a lengthened statistical statement of the fuel consumed by Messrs. Ransomes and Sims in their trial, concluding as follows: "The above data give, according to the English standard, 3.59 lb. per horse power per hour."

Permit us courteously to remark we are not exhibitors at the Paris Exhibition; that we have not this year, up to this time, visited Paris; and that we have neither sent over parties to represent us there, or delegated to any one in Paris, or elsewhere, an authority to appear for us. Early in 1866, we made several engines for Mr. E. E. Allen on his "patent double-expansive principle," one of which remained in our stores until this year, when it was sent to London by the patentee's order: since then we know nothing of the engine.

In regard of the brake employed, permit us, as our name by your correspondent is connected with a defective brake, to observe that in our factory testings we employ brakes much simpler than the one so scientifically described as is the Messrs. Ransomes', and yet so correct in their results, that we find them to accord with the brakes of the Royal Agricultural Society of England when we come under the society's testings at their periodical trials.

In conclusion, we would ask permission, as our names have been brought prominently forward in the report with the names of Messrs. Ransome and Sims, to make some comparison between the consumption of fuel of our own engines and that of the Messrs. Ransomes, using your own reports as the authority for our statements. At the Royal Agricultural Society's Show this year, at Bury St. Edmunds, you gave closer attention to the society's trials of engines than had ever before been given by any scientific representative of the public press, and you produced a more elaborate and complete schedule of results than had ever before been prepared for the scientific public; to this schedule, which was published in *ENGINEERING* in July last, at page 44, we beg to refer, and extract the following:

Tables No. 3 and 4. Portable Engines with Single Cylinders.

1st Series of Trials.

"Tuxford and Sons... 3.55 lb. of coal per horse power per hour.

Ransome and Sims ... 4.55 lb. "

2nd Series of Trials.

(Engines working at 50 per cent. increased power.)

Tuxford and Sons ... 2.98 lb. of coal per horse power per hour.

Ransome and Sims ... 3.64 lb. of coal per horse power per hour."

At Billancourt, the engine of Messrs. Ransomes and Sims corresponds with the one they ran at the Bury trials; it was a single cylinder expansion one, the diameter of cylinder being 10 in., and the length of stroke 13 in.

We are, Mr. Editor, yours very truly,

TUXFORD AND SONS.

Boston, Lincolnshire, September 3, 1867.

MARINE ENGINES OF THE FRENCH NAVY.

TO THE EDITOR OF ENGINEERING.

SIR,—I think every competent observer must concur in the justice of the strictures you have uttered respecting M. Du Puy de Lôme's engines for the French navy, which are not merely heavy, complicated, and costly, but devoid of that power of adaptation to circumstances which every marine engine, but more especially the engine of a war vessel, should possess. The central cylinder measures under all circumstance to the side cylinder a certain modicum of steam, and although the amount may be reduced by throttling, it cannot be increased. In Mr. Penn's engine, on the contrary, the supply of steam can be increased, under urgent circumstances, by a large blast pipe in the chimney, and the engines may be made to consume this increased supply of steam by throwing out the expansion valves. In the case of two war vessels, consequently, of equal size and power, one furnished with M. Du Puy de Lôme's engines, and the other with Messrs. Penn's or other English engines of good construction, the power and speed may be temporarily increased in one engine, but not in the other; and in any contest between two vessels, in other respects equal, it is not difficult to understand what momentous advantage a superiority of speed may give. No doubt a valve might be introduced between the central and the side cylinders to enable the side cylinders to be worked with steam of full pressure throughout the stroke. But this valve would simply have the effect of rendering the central cylinder inoperative, and if inoperative it is better not there. Add to this the fact that if anything happens to any part of

the complex combination, and the whole nicely poised system is overturned—since in such event none of the engines can be worked at all—and it will at once be seen how unsuited for practical use are the overstrained ingenuities by which M. Du Puy de Lôme has managed to spoil the engines of the whole French navy. It is plain that if anything happens to any part of the gear of the central cylinder which hinders it from working, then the side cylinders will not work either, as they cannot get steam; and if anything happens to either of the side cylinders, the central one will be unable to work, as it will be unable to dispose of the steam it discharges. In ordinary engines even, if one engine should be disabled, the other may nevertheless be worked to propel the vessel. But in M. Du Puy de Lôme's *improvement*, if any part of the complex combination goes wrong, the whole of it is thrown out of joint, as no part of it can be worked by itself.

I am, &c.,
OBSERVER.

WATERWITCH, VIPER, AND VIXEN.

TO THE EDITOR OF ENGINEERING.

SIR,—In a letter on the hydraulic propeller, which you did me the favour of inserting in your issue of 9th ult., I mentioned that this invention had been kept back for the last twenty years, mainly through the influence of men of science, who had proved in their own way that this propeller utilised less than one-fifth of the power employed—wasted, in fact, some 80 out of every 100 tons of coals consumed. I further stated that it was but very recently that an elaborate analysis had been published by Mr. J. A. L. Airey, showing that 14 to 18 per cent. was the whole of the useful effect given out by the Waterwitch; but, "with suitable propelling machinery, he saw no reason why we might not, with the same engine power, get nearly 13 knots instead of 9." Seeing that this increased speed required about 200 per cent. additional horse power, and seeing further that the hydraulic had already beaten the double screw, that expectation seemed to me, with all my predilections in favour of the hydraulic, rather extravagant; and I designated it as one of those "vagaries of science" which have so long kept back this invention. To "this attempt to fasten on him an apparent absurdity," Mr. Airey now replies, that "if the useful effect obtained was only 18 per cent., as he still believes it to be, and suitable machinery employed to give a useful effect of 45 per cent., which he also believes may be done, the speed would undoubtedly be raised from 10 to 13 knots and upwards for the same engine power employed." No doubt, if 18 only per cent. be the whole of the present power realised. But in this *if* lies the whole question; and here, I also think, lies the absurdity which should have been manifest to men of science as clearly as to any one taking the very simplest and common-sense view of the matter.

As the Waterwitch had beaten the screw, and as the screw and paddle, as admitted by all, gives out more than 50 per cent. of the power employed, so, obviously and logically, the Waterwitch must have given out more than 50 per cent.; there remained therefore—not 200 nor even 50 per cent. more to be obtained. Further, as the Viper and Vixen had both been beaten, and as they, with their first-class machinery, must be allowed to give out 50 per cent. of their power employed, so must the scientific proofs which showed only 18 per cent. in the vessel which beat them be acknowledged a mistake. It was clearly the *reductio ad absurdum*, and ought to have suggested the existence of grave error.

It would hardly seem, however, that Mr. Airey admits that the screw does, in all cases, utilise 50 per cent. of its power. If, he says, he had referred to the Viper and Vixen at all, "it would only have been to draw a strong presumption that their efficiency was somewhat lower even than that of the Waterwitch—that is, below 18 per cent." Afterwards, he goes on to state that "if the low efficiency assigned to Mr. Ruthven's wheel, in its present form, be really doubted, the Waterwitch should be compared with 'any good example' of the single screw or paddle, as, for instance, the Royal 'Alfred, frigate, when it would be found that the useful effect achieved by the latter was about three times that of the former,' namely, 54 per cent. From this it may be gathered that Mr. Airey supposes that not only the hydraulic—but some alteration in the machinery—may be made to give out three times the present power, but so may it be with the Viper and Vixen. Thus the efficiency of the screw-propeller is also supposed to vary between one vessel and another about 200 per cent. Now, is there any ground for such an opinion? Were it true, how could any engineer guarantee a given speed with his vessel, if the propeller be liable to a varying efficiency of 200 per cent.?

In answer to the suggestion that the Waterwitch ought to be compared with a "good example of a vessel" like the Royal Alfred, in place of bad ones like the Viper and Vixen, it is enough to say that only like vessels can be compared with each other in order to ascertain the relative value of the propellers. The Viper, Vixen, and Waterwitch are similar in length, displacement, and horse power; and, bad as they may be, it is not believed that a single vessel can be named, of same length, displacement, and power, which has attained a greater speed. Many vessels, no doubt, with similar power merely, are much faster; but it will be found that they have greater length or less beam and less displacement.

Is it too much to hope that science would reconsider its verdict on the efficiency of the hydraulic propeller—meaning by that the Ruthven arrangement, which has proved a success, and not any of the many other tried arrangements which have ended in failure, nor any of the many newly suggested or could-be-devised arrangements, which are still merely ideas, and have yet to be tested in practice? Science might thus do a service to the hydraulic propeller, and make up, to some extent, for the injustice which it has done in the past; and as the screw has been beaten, it would seem safe, in the new investigation, to start from the point that the new propeller gives out, not 14 to 18, but something more than 50 per cent. of the power employed.

London, September 3, 1867.

W. B.

LOCOMOTIVE DIMENSIONS.

TO THE EDITOR OF ENGINEERING.

SIR,—Your amusing contemporary, *The Engineer*, last week gave us a copy, from a photograph, of one of the engines which have been running for the last five or six years on the Great Eastern Railway. After half a page of empty generalities, I find the following jumbled string of dimensions, &c.:

"The following are amongst the principal dimensions of these engines, viz.: Weight of engine, empty, 27 tons 10 cwt.; weight of engine on service, 30 tons 10 cwt.; weight of engine, empty, on leading wheels, 9 tons; weight of engine, empty, on driving wheels, 9 tons 10 cwt.; weight of engine, empty, on trailing wheels, 9 tons. Diameter of driving wheels, 7 ft. 14 in.; diameter of leading and trailing wheels, 3 ft. 7½ in.; diameter of boiler (outside), 4 ft.; diameter of cylinders, 16 in.; diameter of boiler tubes (exterior), 1½ in.; length of boiler, 16 ft. 9 in.; length of boiler between tube plates, 12 ft. 1½ in.; surface, 320 ft.; total heating surface, 344 ft.; length of fire-box, 4 ft. 9 in.; stroke of pistons, 2 ft.; total wheel base, 15 ft.; distance from centre to centre of cylinders, 6 ft.; thickness of boiler plates, ½ in.; weight of tender, empty, 11 tons. The copper pipes used are ¾ in. thick; the boiler is butt-jointed and single-riveted."

May I ask what it is of which the "surface" is given as 320 ft., and if it be the fact that the total heating surface is but 344 square feet? Even the famous Rumble engine had twice this surface, although still having not more than one-half what was required for an engine of its weight.

I am, &c.

GEORGE H. HATHERTON.

Manchester, Sept. 3, 1867.

[We are unable to answer our correspondent's query as to what the above "surface" may mean; but we may mention that the heating surface of the engines referred to is as follows: Tube surface, 969 square feet; firebox surface, 82.3 square feet; total heating surface, 1051.3 square feet. Several of the dimensions given in *The Engineer* are also incorrect.—ED. E.]

STEAM FIRE-ENGINES.

TO THE EDITOR OF ENGINEERING.

SIR,—In course of a long article in *The Engineer* of last week, I notice the editor refers to diagrams taken from steam fire-engines, the valves of which have very little lap, and the diagrams, consequently, nearly rectangular—a figure which does not indicate, of course, economical working. He accounts for it by stating that economy of fuel is "a matter of no importance whatever in steam fire-engines." Now I have always supposed that economy of fuel would be a matter of importance, so that the boiler might be reduced in size, but that the valves are made with little lap, on account of the difficulty of working small pumping engines when the steam is cut off, unless they are fitted with very heavy fly-wheels, and it is for this reason, seeing the objection to heavy fly-wheels in such cases, I have supposed that the valves are made with a small amount of lap. I would like to know if I am right in this supposition also. Perhaps some of your correspondents would kindly say if they are acquainted with an arrangement of balanced slide-valves, with the cut-off valves on the back of the main slides, acting the part of equilibrium rings. It seems to me that these cut-off slides, if so fitted with rings, could not relieve the pressure from the main slides; at any rate, if they did, the plan could not be a good one. It is recommended in *The Engineer*. Pardon me for thus troubling you, but I like to know the reason for such things.

Yours respectfully,

AN APPRENTICE ENGINEER.

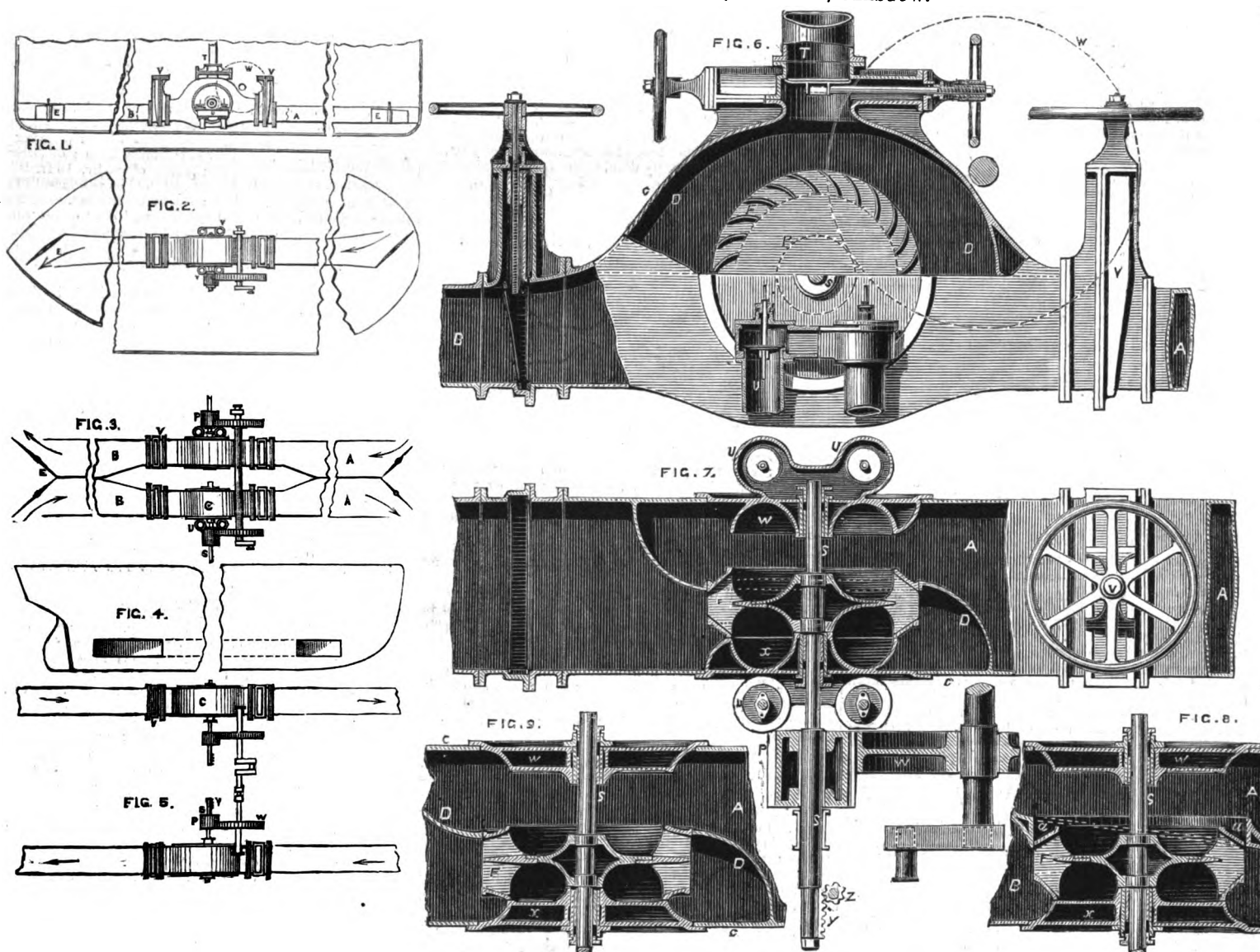
RANDOLPH'S HYDRAULIC PROPELLER.

MR. CHARLES RANDOLPH, of the well-known firm of Randolph and Elder, of Glasgow, has recently patented the arrangement of propelling machinery for vessels, of which we give engravings on the next page. All kinds of propelling apparatus applied to vessels may be considered as machinery for forcing water astern; and Mr. Randolph considers that there is no reason why a pump, properly applied, should not do this work as well as a paddle-wheel or screw, the power required to keep a pump in motion, when not forcing water, being no greater than that which would be required to drive a pair of feathering paddles or a screw with its shafting, supposing these two forms of propeller were doing no work. In arranging his hydraulic propelling machinery, it has been Mr. Randolph's object to convey the water through as direct a course as possible, and he intends that the water should leave the delivery-nozzle with a velocity approximately equal to that which would be given to it by a paddle-wheel or screw-propeller.

The apparatus consists of a fan or centrifugal pump placed in a casing connected with a couple of channels, or ducts, leading the one to the head and the other to the stern of the vessel. The fan-shaft is placed horizontally, and the fan is driven by a simply arranged engine, without reversing gear. The principal feature in the arrangement is the manner in which the direction in which the water is propelled through the ducts is changed by altering the position of the fan in the casing. There is in the casing a diaphragm or partition, the inner edge of which is just cleared by the fan, and the ducts or passages communicating with the bow and stern respectively open into the circumferential parts of the casing on opposite sides of the diaphragm. The fan is shifted by moving its shaft in the direction of its axis; and when the fan has its circumferential openings to that side of the diaphragm, which is in communication with the stern duct or passage, the water will be forced out by that duct, and drawn in by the other, and the vessel will be propelled ahead. When the fan is shifted to the other side of the diaphragm the action will be reversed, whilst, if the fan is in its middle position, the water will move in circles on each side, and the ship will not be propelled in either direction, although the engines may be working at full speed. The fan has an open central eye on each face, but the movement, which brings the circumferential openings to one side of the diaphragm in the casing, causes the eye of that face to be closed against the side of the casing, whilst the eye of the other face is drawn away from the other side of the casing, and the water has thus free access by it into the

RANDOLPH'S HYDRAULIC JET PROPELLER.

DESIGNED BY MR. CHARLES RANDOLPH, ENGINEER, GLASGOW.



fan. Figs. 1 and 2 of the engravings show a vessel in longitudinal, vertical, and horizontal section as fitted with one modification of the apparatus, and Figs. 6 and 7 are longitudinal, vertical, and horizontal sections of the apparatus to an enlarged scale. In this example there is a single centrifugal fan or pump, F, disposed in a casing, C, and fixed on a horizontal shaft, S, which passes through stuffing-boxes in the sides of the casing, and has fast on it a pinion, P, in gear with a spur-wheel, W, driven by an engine which is not shown. The engine may be arranged to act directly on the fan-shaft, S, if preferred. The pinion, P, is made of extra length, so as to admit of the movement of the shaft, S, to one side or the other without its getting out of gear from the spur-wheel, W. The casing, C, is divided by a partition or diaphragm, D, into two compartments, which may be termed the starboard and larboard compartments respectively, the bow being supposed to be towards the right hand in the engravings. In Fig. 7 the fan, F, is represented as having its circumferential openings in the starboard compartment, in which position it will propel the vessel ahead. The water enters a passage, A, at the bow, which communicates with the larboard compartment of the casing, C, and thereby has access to the larboard eye of the fan, F, being driven by the fan out of the starboard compartment along the discharge passage, B, leading to the stern. The sides of the passage, B, merge into those of the starboard compartment of the casing, C, with curves suitable for a proper delivery of the water from the fan into it; and the passage, A, also joins the larboard compartment of the casing in the same manner. This arrangement gives sufficiently free access for the water to the fan, with at the same time the best form for its delivery therefrom in which-ever direction it may be propelled. The propelling action is reversed by shifting the shaft, S, with the fan, F, to larboard, when it will drive the water out of the larboard compartment towards the bow, and the water will enter from the stern by the starboard compartment. This shifting of the fan-shaft, S, may be effected by means of any convenient appliance, which will depend on the size of the parts. In Fig. 7 a rack-toothed bush or tube, y, is shown, fitted on the shaft, S, but so arranged as not to turn with it; and in gear with this rack-toothed bush there is a pinion, z, on a vertical shaft passing up to the deck, so that it can be actuated by a hand wheel.

The form of centrifugal pump or fan shown in the engravings is that preferred by Mr. Randolph, but his patent does not relate to that part of the apparatus, excepting so far as regards the shifting of it transversely to reverse the propelling action.

When the fan is in the position shown in Fig. 7 for propelling ahead, the edge of the starboard eye is in contact or almost in contact with a circular partition, x, cast in the casing, C, to prevent the access of water to the eye of the fan on that side, and similarly when the fan is moved into the position for propelling astern its larboard eye comes into contact or nearly into contact with a corresponding partition, w, at the other side of the casing. Slightly different forms of the partitions, w, x, are shown in horizontal section in Figs. 8 and 9, which figures also show variations in the forms of other parts inside the casing, C. In the arrangement shown in Fig. 7 the circumferential openings of the fan, F, communicate with both starboard and larboard compartments of the casing, C, when the fan is in the middle position, but in that shown in Fig. 8, a cylindrical belt, d, is formed in the diaphragm in such a way that the circumferential openings of the fan are entirely withdrawn from one compartment before they begin to open in the other compartment.

In the modifications of the fan shown in Figs. 7 and 8, both eyes communicate with the same circumferential openings, but in that shown in Fig. 9 each eye communicates with separate circumferential openings, with a view of giving a more nearly radial motion to the water with less liability to form eddies.

Sluices, V, are provided to admit of the casing, C, being shut off from the fore and after passages, A, B, when access is wanted to the inside, such access being obtained through a man-hole door. The casing, C, has also fitted in connexion with it various pipes or passages to admit of the action of the fan being availed of in various ways. Thus a pair of pipes, U, with lift valves is fitted at each side of the casing for withdrawing water from the ship's bilges or hold, whilst two larger pipes, T, having sluices, are fitted in communication with the top of the casing to be used for clearing the ship of water entering at a leak or shot-hole, or for leading water to any part of the ship in case of fire. When the fan is used for drawing water from the ship by the pipes, U or T, or both, the sluice, V, on the inlet side may be more or less closed; and if in the case of a serious leak it is entirely closed, the entire power of the apparatus can be made available for discharging the water from the vessel, and that whilst still continuing the propelling action.

Fig. 8 is a diagram showing in plan a modification in which two fans are employed in separate casings, C C. When two fans are used in this way, they may be both fixed on one shaft, having fast on it, by preference in the middle space between the casings, a single pinion driven by a spur-wheel on the engine

shaft; but in the modification shown in Fig. 8 a different arrangement is adopted in order to obtain increased steering or turning power, the fans being on separate shafts in the same line, each with its pinion, P. The pinions, P P, are at the outer sides of the casings, and are actuated by separate spur-wheels, W W, on the engine-shaft. The inlet passages, A A, forward, and the outlet passages, B B, aft, are for the most part close together, merely diverging near the casings. When the two fans are on one shaft, so as always to act together the forward passages, A A, may merge into a single one, as may also the after passages, B B.

Figs. 4 and 5 are diagrams showing another modification in which the casings, C C, with the fans and the passages, A A and B B, are arranged at the sides of the vessel instead of being in the middle, as in the modification shown in Fig. 3.

For the purpose of steering the vessel, one or more deflecting plates are fitted at the outer ends of the water-ducts or passages, A A, and these deflecting plates are by preference arranged like common throttle-valves or balanced rudders. In the arrangement shown in Figs. 1 and 2 there is a single deflecting plate, E, at each end, and when turning the vessel these are set as shown, so that both assist in the action. In the arrangement shown in Fig. 8, there are two deflecting plates, E, at each end, and if the four are set in such positions as they are shown in the figure, whilst the fans are so placed as respectively to cause the water to traverse the ducts in the directions indicated by the arrows, the vessel will be turned in a very small circle or on its centre. In the arrangement shown in Fig. 5, deflecting plates are not required, as the vessel can be steered or turned by simply moving the fans into different positions, or an ordinary rudder may be used.

FRENCH MECHANICAL INDUSTRY.—The great Creusot works employ 10,000 workpeople, and produce 110,000 tons of iron annually. The Commentry and Châtillon Forges Company employs 9000 workmen, divided among the various establishments of the company, which are situated in five departments. This company produces annually 70,000 tons of metallurgical products. The house of Petin, Gaudet, and Co., which has obtained distinction in connexion with the manufacture of steel, possesses six establishments in different departments, employs 5200 men, and has, besides, steam-engines of an aggregate force of 6000 horse power. It produces annually 50,000 tons of iron and steel.

PUBLISHER'S ANNOUNCEMENT.

Advertisements cannot be received for insertion in the current week later than 5 P.M. on Thursday. The charge for advertisements is three shillings for the first four lines or under and eightpence for each additional line.

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ENGINEERING.

FRIDAY, SEPTEMBER 6, 1867.

THE METROPOLITAN RAILWAY.

WHEN, thirty years ago, the first bill of the Great Western Railway Company was before Parliament, it was opposed, among other things, upon the ground that the atmosphere of the Box tunnel, 1½ miles long, would be dangerous to the health of passengers. Dr. Lardner was one of the principal witnesses against the bill, and, as usual, he was very positive in giving his evidence. The subject was investigated, however, with considerable care, and, as our readers know, the bill passed, and we believe no one has ever suffered in health from a ride through the Box tunnel. That work, however, is of very large sectional area of opening, and its eastern end is 92 ft. higher than its western end, so that there is always a considerable natural draught through it. A much longer tunnel, of much smaller section and much less inclination, is that of the Manchester, Sheffield, and Lincolnshire Railway, at Woodhead, its length being 3 miles 44 yards, and the width of each separate tunnel (for there are two, at a distance of 18 ft. apart) is but 14 ft. 6 in.; and the ventilation is by no means good, neither of the five shafts coming down into either tunnel, but into the 18 ft. wall between them, this wall being intersected by openings at intervals of a few hundred yards. When but one tunnel was open, the men working the pilot and goods engines suffered considerably, and Mr. Peacock, of the present firm of Messrs. Beyer, Peacock, and Co., who had charge of the locomotive stock of the line, several years ago, has told us how rapidly his men were knocked up in the service. The total fall of the Woodhead tunnel, we may add, is 80 ft., or at the rate of 1 in 201, towards Manchester.

Three passengers have lately died, suddenly, in the tunnel of the Metropolitan Railway, and at the inquests the coroner, Dr. Lankester, has treated the foulness of the air of the tunnel as a matter beyond dispute, and has endeavoured, but without effect, to put words in the mouths of the witnesses, and to induce them, or rather to force them, to concur in his own views, which were expressed in the tone of an advocate, and not in that of a judge. In every case, however, the deceased persons were found, upon *post mortem* examination, to be in an advanced stage of heart-disease, with more or less extensive affection also of the liver and brain. They were, according to the medical testimony, literally liable to die at any moment, or in any place where the air was a little close, as in a theatre or a crowded room. In one case, and in spite of Dr. Lankester's persistent attempts to sway the witness into a support of his own (the coroner's) views, the surgeon who made the *post mortem* examination refused to express any opinion whatever that death was attributable to "the foul air of the tunnel."

The tunnel of the Metropolitan Railway resembles, in its mode of working, no other railway tunnel in the kingdom. Although trains are constantly passing through it, the engines have no artificial draught upon their fires, and their steam is wholly condensed in tanks of cold water. We do not say that no consumption of coke goes on in the tunnel, but, as no steam draught is kept up on the fire, the production of carbonic acid gas must necessarily be small, and the production of sulphurous acid gas must be, of course, almost in-

initely less still. It would require, indeed, very nice experiments—and these have not been made, and would, indeed, be very difficult to make—to ascertain exactly what amount of coke is burnt per mile in the tunnel, the steam blast, with which ordinary locomotives are worked, being off, and all the waste steam condensed in the cold-water tanks of 1000 gallons capacity, this quantity being irrespective of the water carried for the purpose of supplying the boiler, and being emptied at each journey. We have good reason to believe, however, that not more than 10 lb. of coke is actually burnt per mile, while the steam blast is off; and assuming this to be pure carbon, it would produce 36½ lb. of carbonic acid gas, and this, at atmospheric temperature, would occupy 319 cubic feet. It would be discharged from the locomotive chimney at a temperature of perhaps 600°, or even more, and would therefore have a volume more than twice greater than that at atmospheric temperature; but as it would be soon chilled against the walls and roof of the tunnel, our estimate of 319 cubic feet will still hold good. Now the cross sectional area of the tunnel is 400 square feet, and each mile of its length therefore contains 2,112,000 cubic feet of air, within which the 319 cubic feet of carbonic acid gas would be diffused. Atmospheric air of average purity contains $\frac{1}{1000}$ of its bulk of carbonic acid gas, or less than the $\frac{1}{10}$ part of 1 per cent., and it is only when this proportion is increased by about one hundredfold, or to 4 per cent., that air becomes fatally dangerous for respiration. Now the discharge of 319 cubic feet of carbonic acid into a space of 2,112,000 cubic feet would increase the proportion of gas by less than one-half that which exists in all pure atmospheric air.

We are following this line of inquiry only because certain unquestionable facts assist us in doing so. But we are to remember that we are not dealing with a single train, but with trains rapidly following each other, and that in this way the accumulation of gas may, in a short time, become insupportable, unless the tunnel is sufficiently ventilated. It is not a question, therefore, of the proportion of gas added to the atmosphere of the tunnel by a single train, but of that which accumulates in the tunnel, after the passage of frequent trains, and supposing the absence of effective ventilation. This is the whole question at issue, and, so far, we have had no tests of the atmosphere of the tunnel to show what is the percentage of carbonic acid and sulphurous acid gases. We are to remember that there is no smoke, no steam, no dust, no sewer gas, and none of that ammoniacal effluvia of decomposing horse-dung, so common in the open streets, to be found in the tunnel. That there is an odour of *something* always in the tunnel, and it may be impossible for chemistry to detect *what*, no one will deny, and so there is in a theatre, an omnibus, a four-wheeled cab, in an eating-house, and in a sleeping-room before opening the windows in the morning. Nor need it be denied that the atmosphere of the underground railway tunnel is never so pure as that at the top of Primrose-hill, or on Hampstead-heath, or on the Highland moors. On every railway in the kingdom, where coal is burnt in the engines, the passengers are now and then assailed with a blast of choking smoke, or a *souffron* of sulphuretted hydrogen, or that asphyxiating compound of pyroligneous acid and sand-powder which attends the sudden application of the brakes. We can never, in crowded channels of conveyance, altogether avoid *smells*, nor close air, but we are not to mistake every slightly oppressive odour as the poisonous exhalation of the Upas valley. For ourselves, we have never detected the characteristic scent of carbonic acid in descending the stairs of the stations of the Metropolitan Railway, and yet we meet it in the neighbourhood of every brewery, distillery, and vinegar factory, and learn of no attendant danger to health or life in consequence of it. As for sulphurous acid gas, we believe it will be found almost beyond detection. The worst coke contains not more than 1½ per cent. of sulphur, and that burnt in the engines of the Metropolitan Railway contains, we know, a very much smaller proportion. The coke employed upon this line is that most in request by iron-founders, as containing the least proportion of sulphur, which, even in minute quantities, is so injurious to iron. This is the Brancepeth coke from Durham, and, as an additional precaution, the railway company stipulate that it shall be coked for 120 hours, to remove the sulphur to the utmost extent. Even if it then contained one-half per cent. of sulphur, which it does not, it would produce but $\frac{1}{100}$ as much sulphurous acid gas as carbonic acid gas, and the proportion of the former in each compartment of a train would be less than

that occasioned by lighting a cigar with a friction match. Indeed, we have said nothing, so far, of the odour from smoking, and, so long as railways exist, smoking can never be prevented in railway carriages. A person in the last stages of heart disease, like those who recently died in the Metropolitan Railway, would, no doubt, speedily succumb to oppression and suffocation in a carriage filled with cigar smoke, and yet the smoking interest is so strong that it is now well known to be useless for railway companies to attempt to contend against it, and smoking is openly or tacitly allowed everywhere in travelling. Sir David Brewster was carried, fainting, out of the meeting-hall of the British Association at Dundee on Wednesday evening last; and David Roberts, the painter, fell down, dying, in Regent-street, not long ago; and Sir William Lawrence broke down in his professorial chair at the College of Surgeons, only lately; yet neither of these mishaps was attributed to poisonous gases, nor to the odour of tobacco. Taking large numbers of persons collectively, there will always be a certain proportion of sudden deaths among them, and these may happen anywhere—in the street, in the omnibus, in the railway train, at the theatre, at the dinner-table, or in bed. The Metropolitan Railway managers profess to carry twenty-five millions of passengers yearly; but this is an arithmetical fiction only, applying to a far smaller number, probably very much less than a million, who often employ the line, and who are counted, over and over, as separate individuals every time they ride. There are passengers, perhaps, who ride up and down the line every working day in the year; and if these were counted as separate passengers on every journey, it would require but 40,000 to make an annual total of 25,000,000. But, without going closely into this, it must be remembered that with 200 deaths daily, from all causes in London, and with many instances of sudden death, a certain proportion must happen upon a crowded thoroughfare like the Metropolitan Railway—a line upon which no less than 120,000 passengers were conveyed upon Whit Monday last.

We are aware that tests are now going on as to the purity or otherwise of the atmosphere of the Metropolitan Railway, and we hope to publish the results very shortly. But we are to bear in mind that Dr. Angus Smith has found the atmosphere of Manchester to contain a proportion of sulphurous acid gas sufficient to redden litmus paper, and that the gases in the air of London are such as to disintegrate the stone of the Houses of Parliament, and to cause it to drop off, from the upper decorated portions, in lumps, as if broken away by sledges, falling to the danger of passengers and that scarcer biped, the policeman, one of whom lately came near being crushed by a stray dropping of this sort.

We have already said that there can be no doubt that it would be desirable to ventilate the underground railway even more completely than at present, but it is to be remembered that, so far as ordinary lungs are concerned, it is tolerably well ventilated as it is. No one, we think, would wish to assert that its atmosphere is pure; but purity is a relative term, and it is a question only whether the air of the tunnel is in any way dangerous to health. At present we believe there is no evidence to support this view.

THE SOCIETY OF ENGINEERS.

WHILE the application of the Society of Engineers, for a charter of incorporation, was before the Board of Trade, it was represented to the Duke of Richmond that confusion had been caused in Paris between the Institution and the Society, because of the reception given there to the principal officers of the latter, and especially, as we understand, that accorded by *La Société des Ingénieurs Civils*, the representative body of the profession in France. Inasmuch as the officers of the Society were personally introduced to M. Flachet, President of *La Société des Ingénieurs Civils*, by the conductor of this journal, we are enabled to say that no confusion whatever arose as to the identities of the English Institution of Civil Engineers and the Society of Engineers; and as bearing upon the matter, and possibly upon the letter of the President of the Institution of Civil Engineers, which appeared in our columns last week, we append the following remarks of M. Flachet, addressed by him to, and as president of, the representative body of the profession in France, on the 16th ult.

Referring to the recent "recognition of public utility"—equivalent to an act of incorporation—of the friendly association of the older scholars of the Ecole Centrale, an association now numbering 1533 members, M. Flachet observed:

The existence and progress of the two societies is very desirable, but this circumstance causes me to refer with pain to a misunderstanding which has come to exist between the two societies of engineers established in London. The Society of Engineers, established in 1854, and now numbering 400 members, made application to the Government for a charter of incorporation, which in its effects is similar to the powers conferred in France by a declaration "*d'utilité publique*," that is to say, the society becomes recognised as a corporate body. It confers the right to possess property, to sue and be sued, in a word, to be recognised by the law of the land. The Institution of Civil Engineers, established in 1818, and incorporated in 1828, has opposed the application of the younger society, alleging that the similarity in names would create confusion amongst the public. They have also asked the Government not to grant any charter of incorporation to any society formed in London with the title of "Engineer."

It is a question of the highest importance if the freedom of action is more restricted in England than in France. The spirit of competition is greater, and it is a matter of great surprise that a society, however eminent it may be, can demand in a large town like London the exclusive right to a word which is the only means of designating a profession.

The society which was first established has taken the name of the Institution of Civil Engineers; the other, the Society of Engineers. If a confusion is likely to arise—and we admit, if it did so even by error or by the actions of either of the societies, it would be objectionable—a number, indicative of the order or the date of incorporation, would certainly be sufficient to prevent confusion.

It is with pain and regret, and so opposed to our own ideas, that we see the engineering profession engaged in disputes.

The Institution of Civil Engineers (1818) has brought together men of the highest eminence, who, by their ability, their information, and their character, form the aristocracy of the profession; but, owing to the terms on which members are admitted, they are few in number.

It is these few in number who wish to be an oligarchical power. "No one is to be an engineer but ourselves." This is to keep up trade "freedom" and trade's unions.

Nevertheless, the young Society of Engineers, more active, more industrious, more careful, already has a number of the members of the Institution, and the terms on which members are admitted are a sufficient guarantee. They particularly admit of all uniting, meeting, and working together, and giving publicity to their transactions and works.

The older society was in want of something which should cause it to take a more active part. It was asleep, and already under the pressure of the younger Society of Engineers they have admitted *students* amongst them.

So far competition is fruitful when it is employed for a beneficial object.

Let us hope that this deplorable controversy amongst men of professional distinction will not be continued, and that, when they are again reunited, it will not be sought to impose a doctrine which, regarded individually, is totally contrary to the interests of all.

AMERICAN PROTECTION.

AN American correspondent of the *Times* draws the following vivid picture of what the trade of that country is suffering under its present exclusive system of "protection," or prohibitive tariffs upon imports of foreign goods: There are general complaints throughout America of the continued dullness of trade in all branches of manufacturing industry. The gathering of the crops and the necessities of the people have stimulated the movements of breadstuffs, but in everything else there is an almost complete stagnation. Our merchants have predicted briskness as the autumn approached, but summer is almost gone, and there is no evidence of it. Mills and factories are still running on short time, or else are completely at a standstill, and our shopkeepers complain bitterly of the absence of buyers. For many years past there has not been known a more gloomy time among American merchants and tradespeople. This stagnation is owing to various causes, chief among them being an excess of production for several seasons past, which has glutted the markets; a tendency among buyers to hold off and wait for lower prices; and the high rates of wages paid to operatives, which are higher than the prices of goods warrant, but which the power of trades' unions in all but a few branches has thus far prevented from being lowered. In this section of country the production of coals and iron are leading industries; yet the owners of collieries cannot get as much for their coals as it costs to get them out of the pit and ship them to market, and English iron can pay the exorbitant rates

of duty charged in the American tariff, and still be sold alongside of the American furnace at a cheaper rate than the product of that very furnace itself. Wages for miners and puddlers and other iron-workers cannot be got down, and the railroads and canals will not reduce their tolls on the transportation of coals, and the production of each languishes. Many collieries are idle, while the iron-mills have but a sickly existence, and the American steel manufacture is at present at a standstill. People can buy both coals and iron in plenty at present prices from the unused stocks of former years. The petroleum producers are similarly unfortunate. The market is glutted, and it is said that refined petroleum is cheaper at Antwerp than in the Pennsylvania oil region. Petroleum can be bought as low as \$1 25c. currency a barrel at the mouth of the well, and it costs fully that much, and sometimes more, to pump it out. The consequence is that wells are being everywhere abandoned, and on Oil Creek, where 20,000 barrels daily were formerly produced, not over 6000 are now reported. The production decreases, yet the price will not advance, and well-owners are now seriously considering whether the wages of their operatives cannot be forced down, while the Pittsburgh refiners are reported to be all on the point of suspending operations until the surplus stock which is overburdening the market is worked off. Of the complete stagnation in American shipbuilding foreign readers are already aware, and although that branch of industry was once a leading one of the country, employing many thousands of operatives and millions of capital, no plan has yet been devised to revive it, nor will it be revived until the Chinese-wall policy of excessive 'protection' is abandoned in America. Our commerce is languishing under this policy, and until its prospects brighten American shipyards will be silent, for ships are never built on speculation. Other vast interests, even those for which the 'protective' system is put in operation, are most vitally affected by the prevalent dullness. The leading New England journals unite in stating that at no time during the past thirty years has cotton and woollen manufacturing in that section of the country been so depressed. The mills are running at a loss in Lowell, Lawrence, and most of the other manufacturing towns of Massachusetts, Rhode Island, and Connecticut. The Manchester, New Hampshire, millowners complain that they have \$2,000,000 worth of goods on hand unsold, with scarcely a buyer offering. The Stark mills have sunk \$40,000 within a few months. The Amoskeag Company also complain of heavy losses. This, which indicates the state of affairs in New England, is also indicative of the stagnation in Philadelphia, the leading manufacturing city of the country, where the mills are running on short time, and the owners gloomily point to piles of unsold goods to tell the silent yet significant story of an almost unexampled depression in trade. The shoe manufacturing trade of Lynn, Haverhill, and other New England towns is also in a low condition, in sympathy with sister industries. The knit-goods trade of the country have determined to stop manufacturing almost entirely. All the knitting-mills at Cohoes, New York, stopped work on the 15th of August. This is one of the chief towns of this trade; and on that day representatives from twenty knitting manufactories met in Albany and resolved to run not more than two sets of machinery in each mill for nine days subsequent to the 1st of September, a determination which will cause almost a total suspension of work in all large mills. This meeting showed the sad condition of the trade. In spite of enormous 'protection,' foreign knit goods from England and Germany can undersell those of American make. The stock of domestic knit goods on hand is enormous, and has been accumulating for months, because no profitable market is open to it. The owners of the knitting-mills stated that it cost them \$11 20c. currency a dozen to manufacture shirts and drawers, yet, owing to successful foreign competition, their goods have not brought for some time past an average of more than \$10 50c. a dozen. There are about 250 knitting-machines for shirts and drawers in this country, and their owners have been expending large sums of money for a long time past, and receiving no returns whatever. It is only among those engaged in the movement and sale of breadstuffs and provisions that any cheerfulness exists. The people, whether at work or idle, must eat, and the demand for food is growing with the increase of population. In every other kind of trade, however, there is unexampled depression, and the tale of gloom and misfortune is echoed from Maine to Texas.

STEAM AND OTHER SHIPPING.—Messrs. Royden and Sons, of Liverpool, have launched two pilot boats intended for Bombay service. Messrs. Bowdler and Chaffer, of Seacombe, have launched a paddle-steamer, named the *Mayflower*, to ply in the Menai Straits between Carnarvon and Anglesea. Messrs. C. Mitchell and Co., of Low Walker, launched two steamers on Saturday. The first was the *Olatz Kyrra*, a screw of 230 tons, built for a Norwegian Steam Navigation Company; and the second was the *Rostoff*, 1400 tons, intended to be employed in the Black Sea, and built for the Russian Steam Navigation Company.

FROM THE NORTH.—Messrs. Palmer and Co., of Jarrow, are engaged on one half of a great bridge for the East Indian Railway. Messrs. Palmer are executing 13 spans, and the other 13 spans are on hand at Leeds. The number of furnaces in blast in the Cleveland district is now 89, while there are 45 out of blast. Business in the Cleveland district is considered to have slightly improved.

RECENT PATENTS.

THE following specifications of completed patents are all dated within the year 1866; and that year should be given in ordering them, at the annexed prices, from the Great Seal Patent Office, Chancery-lane.

(No. 3416, 8d.) Samuel Smith, and John William Jackson, of Keighley, patent arrangements for preventing the too sudden action of parabolic governors. According to this plan, the lever or rod, by which the throttle-valve is worked, is connected through the medium of a spring with a piston working loosely in a cylinder containing oil, this oil opposing sufficient resistance to the motion of the piston to prevent the governor balls from moving too suddenly.

(No. 3417, 6d.) William Smith, of Barnard Castle, patents an arrangement of street-sweeping machine, the principal points claimed being the shape of the brushes, and the methods adopted for enabling them to adapt themselves to the surface of the road.

(No. 3421, 1s. 4d.) William Simons and Andrew Brown, of Renfrew, patent improvements in the construction of dredging-machines. One part of this patent refers to a combined dredging-machine and hopper barge, the after part of the hull of the machine being made of greater capacity than usual, and the dredged material being discharged into it by the buckets, which are arranged in the ordinary way. The after hold of the dredger is fitted with hopper doors, and when it is full the bucket-ladder is raised into the well, and the dredger is steamed out to sea to deposit her cargo in the same manner as a hopper barge. The second part of the patent refers to so constructing a dredger that, in addition to being available for ordinary dredging operations, it may be used for excavating or undercutting land at or above the surface of the water, it being intended that the materials so undercut should fall into the water, and should then be removed by dredging in the ordinary way. To adapt the dredger for this work, the bucket well is extended right through the stern, and it is bridged over at the after end by shears provided with gear, by which the bucket-ladder can be raised through any desired angle.

(No. 3424, 10d.) Charles Harrison, of Manchester, patents a form of cock or valve, in which—when it is open—the steam or water enters at the top of the plug, passes out through lateral orifices to channels or chambers at the sides of the casing, and then back through other lateral openings into the lower part of the plug, which is in connexion with the discharge pipe.

(No. 3426, 1s.) William Wilby, of Dublin, patents methods of making driving belts, or straps, of strips of leather disposed in two layers firmly cemented together by marine glue, these layers enclosing between them iron, copper, or steel wire, thin metallic strips or wire cloth. The strips of leather are scarfed at their ends, and are disposed so as to break joint; and besides being cemented together, they are further connected by rows of wooden pegs. The patent also includes various ways of forming the joints of straps, &c.

(No. 3434, 4s. 2d.) William Clark, of 53, Chancery-lane, patents, as the agent of Jules Vautherin, of 29, Boulevard St. Martin, Paris, various methods of fixing rails to sleepers. The plans claimed are so numerous—the specification having nine sheets of drawings, comprising fifty-three figures—that it is impossible for us to describe them here.

(No. 3436, 1s.) William Exall, of Reading, patents a machine for cutting, reaping, and binding into sheaves corn or other agricultural produce. This gathering and binding machinery may be applied to an ordinary reaping machine; but Mr. Exall prefers to cut the corn by a thin sharp edged steel band-saw, which has a rapid motion given to it, and which is pressed up against the stalks to be cut. In cutting short grass a brush is used to press the latter against the cutters. In the case of corn, the latter, as it is cut, is seized by a system of travelling fingers, which carry it through a suitable conductor to the rear or side of the machine, where it is received by arms carrying suitable bands, which are made to embrace, compress, and properly fasten the sheaves.

(No. 3449, 4d.) Clemens Flemming Flach, of Call (Eifel), Prussia, patents a system of removing silver from lead by the addition of a small per-centage of zinc, the patent also including processes for purifying the desilvered lead, and for separating the silver from the alloy of lead, zinc, and silver.

(No. 3452, 1s. 6d.) George Tomlinson Bousfield, of Loughborough-park, Brixton, patents, as the agent of George Herman Babcock and Stephen Wilcox, of Providence, U.S., various arrangements of cut-off

valves and governors for steam engines. The plans proposed could not be described without reference to drawings.

The following specifications of completed patents are all dated within the year 1867; and that year should be given in ordering them, at the annexed prices, from the Great Seal Patent Office, Chancery-lane.

(No. 3, 8d.) Andrew Dwight Campbell, of Manchester, patents, as a communication from Joseph Jones, of Newark, U.S., an arrangement of bench planing-machine, intended to enable unskilled workmen to plane wood correctly to any required angle. The machine consists of a bed or table, having slide-ways, fitted with a slide carrying the plane. The bed is also furnished with an adjustable ledge for holding the wood to be planed.

(No. 15, 10d.) John William Kenyon, of Chorlton-upon-Medlock, patents a "scummer" for steam boilers. The principal novelty in this "scummer" consists in its being arranged so that it floats upon the surface of the water, and thus acts properly whatever may be the height of the water in the boiler. It consists of a hollow metallic float, to the top of which a plate is attached, so that a space is left between the float and plate for the passage of the scum. The centre of the plate is connected by a short moveable pipe with the fixed pipe leading to the scum-cock, the moveable pipe being connected to the fixed pipe and "scummer" by ball-and-socket joints, so that the "scummer" can rise and fall freely, according to the level of the water in the boiler.

(No. 18, 1s. 4d.) William Chippendale, of Harrogate, patents an arrangement of apparatus for enabling railway carriages and trucks to be coupled and uncoupled without going between the vehicles. According to this plan, each end of each vehicle is fitted with a cross-shaft, having levers at its ends by which it can be moved, and furnished at its centre with an arm by which the coupling links can be thrown over the draw-hook of the vehicle to be attached. A very similar, if not precisely identical, arrangement was tried on several railways some years ago.

(No. 19, 1s. 4d.) Joseph Knowles Broadbent, of Manchester, patents an arrangement of apparatus for admitting a regulated supply of air at the bridges of the boiler furnaces. The apparatus is somewhat complex, and we do not see that it possesses any advantages over the numerous arrangements previously patented to effect the same object.

(No. 30, 8d.) Ebenezer Noah Gregory, of Camberwell, patents preventing the undue wear of the endless wire cloth used in some paper-making machines, by covering the rollers over which the cloth passes, with india-rubber, gutta-percha, leather, or some other yielding material.

(No. 36, 8d.) Edward Kenworthy Dutton, of 3, Smithy Door, Manchester, patents, as the agent of William Barbour, of Lawrence, U.S., a form of nozzle for delivering a broken jet of water. According to this plan, the breaking up or spreading of the jet is effected by a number of radial wedge-shaped fingers which are attached to levers, and are arranged so that they can be simultaneously closed into the issuing jet to any desired extent.

(No. 42, 1s. 4d.) Juan Vila y Jové, of Barcelona, patents a fearful and wonderful arrangement "for obtaining motive power," or, in other words, a perpetual motion. The apparatus is not worth description, but we may mention that the inventor, evidently afraid of its running away, has fitted it with a governor and brake.

(No. 43, 1s. 8d.) Frederick Bernard Döring, of Bayswater, patents further improvements in his rock-boring machines, and in the carriages for supporting them.

THE MESSINA BRIDGE.

(Continued from page 172.)

Effects of the Wind.

THE pressure of the wind against a plane surface struck fully is described by the formula $P = 0.11 d S V^2$, in which d is the weight of a cubic metre of air in movement.

S is the surface struck.

V is the velocity of the wind per second.

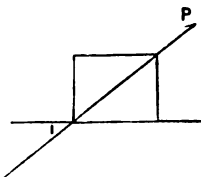
The velocity of the wind varies very much according to places and times from 2 to 45 metres per second.

In order to secure perfect tranquillity in the spans of the Messina Bridge, it would be necessary that they should be able to bear with impunity the shock of the wind during a great hurricane having a velocity of 45 metres per second, and exerting a pressure of 275 kilos. per square metre.

It is scarcely probable that the wind of a hurricane would strike the girders along their whole length, and at the same moment, with equal force, and that it would not act horizontally, nevertheless, for the sake of security, it must be admitted that

such a case might happen, and besides that the wind might act obliquely, so as to strike the underneath part of the platform.

In the latter case the action would be equivalent to that of two forces, the one applied horizontally on the side face of the girder, and the other vertically from beneath upwards, tending to raise it.



The force exerted by the wind striking below the platform at an angle, i , is expressed in the formula

$$P = 0.11 d S V^2 (\sin i)^{1.81 \cos i}$$

That force is exerted in the same direction as that of the wind, but comprising a horizontal force, $P \cos i$, and a vertical force, $P \sin i$.

It is easy to find out the value of i , which gives the largest result from $P \cos i$, and which is equal to about 40° .

For $i = 40^\circ$, the coefficient by which the intensity of the calculated force must be multiplied, if the wind acts regularly beneath the platform, in order to obtain the strength of the horizontal force, is about 0.52.

The horizontal force produced by the action of the wind on the trussing of the platform, when the wind acts at an angle of 40° on the under part of the platform will be obtained by multiplying the intensity of the calculated force, if the wind acts regularly on that area, by 0.52. If H be the reduced height of the surface of the platform, and L the width, the greatest horizontal effort which the wind could produce, will be per lineal metre,

$$(0.32 H + 0.52 L) \times 275 \text{ kilos.}$$

The vertical effort tending to raise the bridge would be in the above case, per lineal metre,

$$(0.95 H + 0.85 L) \times 275 \text{ kilos.}$$

As $H = 2^m.10$, and $L = 16^m.20$, the greatest horizontal force that could be brought against the spans would be 2502.50 kilos. per lineal metre, and the greatest vertical force 4336.70 kilos. per lineal metre.

The weight of the platform of the spans being much greater than the greatest vertical pressure, there is no need to take up one's time with reference to the raising of the platform by the wind.

Neither is it necessary to discuss here the vertical oscillations which might affect the system, an account of the rigidity of the whole of the suspension chains. The vertical pressure which would tend to raise the platform would be equivalent to a diminution of weight in the latter, which would also cause a diminution of pressure on the suspension chains, and cause no visible vertical movement.

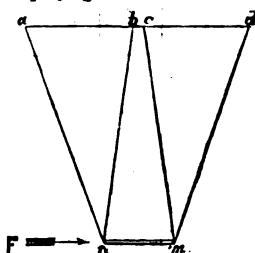
The equilibrium could not be disturbed, and oscillations could not arise.

To contend with the effect of lateral displacement arising from the horizontal force of the wind, we would support the platform by four sets of chains, each constituting a rigid system under the influence of parallel forces acting in the same plane. There would be two systems on each bridge head. The plane containing those systems would be oblique to that of the platform; the intersection of plane of the two systems at each head would be a line parallel to the edge of the platform, in which the points of suspension of the latter are placed.

At each head, one plan of suspension would incline outwards, and the other inwards. The inclination of the former would be 18 metres at base to 50 metres in height, and the latter would be 8 metres at base to the same height.

These arrangements would be repeated on both the heads of the bridge.

The four systems of suspension would unite in one and the same vertical projection, having a chord of 1000 metres to a rise of 50 metres; in horizontal projection they assume at each bridge head curves of the same kind, but reversed towards the summit. Each head of the platform would thus be suspended by two series of oblique rods. Each series would be comprised within the plane of the suspension system. The corresponding rods of the four systems would be comprised in one and the same transverse vertical plane, the corresponding rods appearing as shown in the accompanying sketch.



The points, a, b, c, d , of fastening the oblique rods on the chains are in one and the same horizontal line. The points m and n of fastening the rods to the platform are also in one and the same horizontal line. If we assume that the line a, b, c, d be fixed in space, the platform m, n will be in firm equilibrium, and that equilibrium will not be easily displaced.

In fact, if a horizontal force, F , were sufficiently powerful to disturb the system from its state of equilibrium, the platform would have a tendency to oscillate from the points a and c , for the rods b, m and d, n should shorten in proportion as the displacement occurs; their tension would therefore disappear little by little, and the strain on the two rods, a, m and c, n , correspondingly increase.

Admitting that this disturbance may be appreciable, these rods would carry the whole weight of the platform. When that occurs, the horizontal composition of the tension of the rods, which is equal to the weight of the platform divided by the

tangent of inclination of the rods with the horizon, will come in opposition to the force F .

So long as F is less than the tangent of a certain angle, the oscillation cannot occur.

In the platforms of the Messina Bridge, the force F , even when it is as powerful as possible, will be considerably inferior to that tangent; consequently, the horizontal force of the wind cannot disturb the platform from its position of equilibrium, and then, on condition that the platform is sufficiently heavy and supported from each head by two rods sufficiently inclined in opposite directions, it will be immovable under the action of the wind.

In fact, when the platform is subject to the force F , it produces an inappreciable lateral movement, by reason of which the corresponding rods from one and the same head assume unequal lengths. The rods a, m and c, n would become longest, whilst b, m and d, n would become shortest. The difference of length between the rods c, n and d, n will represent the lengthening of the rods a, m and c, n , arising from the additional tension as compared with the other two rods, b, m and d, n , which would be partially released at the expense of the two others; but it can never happen that the rods b, m and d, n should be completely released, or could become loose, for, in order to provide against the most violent horizontal perturbations, the inclinations of the rods and the weight of the platform can be regulated.

The conclusion which has been deduced, that the platform will be immovable under the action of side winds, supposes that the points a, b, c, d rest fixed in space; besides, the fact that the four suspension systems rest in the planes of suspension, although those planes are oblique, supposes that those systems are free from the laws of gravitation.

The two preceding hypotheses, although inadmissible at first view, can easily be realised in practice. It will suffice for that purpose to support between them the four suspension systems by rigid cross bars, contained each in a vertical plane transverse to the corresponding rods in the four systems.

The systems will be so tied together that they could not, in spite of their actual weight, deviate from the plane of suspension, for in each cross bar would be developed a horizontal tension, so that, combined with the weight of the suspension chains of one system, the resultant would be directed in the plane of suspension of that system. The horizontal tensions existing in each cross bar would mutually counteract one another in pairs respectively.

The platform of the spans of the Messina Bridge being attached as near as possible to the suspension chains, it would be impossible to introduce tie rods between them for a length of about 160 metres on each side of the middle of the spans, for these tie-rods would interfere with the traffic, but they might easily be placed between the two suspension chains at the higher parts.

Effects of a Weight on the Longitudinal and Transverse Profile of the Platform of the Spans.

The suspension systems being calculated to support the dead weight of the bridge itself, which is about 19 kilogrammes per lineal metre, and the load which it could receive being $7\frac{1}{2}$ tons per lineal metre, the united force of these two loads would amount to 70 kilogrammes per square millimetre, the greatest increase of force per square millimetre which the greatest possible load could bring upon the suspension systems would be:

$$70 \times \frac{7.5}{25.5} \text{ or about 20 kilos.}$$

The coefficient of the lengthening of tempered and annealed steel may be estimated at 20,000 kilos. per square millimetre, the tension of 20 kilos. would produce a lengthening of $\frac{1}{1000}$; let 20 be 0.001 of the length of the suspension systems, their lengthening which would take place would then be about 1 metre, and the difference in the rise which would consequently occur in the suspension systems would be 3.70 metres.

In fact, during the passage of two heavy goods trains going in opposite directions, which would in practice be the most trying occurrence, the increase of the curve of the suspension systems and the consequent diminution in the convexity of the platform, would be less than 0.60 metre; during the passage of one very heavy goods train that deflection would certainly not be above 0.30 metre.

In the latter case the weight would not distribute itself equally over the entire suspension systems of both ends, but would proportion itself between the two systems in the ratio of about 1 to 2, the diminution of convexity of the platform would be 0.40 metre on one side, and 0.20 metre on the other.

Variations of Temperature.

The girders at Messina would be exposed to a variation of temperature of 45° centigrade, or more, being between 2° and 47° above zero.

When the temperature increases, the suspension chains increase in length, and the chord remaining constant, the curve must increase, and the inverse would be the case when the temperature fell.

At the temperature of $24\frac{1}{2}^\circ$ the platform would assume its normal curve, the rise of that curve being about 2.50 metres.

At the temperature of 47° , the rise of the suspension systems would be increased by about 1.05 metres, the rise of the convexity of the platform would be diminished to a similar extent, and reduced by about 1.45 metres; at the temperature of 2° , the rise of the suspension systems would be reduced by about 1.05 metres, the rise of the convexity of the platform would be increased to about 3.55 metres.

(To be Continued.)

RAILWAY CAPITAL.—The capital of British railways amounted in the year 1865 to 455,478,143*l*. The total railway revenue was 35,751,655*l*.

THE WATERWATCH.—The jet-propelled vessel Waterwatch has had two further trials since that reported by us three weeks ago, but she has only exerted still greater engine power, and attained less speed. The trials at half boiler power show a large loss of effect, the mean speed being but 0.326 knots.

TWEDDELL'S HYDRAULIC RIVETTER.

The hydraulic-rivetter, of which we give engravings above, is a machine of simple construction, designed by Mr. Ralph Hart Tweddell, of Sunderland. The arrangement will be readily understood by reference to the figures. The rivetting is performed between a pair of dies, one fixed at the top of a strong standard, and the other carried by the plunger of a hydraulic press formed within a second standard, as shown in the illustrations. The ram of the hydraulic press is forced forward by the pressure of the water behind it, and on the water being allowed to escape from the press, it is drawn back by a strong volute spring, which is connected to the plunger by a rod passing through a stuffing-box at the inner end of the hydraulic-cylinder. The water for working the machine is drawn from an accumulator, this accumulator being in its turn supplied by a pump worked from an eccentric on the crank-shaft of a stationary engine, as shown in the engraving. The accumulator is arranged so that as it becomes full, and its weight consequently rises, it lifts a weight attached to the end of a chain, which passes over pulleys, and is connected to the weighted lever of a cock on the supplying pipe of the pump, and thus closes this cock.

THE ILLYRIAN.—Messrs. Harland and Wolff, of Belfast, have launched a sister ship to the Iberian and Istrian steamers, built by them for Messrs. Bibbey, of Liverpool, and which, with the exception of the Great Eastern, are the longest commercial steam-ships yet built, being 401 ft. long. Their beam is but 37 ft., and they are registered as 2900 tons, their burden being about 4000 tons.

TUBE WELLS.—We described last year an American plan of sinking wells by driving an iron tube, perforated at its lower end, down to where water may be found beneath the surface of the ground. A trial of this plan was made last week in Manchester. Water was reached in five minutes from the commencement of operations, and in 22 minutes a depth of 10 ft. had been reached; the pump had been fitted to the top of the well, and a flow of water was obtained. The well consists of an iron pipe 1½ in. in diameter, about 12 ft. long, pointed at one end, and perforated with holes about 16 in. up the pipe from the pointed extremity. A movable iron clamp is fitted round the pipe, and, upon the principle of pile-driving, a 56 lb. hollow weight is raised and allowed to drop upon the clamp; thus the pipe is driven into the ground. Earth, sand, &c., first enter the pipe through the holes, and, when these are pumped out, the theory is that pebbles rest against the pipe and form a natural filter. Such a well is free from the liability common to others of receiving surface drainage, and the water obtained from it is always cold and fresh. No dirt is made in sinking the well, no accident is possible from foul air or from the falling in of the sides; and, besides the rapidity with which the well is made, its cheapness, about 5s. for the completion of a well 15 ft. deep, is another great recommendation.

THE TRIAL OF SAFES AT PARIS.—At the end of our report of the competitive trials of Chatwood's and Herring's safes at Paris, given in page 132 of our number of the 16th ult., two misprints occur. The times occupied in breaking a hole in Chatwood's safe proper, and in completely opening the small box within Herring's safe, are given as 4 hours 35 min. and 4 hours 43 min. respectively, whereas they should have been 3 hours 55 min. and 4 hours 13 min. The errors are, however, of the less importance, as the correct periods occupied in the various operations performed are readily obtainable from a comparison of the hours of the day at which they were commenced and terminated, these times being all given in the earlier part of the article.

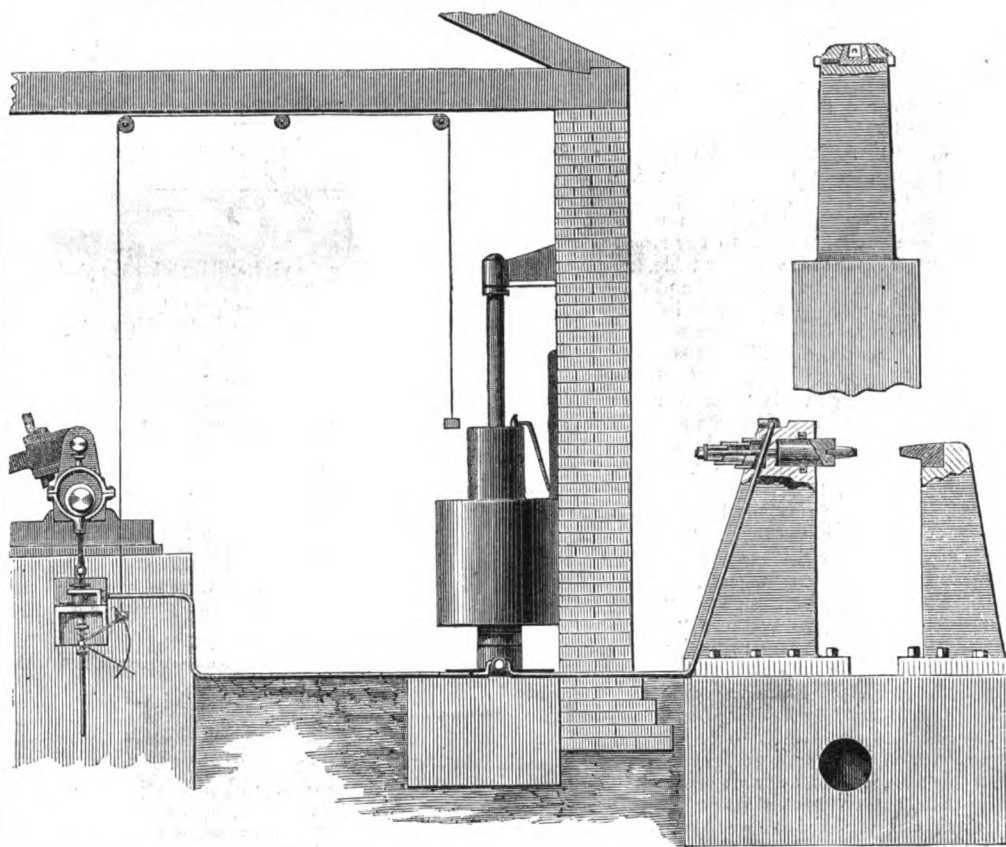
PRESTON.—Messrs. Bell and Miller have delivered a report recommending some important dock works and other operations for the improvement of the Ribble at Preston. Messrs. Bell and Miller propose two plans of docks; one of the plans gives an area of 36 acres for dock accommodation, at a cost of 74,000*l.*, and the other gives an area of 60 acres, at a cost of 60,000*l.* The whole expense of the works recommended by Messrs. Bell and Miller is estimated at from 120,000*l.* to 130,000*l.* The subject remains "under consideration" by the local authorities, and that is all that can be said at present.

DAGENHAM (THAMES) DOCK.—It appears that the efforts made during the past six months to raise additional capital for the Dagenham (Thames) Dock Company have not been successful. A negotiation with some of the shareholders is now pending for raising a sufficient sum to put the jetty, &c., into working order. Should this negotiation be brought to a successful issue, the directors believe that a considerable traffic in cattle and goods will be at once obtained. With the stimulus thus given to the enterprise, they hope to be able ultimately to place sufficient of the unallotted capital to complete the undertaking.

DOWLAIS.—It is stated in *The Engineer* that, "The Dowlais Iron Company, it is reported, have made arrangements for the exclusive right of working Bessemer's patent in Glamorganshire, 10,000*l.* being the amount paid for the concession." This would have been true if printed in 1856, or eleven years ago. At that time the Dowlais Company did purchase the exclusive right to the use of Mr. Bessemer's patents in Glamorganshire, and for 10,000*l.* Mr. Bessemer some time afterwards repurchased this right, and the Dowlais Company are now on the footing of his ordinary licensees.

NEW HARBOUR WORKS AT WICK.—The British Fishery Society, who are proprietors of Pultneytown, on the south shore of Wick Bay, are engaged in the important work of constructing a new harbour on a large scale, from the designs of Messrs. Stevenson, of Edinburgh, in the Bay of Wick. This almost national work has now been going on for some years, but owing to the great depth of water in which the breakwater is founded (being about 30 ft. at low water), and the interruption to the work, in consequence of the heavy seas raised by easterly winds, the progress is slow, being only about 200 ft. per annum. The contractors are Messrs. A. and K. Macdonald, of Glasgow.

TWEDDELL'S HYDRAULIC RIVETTER.



ROOF OF THE MOSCOW RIDING-SCHOOL.—A contemporary, in referring to the Midland Railway roof of 240 ft. clear span, observes, "This, however, has been equalled within 5 ft., many years ago, by the laminated timber system of De Lorme, in the splendid example at Moscow." As this refers probably to Betancourt's roof over the riding-school at Moscow, erected in 1817, we may say that its clear span is 147 ft., and its length 574 ft. The span, therefore, is 93 ft. less than that of the Midland roof.

BESSEMER RAILS IN PRUSSIA.—Some of the works in Rhenish Prussia and Westphalia have received orders for Bessemer steel rails for the Leipzig and Dresden Railway. Almost all the Prussian railway companies are commencing the use of Bessemer steel rails.

ERRATUM.—In our article on "Permanent Way Accounts," on page 179 of our last number, third column, line 38 from the bottom, for "up to the end of the year, 971,013*l.*," read, "up to the end of the year, 371,013*l.*"

TRIAL OF THE PALLISER CONVERTED GUN.

We subjoin the following report of the trial of a 64 pr. rifled M.L., rifled on Sir W. Armstrong's shunt system, one of a number of guns for the colony of Victoria, converted from 32 pr. cast-iron guns of 58 cwt., on Major Palliser's system, by Sir W. Armstrong and Co.

Weight, 61 cwt.; preponderance, 6 cwt. 1 qr. 14 lb.; length, over all, 9.5 ft.; of bore, 9 ft. 0.25 in.; calibre, 6.28 in.; spiral, 1 turn in 40 calibres; grooves, 3—width, 1.12 in., depth, 0.11 in.

Results of the firing of 70 rounds from the above-mentioned gun, for range and accuracy:

Carriage—garrison sliding on dwarf traversing platform without trucks.

	Capacity.	Length of bearing.	Diameter and over 1 stud.	Studs, 3 rows, 2 in a row.
	lb.	in.	in.	Diameter.
Palliser shell ...	1.062	5.52	6.34	Brass ... 0.85×0.70
Common shell ...	6.750	8.30		Copper ... 0.80×0.68

Cartridge { 8 lb.; length, 10.5 in.; diameter, 5.75 in.
16 " " 17.5 " " 6.0

Date of practice, 9. 8. 67.

Powder—L. G., W. A. rifle, 6. 1. 66., lot 992.

No. of rounds fired.	Projectile.			Charge.	Corrected elevation.	Mean recoil on a dry platform.	Slope of platform.	Time of flight corresponding to mean range.	Ranges.			Mean difference of range.	Mean observed deflection.	Mean reduced deflection.	Remarks.
	Nature.	Mean weight.	Windage.						Minimum.	Maximum.	Mean.				
3†	Palliser K. O. C. 1	86.1	0.04	16	1° 19'	6.6	11° 6'	2.19	849	931	885	30.7	1.1	0.6	Breeching on, but not taut.
7	"	"	"	"	3° 10'	8.2	11° 27'	4.59	1663	1731	1703	15.1	4.1	0.7	Breeching removed.
3†	" 2	"	0.05	"	1° 19'	6.8	"	2.33	891	919	907	10.3	1.6	0.7	Breeching on, but not taut.
7a	"	"	"	"	3° 10'	8.2b	"	4.60	1665	1717	1683	13.5	3.9	1.0	Breeching removed.
10*	"	65.4	0.06	8	1° 19'	3.5	"	2.07	780	820	801	12.3	1.5	0.2	"
10	"	"	"	"	2° 14'	3.4c	"	3.29	1188	1223	1205	10.2	2.1	0.6	"
10	"	"	"	"	3° 11'	3.4	"	4.52	1590	1625	1611	7.0	2.9	0.6	"
10	"	"	"	"	5° 7'	4.3	8° 0'	6.79	2335	2412	2364	18.3	5.1	1.2	"
10d	"	"	"	"	10° 4'	4.2	6° 0'	12.42	3936	4031	3980	28.9	18.7	2.1	"

† Initial velocity observed. * Initial velocity of first 3 rounds observed.

a Means are of 6, 1 shell breaking up.

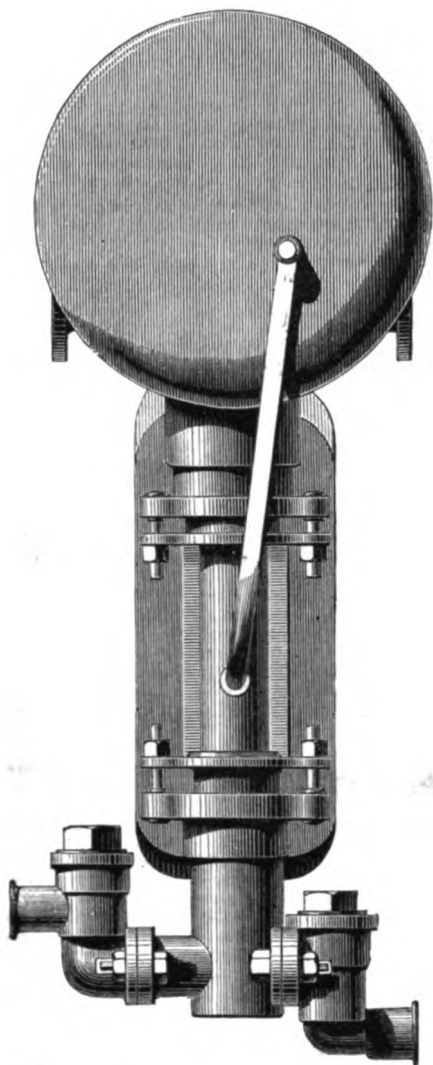
b Mean of 5, 1 not observed.

c " 9, 1

d Means are of 9, 1 doubtful round recorded as giving a range of 3400 yards being rejected.

A damp sponge was used. No difficulty occurred in loading.

DONKEY INJECTORS.



We have re-engraved, from a contemporary, illustrations of a "donkey injector," or steam pump for feeding boilers, the construction of which will strike the engineer at first sight as most faulty, and its use, where a steam boiler is to depend upon it for its supply of water, as most dangerous. This contrivance was nevertheless brought out last year, in a full-page engraving, and in a lengthy and most laudatory notice, as if it were a legitimate rival to Giffard's beautiful invention itself. The quality of this laudation will be understood however when we quote one sentence contained in it, and which is as follows: "Every part of this portion of the machine is made so light that it is exposed to few strains, and is therefore strong, steel being used throughout as an additional precaution!" So light that it is, therefore, strong! Further on we are told that this extraordinary pump "can, of course, pump boiling water without a lift on the suction side!"

These donkeys have occasioned much trouble to their purchasers and users, as is fully shown by letters before us from most respectable manufacturers who had been induced to try them. They are made with from 3 in. to 8 in. stroke, and to work at from 100 to 200 revolutions per minute, or from 50 ft. to 267 ft. of piston per minute, with 200 dead centres to pass per minute in one case and 400 in the other. In all direct acting pumps the resistance is uniform, for successive portions of the length of the stroke, and, if disconnected from any rotating parts, the piston would move through each inch of its stroke in the same space of time. If the piston be connected to a fly-wheel, the tendency of the latter is to maintain a uniform rotary motion, and this requires a gradually accelerating and gradually diminishing motion of the piston on each stroke. Now, whether the piston can maintain its uniform motion uncontrolled by a very light fly-wheel, or whether the latter be heavy enough to force the piston in obedience to its own movements, there will be in either case considerable and irregular strains upon the connecting-rod. This is one of the parts which, in the astute description from which we have quoted, "is made so light that it is exposed to few strains, and is, therefore, strong!" To increase its strength, we suppose, it is bent sideways for several inches out of the line of strain, the action being much the same as that of the human arm bent, and when turning a crank in a plane at right angles to the direction in which the upper portion of the arm is projected from the body, or when bent in the position in which the arm is held to a tailor while he is measuring the length of a coat-sleeve. No form of connecting-rod could be worse to resist the irregular strains to

which such a combination is exposed when, with a very slow absolute speed of piston, from 200 to 400 dead centres have to be passed per minute. The action is necessarily jerky at best, and there is the constant risk of the whole thing sticking fast at any moment. All this implies danger, and it is to be deeply regretted that any professional journal making the least pretensions to respectability and influence should help to hoist such a contrivance into notoriety, whether because of the gain from an advertisement or, to be more charitable, the astounding ignorance shown in that part of the description which we have quoted.

LIGHTNING-ARRESTERS.

TO THE EDITOR OF ENGINEERING.

SIR,—Having noticed in your last week's number what is supposed to be a new invention of a lightning-arrester constructed by Dr. L. Bradley, of Jersey City, may I beg to state that such a lightning-arrester was invented by me in India in 1855; and in 1858, when I was deputy-superintendent of the East Coast line, all my river cables, from Madras to Calcutta, were so protected. I likewise furnished the late Colonel Stuart with drawings of such an instrument in 1863; and an instrument of this kind can now be seen in Mr. Latimer Clarke's office, No. 5, Victoria-chambers, where I left one some time since, which I had constructed when out in Russia last year. My plates were of brass, 1 in. thick—one carrying twelve and the other nine steel points (for the want of platinum) fitted up in a small box, with glass front and back, with set screws at top to adjust the points by lowering or raising the top plate.

Yours respectfully,

W. MAYES.

Millfield, Peterborough, September 2, 1867.

BRIDGE OVER THE NIAGARA RIVER.—The projected new suspension bridge at the Falls is being pushed forward with great prospect of speedy success. Contracts have already been made for the materials, except the wire, which the chief engineer, Mr. Keefer, is on his way to England to procure. The towers will be 105 ft. high, the span 1250 ft., height above the water 175 ft., and width of roadway 10 ft. The bridge is intended for the passage of carriages and pedestrians, and will be one of the most substantial structures of the kind in America. The towers will be completed this month, and the bridge opened to the public early next spring.

NEW STANDARD FOR LOCOMOTIVE CONTRACTS.—The price of the twenty locomotives recently let for the Belgian State Railways is stated to have been between 45*l*. and 50*l*. per ton. Corresponding contracts entered into last year were let at 65*l*. to 70*l*. per ton.

INDICATED HORSE POWER.

TO THE EDITOR OF ENGINEERING.

SIR,—In reply to your correspondent "J. W. R.," I would inform him that in Willis's "Principles of Mechanism," art. 82, he will find the solution he is in want of. As the book is out of print, I subjoin the proposition therein contained, so far as is necessary for our purpose.

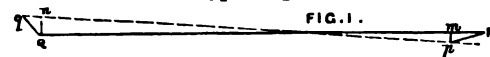
Let PQ be a link joining the two points, P and Q ; let it be moved into the new position, pq , very near to the first.

Then Pp , Qq are respectively elements of the paths of P and Q . Draw $p'm$, $Q'n$, perpendiculars on PQ .

Then since $PQ=pq$, we shall have, ultimately, as p and q tend to coincide with P and Q respectively, $Pm=Qn$, whence

$$Pp \cos p'Pm = Qq \cos Q'n,$$

$$\text{or, } \frac{Pp}{Qq} = \frac{\cos Q'n}{\cos p'Pm}.$$



Hence the linear velocities of P and Q are to each other inversely as the cosines of the angles which the link, PQ , makes with their respective paths.

Applying this to the particular case in hand, we have

$$\frac{\text{velocity of piston}}{\text{velocity of crank-pin}} = \frac{\sin Cqp}{\cos p'PQ}$$



The following will be a convenient method of using the formula:

From C , the centre of the crank-pin circle, draw Cm perpendicular to PQ , and from Q draw Qn perpendicular to Pp , the centre line of motion.

Then let $CQ=R$ } velocity of crank-pin= v .

$$\text{Now } Cm = A \sin CQP \therefore \frac{\sin CQP}{\cos p'PQ} = \frac{L}{R} \frac{Cm}{P'N}$$

whence velocity of piston = $v \frac{R}{P'N}$

$$= \frac{Cm}{P'N} \times \text{a constant.}$$

"J. W. R." does not give the length of his connecting-rod, but supposing it to be $=6R$, we have

$$\text{velocity of piston} = (6 \times 471 = 2826) \frac{Cm}{P'N}$$

The piston speed increases so rapidly at the two ends of the stroke that unless a great number of measurements be made, say twenty instead of ten, the results will be much too high.

The simplest way of getting at this result is as follows:

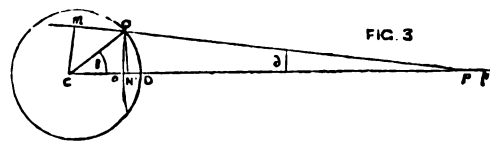
If F = pressure on piston at any time,

f = resistance along PQ .

$$\text{Then } \frac{f}{P} = \frac{PQ}{P'N} \text{ and velocity of } f \text{ along } PQ = \frac{PN}{PQ} = \frac{P'N}{L};$$

also, velocity of f along $PQ = \frac{Cm}{R}$, evidently;

$$\text{whence, immediately, } \frac{v}{V} = \frac{Cm}{P'N} \frac{L}{R}$$



If he prefers to differentiate, he will see at once from Fig. 3, that

$$Pp = \text{space moved through by piston} = DO = R(1 - \cos \theta) + NO,$$

$$= R(1 - \cos \theta) + L(1 - \cos \alpha).$$

$$= R(1 - \cos \theta) + L - \sqrt{L^2 - R^2} \sin' \theta = P, \text{ say.}$$

Now, if T be the time occupied by the piston in moving through the space, Pp ,

$$\theta = \frac{DQ}{R} = \frac{v}{R} T,$$

where v = velocity of Q . Now, v and L and R are constants, and

$$P = R(1 - \cos \frac{v}{R} T) + L - \sqrt{L^2 - R^2} \sin' \frac{v}{R} T;$$

$$\text{whence } \frac{dP}{dT} = 0 + v \sin \frac{v}{R} T + 0 + \frac{R v \sin 2 \frac{v}{R} T}{2 \sqrt{L^2 - R^2} \sin' \frac{v}{R} T}.$$

$$= v \sin \theta + \frac{R v \sin 2 \theta}{2 \sqrt{L^2 - R^2} \sin' \theta}$$

= velocity of piston.

$$\text{Or, } \frac{V}{v} = \sin \theta + \frac{R \sin 2 \theta}{2 \sqrt{L^2 - R^2} \sin \theta} \dots \dots \text{I.}$$

$$= \sin \theta + \frac{2L \cos \theta}{Qn \times Cn}$$

$$= \frac{Qn}{R} + \frac{R}{Pn} = \frac{Qn}{R \times Pn} \times PC$$

$$= \frac{PC \sin \alpha}{Pn} + \frac{Qn}{R \sin \alpha} = \frac{Cm \sin \theta}{Pn \sin \alpha} + \frac{Cm}{Pn \sin \alpha}$$

$$= \frac{Cm}{Pn} \times \frac{L}{R}, \text{ as before } \dots \dots \text{II.}$$

Crews Works.

Your obedient Servant,
W. M. MOORSOM.

EDITORS AND ADVERTISERS.

Messrs. —, —, AND Co. and "A. B." have called attention to an abuse of the press, which is, we believe, as rare as it is reprehensible. No better definition of this phenomenon of journalism than that adopted by our correspondent "A. B." as the title of his letter, which we publish this week, can be devised. The words "newspaper rattening" pithily express the scope and intent of the practice to which he alludes, and the parallel implied between this practice and the policy of Sheffield trade-unionists is not far-fetched. We have examined the articles to which both our correspondents refer, and we have been at some pains to investigate the accuracy of their statements before admitting their letters to a place in our columns, and it is only fair to both to say that the contents of their letters are fully justified in every particular. A journal conducted on the principle of rattening those who will not advertise in its pages can only hope to subsist on the weakness of those whom the proprietors or editors endeavour to terrify into compliance with their wishes. It unfortunately happens that a large class of manufacturers entertain an unwholesome fear of leading articles depreciating the goods which they produce; and as a result this black mail system, if managed with some caution by unscrupulous men, may succeed for a time. In the long run, however, it is certain to be exposed and denounced by some individuals stronger-minded than his fellows, who refuses to submit to unwarrantable exactions. We leave our readers to determine what the result of such an exposure may be. We have happily no precedent to go on in forming an opinion as far as the respectable portion of the London press is concerned; but there are, we believe, instances of newspaper rattening to be met with in the history of American journalism, and to a very limited extent indeed in English provincial districts. It is not difficult, however, to arrive at tolerably accurate conclusions on this subject; or to perceive that any journal adopting the practice must ultimately lose caste and influence. A journal which rattens a man because he withdraws an advertisement, or because he will not give one, must be weak. Any newspaper which enjoys a large and influential circulation can obtain all the advertisements for which it has room without trouble, by the most perfectly legitimate means. Advertisements appearing in its pages are found to pay, and therefore they are inserted; as a consequence the difficulty is not to obtain them, but to find room for them. It may safely be asserted, therefore, that a paper which can only fill its advertisement pages by illegitimate means is powerless for either good or evil; and this fact we commend especially to the attention of those who pay in order that their reputation, or that of their goods, may not be assailed. Once its impotence is recognised, the power of the offending journal is gone, and its abuse or its praise equally become matters of no moment whatever. The opinion of an editor who measures the merits of men or machines by the contents of advertising columns with which he should have nothing to do, of whose existence he should scarcely be aware, cannot possess the smallest value, and his praise or his blame will equally fail to influence public opinion. No newspaper or periodical can hope for a large measure of permanent success in this country unless it is conducted with strict impartiality and honesty of purpose. These things are dear to the hearts of Englishmen, who are quick to perceive when they are wanting. A little experience will suffice to convince the most unpractised advertiser that he has nothing either to fear or to hope from the influence of any journalist sufficiently venial to praise for pay, or sufficiently audacious to drive advertisements into its pages by an organised system of terrorism.

Although we seldom copy, except for the purpose of correction, from *The Engineer*, we transfer the foregoing remarks to our own columns, and with the strongest concurrence in the sentiments they contain. Nor do we copy them the less readily because we know the strictures are intended to apply to ourselves, for the pretended cases upon which they are based have no foundation except in the merited exposures which we have been lately compelled to publish with reference to a firm who had attempted, and with some success, to use the press for the purposes of the most gross and nauseous puffing, and to another firm who have succeeded in persuading certain purchasers to buy of them one of the most conspicuous mechanical absurdities of the age. The first-named firm had exhibited certain second-class wares at Paris, and had been awarded a bronze medal, another firm of greater repute having received a silver medal in the same class. The bronze medallists wrote to the British commission, claiming for themselves, in the most fulsome and unwarrantable terms, the very highest position in the trade, refused the humbler award offered them, and sent their flourish to several of the newspapers, our own among the rest. One or two, *The Engineer* among the number, gave this precious production to their readers. Shortly afterwards, a semi-official report was made upon the machinery in the class in question, and by a most extraordinary omission the first-class firm, who also received the higher award, were not even mentioned, while the firm to which the bronze medal had been offered were accorded a position wholly undeserved. We at once called attention to this, and rectified the omission made in the semi-official report. For this we received a spiteful letter from the puffing firm in question, charging us with attempting to "write down" their reputation, and suggesting the most contemptible motives, and this letter was duly paraded a fortnight ago in our contemporary, and was noticed by us last week.

The other case, anonymously referred to in the article we have copied, is that of the makers of the impracticable "donkey injector" which we lately had occasion to criticise, and which we have further noticed on another page of our present number. The absurdity of this contrivance is sufficiently apparent, at the first glance, to every competent engineer, yet it has, notwithstanding, been palmed off upon several respectable manufacturing firms, with whom its failure was but a matter of course. One of these firms—one of great eminence, too, in their special line of business—had written us as follows:

"We had ————'s donkey injector on trial. It would not do at all. The connecting rod came off, the valves were too small, and altogether it was a rattling affair. Some one came down from them, consulted with our Mr. ———, and undertook to make another from a new set of patterns. We have this at work. It is better designed and better fitted than the first, but still it only works tolerably. We do not intend to keep it."

Our strictures brought forth a letter, also published in our contemporary, charging us, not at all to our surprise, with the most unworthy motives; and, to eke out the complaints of their justly criticised authors, these letters are made the text of the homily which we have copied, and with the sentiments expressed in which, we again say, we heartily concur, although knowing that they are turned to account for the purposes merely of private spite.

The readers of *ENGINEERING* need not be assured here that no attempts to frighten us will in the least alter our course, nor that, as heretofore, our journal will continue to be the terror of quacks and puffing tradesmen, impaling them on the sharp spear of criticism for the purposes of truth and public advantage alone, and with neither hope of gain nor fear of the spiteful writhings which our strictures may produce.

It will be as well here, however, to speak somewhat more broadly upon the whole subject which our contemporary has touched upon. It is well known that the trade price of neither our own journal nor *The Engineer* covers the cost of the bare white paper and its "machining," or the running through the press. All other expenses, the cost of setting or composing the type, drawing and engraving, the editorial, reporting, and publishing staff, office expenses, and general charges, are paid out of the sums received from advertisements. This fact, well known, in no way involves the perfect independence of first-class journals, such as the *Times*, and many others; but it is not unlikely that it does in many ways influence the utterances of some of the second and third rate journals, and if we are to judge from the ever-ready puff of such abortions as the "donkey injector," it may influence the management of papers like *The Engineer*. That paper, although its repeated and extraordinary mistakes have well-nigh forfeited the confidence of our profession, and although it is no longer read or seen by many of the leading engineers who were its former supporters, when under different management, nevertheless obtains a large advertising support by systematic misrepresentation of its real position, by privately and greatly overstating its circulation, and by a private and systematic course of detraction with respect to other journals, our own among the rest. The facts are, however, that its circulation is less than that of *ENGINEERING*, a fact well known in the news trade, and that its circulation is declining also among the influential class of readers whom advertisers especially wish to reach. Although we refer to such matters only at a certain sacrifice of feeling, it is but just that we should speak plainly and honestly upon them. The position of this journal within the profession is now too well known and appreciated to require that we should make any representation to its leading members; but they, and indeed all classes of engineers, will but do an act of simple justice in correcting as far as they can the injurious influence of misrepresentations to which this journal has been from the first privately subjected, and which undoubtedly have their intended effect with a certain inexperienced class of advertisers, who thus contribute so much to the means employed against us.

THE CORLISS ENGINE.

TO THE EDITOR OF *ENGINEERING*.

SIR,—I agree with your correspondent, Mr. Pooley, in thinking that the correspondence respecting the Corliss engine has now extended to an inexpedient length, and I will not further offend in aggravation of the fault, as this is the last letter I intend to address to you upon the subject. I further agree with Mr. Pooley in thinking that much of the correspondence is wordy and weak, and that what we want are not vociferous assertions of perfection, but properly attested facts, to show that the Corliss engine is what its advocates assert it to be—better than

any other. Either such facts are producible, or they are not. If producible, why are they not forthcoming? If not producible, is it not a piece of unwarrantable effrontery to require us to believe that this costly and complicated engine is more eligible than ordinary engines which are simpler and cheaper, and quite as equable and economical? Those who think such a demand upon their faith reasonable will probably obey it. But certainly the advocates of the Corliss system, in their utter destitution of relevant facts, do not by their letters exhibit any such power of intellect as to inspire the least respect for their opinions. We have been told again and again that a Corliss engine which had been introduced into some factory in substitution of a common engine did the same work with less fuel. But no one has been sufficiently courageous to maintain that the best Corliss engine is able to work more economically than certain good ordinary engines at present working. Until this can be proved, the encomiums passed upon the Corliss engines will be taken for what they are worth by every competent

OBSERVER.

TO THE EDITOR OF *ENGINEERING*.

SIR,—Will you kindly allow me to make the following corrections in my letter of last week? In fifth paragraph, fourth line, it should read, "capacity of cylinder above that, &c." Sixth paragraph, fifth line, omit the words "weights and," reading, "with the aid of springs, &c." Seventh paragraph, last line but one, read, "on the least increase, &c." And in ninth paragraph, seventh line, it should read, "and steam is totally cut off."

Sir, as Mr. Selt has alluded to the length of this discussion, and the wholesale abuse that seems so to delight some of your correspondents, I trust you will permit me to explain that it was this unqualified abuse levelled at the Corliss engine and its builders which induced me to presume on your space and the patience of your numerous readers. These correspondents, at least *primâ facie*, seemed not only practically unacquainted with the history, construction, and performances of the Corliss engine, but determined to ignore every statement of facts the least favourable to these engines, and *per fas et nefas* (if possible) cast a stigma over them. All I contend for, is, that "J. C. E." and others should first read the statements already published, of the saving effected by the Corliss engines, which have replaced engines of the common class, and when they have fairly explained away these data of the actual performance of these engines, then they may with becoming grace use their pens in condemnation and call for further attested facts. Mr. William Inglis, in *ENGINEERING* of the 28rd ultimo, gave the results of certain trials of both common and Corliss engines, conducted under the most favourable circumstances for arriving at fair and just results, which I need hardly add were decidedly in favour of the Corliss. Yet, Sir, your correspondents, "Observer" and "J. C. E.," have apparently nothing to say thereon. May I ask them if they accept these statements as proof of the superior performance of the Corliss engine, and if not, will they kindly state clearly, once for all, what is the precise nature of the proof they require, and how they want it "attested," so that this discussion may be terminated.

Mr. Pooley, of India Mills, Manchester, in his letter which appeared last week, writes favourably of the Corliss engine, but seems unaware of the facts already published by you, and pointed out by me in my letter of last week. Mr. Pooley, will find plenty of facts, and more will be shortly added, of engines either just started or on the point of starting. Mr. Pooley in the concluding portion of his letter seems to overlook the fact, that he is merely giving words instead of facts, which in the first part of his letter he deprecates. I hope, for his sake, that the opinion he expresses relative to the expectation he has of the Allen engine, which is not yet at work, will turn out to be well founded. I am sure that if good material and workmanship can make this engine a success, the Whitworth Company (limited) ought to be a sufficient guarantee; but Mr. H. H. Grierson, of St. George's Ironworks, Manchester, writing to the Editor of *ENGINEERING*, September 5th, 1866, says, "We have been manufacturing the Allen engine now for three years, and spent several thousand pounds experimenting, improving, &c.; but, after all our labour, we find that the cost of the engine precludes it being successful as a commercial speculation. We have had no orders for them lately, although plenty of inquiries for price, and we were astonished to see in the public papers that the Whitworth Company was about to commence manufacturing them. Our experience of the Allen valve-gear is, that it is admirably adapted for the high speed which Mr. Porter has advocated; but that such speed, although practicable, is commercially a complete failure, and we have not the slightest doubt that the Whitworth Company will soon find that out. We are prepared to supply engines that, going at a lower speed, will give an equally good result as regards consumption of fuel, and steadiness of motion, and with an equally valuable expansion, at a lower cost than the Allen engine can be produced at." I trust Mr. Pooley's engine may realise his expectations, but in presence of the above, I think, till they are realised, we may fairly consider the Corliss engine superior, seeing the Allen engine is, as it were, Phoenix-like, rising from its own ashes. I have given the opinion expressed by Mr. Grierson, after three years' experience with the Allen engine to sustain my statement in a former letter, when speaking of the anatomical qualifications of the Corliss engine, that not even the Allen engine can compare with it in rapidity of action and adaptability under the most varying load. I think, Sir, that I have justified my statement; and shall be glad to do justice to the Allen engine when Mr. Porter and the Whitworth Company give as sufficient data of the success of the Allen engine as the builders and promoters of the Corliss engine have given of its success.

I am, Sir, your obedient Servant,

J. W.

STEAM TOWING ON CANALS.—The attempt made to establish lines of screw steamers on the canals of France seems to have proved a failure. It has been otherwise, however, in Belgium, a "General Steam Towing Company" having commenced operations in June on the Willebriek Canal.

ON THE CONSTRUCTION AND WORKS OF
THE HIGHLAND RAILWAY.*By JOSEPH MITCHELL, F.R.S.E., F.G.S., C.E., and Member
of the Institution of Civil Engineers.

This title represents the union of several companies in the North of Scotland, amalgamated three years ago under the name of the Highland Railway Company. The works consist of a main line from a point near Perth, extending northward 117 miles to the town of Forres, and a base line running nearly at right angles to the other, extending westwards from the town of Keith by Elgin and Forres along the shores of the Moray Firth to Inverness, and thence along the Beaulieu, Dingwall, and Dornoch Firths, northwards to Bonar Bridge, measuring from Keith to Inverness 55 miles, and from Inverness to Bonar Bridge 58 miles, and making together a base line of 113 miles. These railways traverse the northern part of Perthshire, and are the main lines of communication through part of Banffshire and the counties of Inverness, Nairn, Moray, and Ross, the whole including three branches, two to the ports of Burghhead and Findhorn, in Morayshire, and the other to the village of Aberfeldy, in Perthshire, extending to 246 miles in length.

The country is fertile and comparatively flat for a distance of about 40 miles north of Perth, and also along the shores of the Moray, Dingwall, and Dornoch Firths, but between Perthshire and Morayshire the line crosses two ranges of the Grampian Mountains, the one separating the valley of the Tay from that of the Spey, and the northern range separating the Spey from the valley of the Findhorn.

The large rivers which drain these mountain regions debouch into the Tay, the Moray, the Dingwall, and the Dornoch Firths, and as the railway in most cases crosses these rivers near the sea, bridges of considerable magnitude were required. Besides the crossing of these rivers, other difficulties of a formidable character arose in crossing these mountains at so great an elevation, and in passing the rocky and precipitous defiles through which portions of the line had to run.

The northern counties traversed by these railways, except along the shores of the Firths, are chiefly pastoral, exporting large numbers of sheep and cattle.

The fisheries also are on an extensive scale; besides the salmon fisheries in the rivers, the annual take of white fish in the Moray Firth amounts to about 60,000 tons.

The object of the promoters, therefore, was to sweep the fertile shores of the Moray Firth, and to send the produce of the country by the most direct route to Perth, across the mountains, thus saving a detour by Aberdeen of nearly 60 miles. In laying out the main line, and crossing the Grampians between Perth and Forres, long and steep inclines could not be avoided; but there is no steeper gradient than 1 in 70 throughout. The line to Blair, 36 miles from Perth, rises only 443 ft. above the level of the sea; but from Blair to the summit of the southern range of the Grampians, a distance of 17 miles, the line rises 1045 ft., making the extreme 1488 ft. above the sea. In this distance there are gradients for 10 continuous miles of 1 in 72, and 1 in 70; and in the remaining 7 miles the inclines vary from 1 in 78 to 1 in 110. After passing this summit the line descends into the valley of the Spey, falling 747 ft. in 18 miles, the steepest gradient being 1 in 80. On crossing the Spey the line is comparatively level for a distance of 24 miles, when it again ascends by gradients of 1 in 84, 80, and 100, in order to pass the northern ridge which separates the valley of the Spey from that of the Findhorn. This summit is 1046 ft. above the sea level. It afterwards descends to Forres—the point of junction with the base line—by gradients, the steepest of which are 1 in 70 for 8 miles, and 1 in 76 for 4 miles.

In this length of the main direct line of 104 miles there are two small tunnels, one of 350 yards, near Dunkeld, and the other, in the Pass of Killiecrankie, of 110 yards in length, both constructed very much with the view of avoiding injury to the adjoining scenery.

The principal difficulties that arose in laying out the line were in passing through the narrow defile at Dunkeld, the beautiful demesne of the Duke of Athole, and again in penetrating through the picturesque Pass of Killiecrankie, where the mountains, as it were, close in upon each other for a great height; likewise in passing along the narrow, precipitous, and rocky valley of the Garry, close to a large and rapid mountain stream; also the park at Castle Grant, and the defile at Huntly's Cave, near Grantown. These points in particular required much study, with repeated trial and contour levels, so as to obtain a knowledge of the precise formation of the ground, and to choose the best direction at the lowest possible cost. At the Pass of Killiecrankie the banks were so precipitous and steep that the line had to be supported by breast or retaining walls to the extent of 690 lineal yards, and to the average height of 26 ft., the extreme height of one being 55 ft.; and in order to carry the railway at the narrowest point in the pass, where the precipices close in, as it were, on either

side, and afford scarcely any additional space beyond that occupied by the channel of the river, instead of supporting the line by breast-walls, it was deemed prudent to construct a viaduct of ten arches 60 ft. above the river, which, with a tunnel at the north end, carries it successfully through the pass. At two other points on the line, in running up the sides of the Garry breast-walls had to be formed, respectively 94 and 35 yards in length, and 15 ft. in average height. All these breast-walls, extending to 1650 lineal yards, are built with lime, and set on a solid foundation of dry gravel or rock at right angles to the face of the wall, which batters at the rate of 1½ in. to the foot.

The spaces behind the walls are filled with rubble stones set by hand for ten feet wide, and further back with dry gravel, it being important that all earth or clayey substances should be excluded. The writer prefers the curved to the straight batter, as it gives more effectual resistance if well built; but breast-walls are to be avoided wherever earth embankments can be substituted, as, in his experience, there are subtle influences in the Scottish climate of alternate frost and wet in winter, which operate imperceptibly to their destruction, and they require careful and constant inspection. Except where those breast-walls became necessary, the whole of the lines were formed in cuttings and embankments, and for considerable distances along the slopes of valleys. Where the ground was precipitous or irregular in the cross section, level benchings were formed ten feet in width immediately underneath the permanent way, in order that the sleepers should have an equal and solid bearing throughout.

In running through so large an extent of mountainous country, the line, as might be expected, had to pass over some lengths of soft ground and morass. The principal of these were for two miles near the town of Nairn, also for about two miles near Keith, one mile on Dava Moor, and about a mile in crossing through a hollow at Drumochter, on the summit of the Grampians. In all places where the ground was particularly soft, a uniform mode of treatment was adopted. Two parallel drains were first cut outside the fences, about 50 feet apart, from 4 to 6 feet deep, and with slopes of 1 to 1. This drained off the surface water, and after making up the holes and other irregularities of the surface with turf, the space for the railway to a breadth of about 15 feet was covered with two or three layers of swarded or heather turf, having the sward side of the lower layer undermost, and that of the top layer up, the joints breaking bond. In this way a good sustaining surface has uniformly been obtained.* On this bed of turf the ballast was laid for two or three feet in depth. This was quite sufficient to support the traffic, but as, in some cases, the bed of moss was from twenty to thirty feet in depth, the railway merely floated on the surface, and was in the first instance undulating, and yielded in some parts from three to four inches under the weight of the engines passing over. To obviate this undulation, longitudinal beams of timber were tried at one place, thirty to forty feet long, below the sleepers; but this was found objectionable, as rendering it more difficult to raise or repair the surface of the road; and an additional sleeper (making the sleepers 2 feet 6 inches from centre to centre, instead of 3 feet) was found preferable. There was nothing for it at the worst but to lift the road every other week, as it sunk, until it had acquired a solid bearing. In many places we had to lay on four, five, or six feet in depth of additional gravel, and in one place no less than twenty-seven feet, before the road became solid. In the course of two or three years, however, with due attentions, the rails being fished, the lines through these mosses were all that could be desired for solidity and permanence.

As the writer has said, in crossing so many mountain rivers, bridges of magnitude had to be constructed, involving considerable varieties of execution. The principal of these bridges may now be described, and any peculiarity will be noticed which may have arisen during the progress of the works. It will be observed, that the beds of the rivers in the north of Scotland differ in many respects from what is common in England, consisting frequently of depths of 10 or 12 ft. of gravel and boulders, the solid and compacted debris of successive floods, below which, if the country is of rocky formation, there is usually hard clay and then rock, or, as in one case at the mouth of the river Ness, after penetrating 12 ft. of shingle and boulders, a sort of admixture of whitish clay and sand was obtained. In some cases we had to deal with soft clay and mud of great depth, but these were exceptions. Nor was it possible, in general, to ascertain by boring the precise nature of the foundations, because many of the boulders in the gravel were of large size, and were often mistaken for rock. The only way in which an approximate knowledge of the foundations could be obtained was by driving iron rods at various places, and, when the bed of the river admitted of it, wooden piles. Still, we worked very much in the dark, but the writer's long

experience of these rivers, and of the nature of their floods, was of great advantage in enabling him to fix the depth of the foundations and the precise description of works to secure the necessary stability of construction. In only two or three cases was there any fear of sinking. What had chiefly to be guarded against was sudden and impetuous floods, sometimes accompanied with floating ice and trees, undermining the foundations and damaging the piers; it was, therefore, important to provide ample waterway. The construction of these bridges ranged over twelve years, and during that time there has been considerable changes in bridge-building, by the adoption of iron cylinders for piers, and lattice girders in spanning the waterways, so that, as the works progressed, these improvements were adopted where found suitable.

In planning these works, the writer, while having every regard to economy, felt the importance of their being of the most substantial character, seeing that they were exposed in these districts to every vicissitude of climate and flood; but indeed he feels that all permanent public works involving the safety of the lives of the community should be of undoubted stability. On the whole system there are only three timber bridges, which he was forced to adopt chiefly with a view to save time, but these are very substantial of their kind. All the other bridges are constructed of stone, and where iron is adopted the piers are in general constructed of masonry.

The iron-work of the bridges on all these lines were constructed by Messrs. Fairbairn and Sons, of Manchester, for about 20¢ per ton on the average, and are admirable specimens of workmanship in this department.

Accompanying this paper, the writer has furnished the working drawings of fourteen of these bridges with the sections and dimensions in detail. They exhibit a variety of forms suited to the localities in which they are built.

No. 1 is an iron girder bridge across the Tay, six miles north of Dunkeld, with stone abutments and pier, constructed on platforms and piles in the usual way. The banks are low, and the river is spanned by two openings, one of 210 ft. and the other of 141 ft. The cost of this work was 20,395*l*. Extreme length, 515 ft.; height above the bed of the river, 67 ft.; cost per lineal foot, 39*l*. 12*s*.

Nos. 2 and 3 are the most recent bridges erected by the writer, and here he has taken advantage of the modern plan of using cylinder-piers to carry the girders. Both bridges are constructed in the same manner, and on the same principle. The cylinders form the piers in the centre and abutments. Each cylinder is 8 ft. in diameter, and has been sunk into the bed of the river 27½ ft. in their extreme depth by means of divers. When these cylinders were adjusted and brought to the full depth, about 3 ft. of cement concrete was lowered into the bottom. On the concrete setting, the water was pumped out, and the interior filled in with rubble masonry, laid with Portland cement. To provide for extreme floods, two side openings were made 41½ and 35 ft. span, of plate girders, one end resting on the masonry in the cast-iron cylinders, and the other on a stone abutment landward, secured on a platform and piles. These bridges answer their purpose very satisfactorily. The cost of No. 2 bridge, which consists of two openings of 122 ft. and two side openings of 35 ft. span, was 11,156*l*. Total length of No. 2, 350 ft.; cost per lineal foot, 31*l*. 17*s*. 6*d*.; height above the bed of the river, 36 ft.

The cost of No. 3 bridge, consisting of two openings of 137 ft. span and two side openings of 41½ ft. span, the cylinders being sunk into the bed of the river 25 ft., amounted to 13,772*l*. Length of No. 3, 419½ ft.; cost, 32*l*. 16*s*. 7*d*. per lineal foot; height above the bed of the river, 49 ft.

No. 4 is the viaduct in the Pass of Killiecrankie, already alluded to. It consists of ten arches of 35 ft. span, with an extreme height from the foundations to the top of the parapet of 54 ft., and is built with a curve of twenty chains radius. The Pass of Killiecrankie is a well-known object of picturesque beauty, and it is generally admitted that the railway, now that the slopes have attained their proper verdure, has in no way diminished its attractions. Indeed, this viaduct is thought to give it additional interest. The cost was 5720*l*. It is adapted to the single line, and is 17 ft. in width, over parapets. Length, 508 ft.; cost per lineal foot, 11*l*. 5*s*.

No. 5 is a viaduct across the river Tilt, near Blair Athole, spanning the river by one wrought-iron girder of 150 ft. The abutments are of stone, laid 3 ft. below the bed of the river, on a platform of timber 6 in. thick secured to piles. As it is situated close to Blair Castle, it has been made somewhat more ornate than was otherwise necessary. The cost of this bridge is 6500*l*, being for a single line. Length, 256 ft.; cost, 25*l*. 7*s*. 9*d*. per lineal foot; height above the bed of the river, 40 ft.

No. 6 is a bridge across the river Garry, at Calvine, of three spans, one of 80 and two of 40 ft., and is 55 ft. from the bed of the river to the top of the parapet. There was considerable difficulty in fixing the crossing of the river at this place. The Garry is here a large and rapid mountain stream, on a rocky bed, with several

* Paper read before the British Association, at Dundee. We shall give engravings of many of the works referred to in this paper in an early number.

* Had this plan, which the writer has found to answer so well, both for roads and railways, been adopted in the clayey ground at Balaklava, in the Crimea, a good road might have been formed.

falls immediately adjoining, running through an ornamental plantation; and as this was a spot of interest in the grounds of Blair Castle, we were precluded from crossing the river at any other point within the demesne. It occurred to the writer, however, as the road bridge passed over about the narrowest part of the river, the object aimed at could be effected both economically and unobjectionably by spanning both road and river, thus forming an object of additional interest in this peculiar locality. The cost of the bridge was 5100*l*. Length, 274 ft.; cost per lineal foot, 18*l*. 12*s*. 3*d*.

No. 7 is a bridge of no particular interest, 80 ft. span, crossing the river Durnain, a mountain stream near Grantown, but is given as a specimen of a substantial bridge of this size. The cost was, masonry, 2238*l*.; ironwork, 1060*l*.; total, 3298*l*. Length, 148 ft.; height, 27 ft.; cost per lineal foot, 22*l*. 5*s*. 6*d*.

No. 8 is a viaduct crossing a picturesque ravine and stream called the Divie, 10 miles south of Forres. Its length is 477 ft., constructed for a single line, and the cost amounted to 10,231*l*. It is 106 ft. in height from the river bed to the top of the parapet, and 16 ft. in width; all the piers within the limits of the stream are founded on rock. It consists of 7 arches of 45 ft. span each; cost per lineal foot, 21*l*. 9*s*.

These viaducts constitute the principal works on the through line between Perth and Forres. The writer will now proceed to allude briefly to the principal works on the coast line between Keith and Bonar Bridge.

The portion from Keith to Inverness being one-half the distance of the railway from Aberdeen to Inverness, the capital of the Highlands, extends to 55 miles in length. It may be stated that this portion from Inverness to Keith originally formed part of the Great North of Scotland Railway, the act for which was obtained in 1846, but pecuniary difficulties prevented the promoters from constructing this part of their scheme, involving, as it was then supposed, the construction of very heavy work in the neighbourhood of the river Spey. It was eventually left to the Highland Companies to carry it out. There is a deep and precipitous ravine on the south side of the Spey, with flat meadows on the north side, and the original plan of the Great North of Scotland Company was to cross the river at a gradient of 1 in 90, with a high viaduct, with expensive works in the ravine, at a cost of about 100,000*l*., the bridge being estimated at 60,000*l*. After much careful survey and consideration, and consultation with Messrs. Locke and Errington regarding this work, it was fixed to pass through the ravine by a gradient of 1 in 60 for 2½ miles, which is the steepest gradient on the Highland system, and span the river by a box-girder of 230 ft., with six side arches of masonry, each of 30 ft. span, to meet the contingency of flood waters, which are on this river very sudden and very rapid; and the work has been carried out successfully. It may be mentioned that this was about the greatest single span of an open girder at the time built (1856). The propriety of a stone bridge at this place, with a gradient of 1 in 70 was considered by the directors, but it was found to be too expensive. The present line, however, answers quite sufficiently for the traffic of the country, which is now chiefly local since the opening of the Highland line. The cost of the bridge, which is 660 ft. long, and 74 ft. high from the foundations to the top of the towers, constructed for a double line, was 34,480*l*. Cost per lineal foot, 52*l*. 5*s*. The east abutment of this bridge is founded on rock, and it was provided that the west abutment should be sunk and founded on piles and a platform, the first imperfect trial having led to the conclusion that there was nothing beyond indurated shingle at this place. On sinking 14 ft. from the surface, however, through a conglomerate of boulders 2 to 3 ft. in diameter, hard mountain clay appeared, and on penetrating this for about 3 ft. rock was found, thus securing for this structure a rock foundation on either side. Immediately at the east end of this viaduct the line, as already said, runs through a narrow and precipitous ravine, the stream of which had to be diverted for the railway by a new channel cut out of the solid gravel, 30 ft. wide, sloping longitudinally 1 in 40, and pitched with stones from 12 to 18 in. deep. This pitching, which consists of squared stones, had, to a small extent, broken up several times since the line was opened ten years ago, from the floods bringing down stones and trees, and we found that the most effectual way of securing it was by inserting walings of timber 40 ft. apart, 12 in. by 4 in., across the channel, secured at every 3 ft. by iron piles, and grouting the joints of the pitching in dry weather with lime grout, so as to prevent the lodgment of air and water, which, under the pressure of floods, has a tendency to dislocate the stone-work.

No. 10 is a viaduct crossing the Findhorn, a dangerous and rapid river. It sometimes comes down in great flood, almost in a body of 2 or 3 ft. of perpendicular height at a time, notwithstanding that in summer it is a very moderate-sized stream. This bridge consists of 3 spans of 150 ft. each, with stone abutments and piers of solid ashlar, and is constructed for a single line. There was no appearance of rock in the immediate neighbourhood of the site, although rock appeared on one side of the river about half a mile above; and the

channel, as far as could be ascertained, consisted of shingle and gravel. It was provided, therefore, that the foundation should be sunk 6 ft. below the deepest part of the bed of the river on a platform and piles. The east abutment was so sunk, and the piles were driven through the gravel to a depth of 10 ft., making 16 ft. below the bed of the river. It was observed that at that depth the piles uniformly would drive no further, and this suggested the possibility of rock. Rock was accordingly searched for, and it was found that, about 18 ft. under the bed of and across the river, rock existed. Coffor-dams were therefore formed, and rock foundations were secured for the remaining piers and abutment. The cost of the bridge, including a pitched embankment on the east side, the bottom of which was secured by piles and a waling of timber, amounted, masonry, to 11,170*l*.; ironwork, 10,260*l*. Extreme length, 608½ ft.; height above foundations, 46½ ft.; cost per lineal foot, 35*l*. 4*s*. 4*d*., making a total of 21,430*l*.

No. 11 is a bridge across the river Nairn, consisting of four arches of 55 feet span, and is an admirable piece of masonry. An incident connected with the foundations of this bridge deserves to be mentioned. The contractor, when instructed to ascertain the nature of the foundations, insisted that it was unnecessary to take any trouble about them, as rock cropped out on either bank; the turnpike-road bridge across the river, a quarter of a mile below, was founded on rock, and he said there could be no doubt that rock would be got in the centre 3 or 4 feet below the bed of the river. Rock, however, was not reached until we sank from 13 to 14 feet, showing that experienced persons may be misled even under the most convincing circumstances. The structure, however, is founded on the solid rock throughout, and the cost, for a double line, was 8620*l*. Length, 371 feet; height, 56 feet; cost per lineal foot, 23*l*. 4*s*. 8*d*.

No. 12 is a viaduct across the Ness, consisting of five arches of 73 feet span over the river, four land arches of 20 feet span, and two cast-iron openings of 27 and 35 feet span over roads. The foundations of this bridge, as in many others, consisted of shingle for 20 feet down; but at the north abutment and pier the iron rods driven in appeared to penetrate considerable easier than at other points of the channel, and it was deemed prudent to construct this abutment and pier upon bearing piles and a platform, and they were accordingly so done, as exhibited in the drawings. The total length of this bridge, including the side arches, is 669 feet; and the total height, from the bed of the river to the top of the parapet, is 40 feet. It is constructed for a single line, and cost 13,410*l*.; cost per lineal foot, 20*l*.

No. 13 is a good example of a swing bridge, built across the Caledonian Canal, which the line spans on a skew of 65 degrees. It consists of two girders of 126 feet in length, 78 feet of which, from the centre of the turntable, spans the canal, and the remaining 48 feet forms the balance-weight. Advantage was taken of the canal being emptied for repairs to lay the foundations of the masonry, which are on a platform and piles in the solid gravel, 9 feet below the surface of the water. The depth of the canal is 18 feet, and the width of the locks 40 feet, the canal banks being 120 feet apart. Some difficulty occurred at first during hot weather from the expansion of the iron affecting the adjustment and closing of the bridge, which was remedied by means of a powerful screw, and the bridge has been worked with satisfaction and safety for the last five years. This bridge, with its machinery, timber wharves for protection from vessels, distant and station signals, &c., complete, cost 4718*l*.

No. 14 spans the river Conon, in Ross-shire. From peculiar circumstances it was necessary that this bridge should cross the river on a skew of 45° to the stream, and as there were rock foundations, there was no difficulty to contend with beyond that of 4 ft. or 5 ft. of water in the channel of the river to reach the rock, and which was successfully accomplished. The peculiarity of the skew with the river at this place would have been more easily provided for by the adoption of iron girders from pier to pier, but as the writer found at that time that iron girders would be fully as expensive and not so permanent as a stone bridge, and as there were admirable quarries in the neighbourhood, he resolved to construct this bridge, as already said, on a skew of 45° with the river, by a series of right-angled ribs or arches spanning from pier to pier. This is no new arrangement, but the writer is not aware of this plan being adopted for a series of arches of so large a span in any previous instance. The bridge consists of five arches of 73 ft. span each, the arches being constructed of four ribs, each 3 ft. 9 in. wide; the arch stones are 4 ft. deep at the springing, and 3 ft. deep at the crown. The key-stones of the centre part of each arch were made to connect with each other as were the stones in the haunchings of the arches, and some cramps of iron were inserted at the joints to connect the ribs. The work was successfully accomplished, and constitutes a very perfect piece of bridge masonry. The total length of the bridge is 540 ft. and the height 45 ft. from the bed of the river. The north abutment

is founded 304 ft. lower down the river than the south, and the whole structure, when the centres were removed, was found so accurately built, that no joint in it showed any indication of setting. The cost of this bridge for a single line was 11,391*l*.; cost per lineal foot 21*l*. 2*s*.

There are many other bridges, as may be supposed, over so great an extent of country, and a country so much exposed to floods; but those above described are the principal, the entire waterway spanned over the entire system being 9828 ft.

On the central railway from Dunkeld to Forres, 104 miles, being a single line, there are 8 viaducts, 126 bridges over streams, 119 public and accommodation road-bridges, and 8100 yards of covered drains, varying in size from 18 in. to 36 in. square. There are 1650 lineal yards of breastwalls, 304,700 cubic yards of rock cutting, and 3,416,000 cubic yards of earthwork, being, including rock and earth, at the rate of 35,776 cubic yards to the mile. The largest embankment was at Rafford, near Forres, which contained 308,000 cubic yards.

The permanent way consists of larch and natural grown Scotch fir sleepers of the usual size, 3 ft. apart; the chairs are 22 lb. in weight; the rails weigh 75 lb. to the lineal yard, are in lengths of 24 ft., and are fished at the joints.

The total cost of the works, including all extra and accommodation works, amounted, for the 104 miles, to 798,311*l*.; the land, including severance, to 70,000*l*.; and the preliminary, parliamentary, engineering, and law expenses, to 50,893*l*.; making the cost of this portion of the company's lines 919,204*l*. or 8860*l*. per mile.*

The contracts were entered into immediately after the passing of the bill in July, 1861; the first turf of the railway was cut on 17th October of the same year, and the whole line was passed by the Government inspector and opened for public traffic on the 9th September, 1863, being one year and ten months, an unprecedentedly short time for works of such magnitude. The works between Forres and Dunkeld were divided into nine contracts, let by public competition, and were undertaken 15,705*l*. below the engineer's estimate, and were completed at 12 per cent. over the engineer's estimate, including 4 per cent. for accommodation works ordered by land-valuators. The traffic has been worked successfully and without accident for four years. The mail trains perform the journey between Inverness and Perth, 144 miles, in 5½ hours. It was proposed to the Post Office, but not agreed to, on account of the expense, to run them in 4 hours.

An ordinary goods train of 20 wagons, or 200 tons gross load, is drawn up the steepest inclines by one engine, having 17 inch cylinders and 24 inch stroke.

The traffic is rapidly increasing. The sheep and cattle which used to reach the southern markets by a toilsome journey of a month or six weeks, are now conveniently transported in a day at less cost, the company having carried in one week upwards of 21,009 sheep.

In passing over the mountain ridges already described, it was feared that serious interruptions would arise from snow during the winter; but as the writer had a knowledge of the whole country for many years, he did not anticipate any difficulty on this head which might not be overcome. The summit is about 500 feet higher than that of the Caledonian line, or some 1500 feet in all above sea level, and is no doubt more exposed. The first winter, viz., 1863-64, was wholly open, and the traffic uninterrupted; in February of the second winter, viz., 1865, a very heavy snow-storm occurred all over the north of Scotland, impeding the traffic of almost all the northern railways, and stopping the traffic on the Highland line for four or five days, which was only restored with great difficulty by the labour of large bodies of men. It was evident, therefore, that some decided steps must be adopted to overcome the snow difficulty, and, in the beginning of 1866, the road was kept pretty well open by the application of snow ploughs; and the experience of that winter made it quite clear that this difficulty might, with proper appliances, be effectually overcome, and means were accordingly adopted for that purpose.

In these elevated regions, when a snow-storm occurs, it is accompanied with high wind, and the snow is consequently drifted with great rapidity into the hollows and cuttings. With the view of obviating this, screen fences of light timber or of decayed sleepers, or earthen mounds, were erected a few yards from each side of the cuttings where the line was exposed. These were found very effective for intercepting the drifts. There was then provided snow-ploughs of three descriptions—viz. one, a light plough, fixed to all the engines running on the line, and capable of clearing 12 to 24 in. of new snow. The second was a more formidable snow-plough, which was fixed to a pilot engine, and was found capable of clearing 2 to 5 ft. of snow. This pilot engine was attached to goods or passenger trains. The third, and

* The extra work claimed by one contractor is still unsettled, but is valued at the rate at which the extra works on 160 miles of this system of railways have been amicably settled.

largest class of plough, was found to clear snow 10 or 11 ft. deep with the aid of four or five goods engines.

These appliances, notwithstanding the very serious snow-storms which were encountered on the line in January last, were capable of keeping the line almost wholly clear.

This the writer considers a great triumph, inasmuch as the Highland line over such high elevations was kept clear, while by the same storm the lines throughout Scotland, England, and France were more or less blocked up; the lines in the north of Scotland being stopped entirely five or six days; the mails for Aberdeen being delayed three days from London, and two from Edinburgh; the Norfolk line was blocked up for some days; the Holyhead mail detained from twelve to sixteen hours; the London, Chatham, and Dover blocked up for two days, as well as the trains in France to Marseilles.

Much credit is due to the activity and attention of the Highland Company's officers, Mr. Stroudley, the locomotive superintendent, and Mr. Buttle, superintendent of permanent way; Mr. Stroudley having planned and constructed the snow-ploughs.

As a specimen of a cheaply constructed line of railway, the writer annexes a note of the details of the northern portion of the Highland Railway from Invergordon to Bonar Bridge, 26½ miles in length. The country through which this section of the line passes is comparatively level, and several parts skirt and run through the sea, where the works had to be protected at considerable cost. The cuttings amounted to 549,000 cubic yards, of which about 20,000 was rock. There are 27 bridges over streams, 4 of them 40 to 50 ft. span; 26 public and accommodation road bridges; and 2942 lineal yards of drains, varying from 18 to 36 inches square. The rails are double-headed, and weigh 70 lb. to the yard, and are fished at the joints; ¾ of the chairs are 20½ lb., and ¼ 28 lb. in weight. There are ten stations, with permanent dwelling-houses for the agents and porters.

The total cost of this portion of the line, the works being of the very best quality, and the masonry all of stone, amounted to 5018½ per mile; or, including parliamentary and law expenses and land, 5888½ per mile.

Commercially, these lines, extending over 246 miles, have not as yet been quite successful, from the fact of too great an extent of line having been undertaken at once, it requiring, in an agricultural country, considerable time to develop the traffic.

Under the whole circumstances, however, the traffic is satisfactory.

The works are of the most substantial character. The capital account, which is under 2,800,000½, is about closed, as far as new works are concerned, while the revenue is rapidly increasing. For the half year just ended the company will be able to pay its preference and debenture stocks, 5 per cent. on its floating liabilities, and about 2 per cent. on its ordinary stock of 740,000½.

It will thus be seen that if the revenue increases in the same ratio that it has hitherto done, viz. from 15,000½ to 20,000½ per annum, the company will be able to pay in two or three years a satisfactory dividend of 5 per cent. When that event occurs, the directors may, with propriety, give some moderate aid to the further extension of the main lines of communication to Caithness and Skye, both of which must prove valuable feeders to the Highland system.

These lines were promoted chiefly by the great landed proprietors in the country, among the most prominent of which were the Earl of Seafield, Lord Fyfe, Mr. Mathew, of Ordness, M.P., Mr. Meny, of Belladun, M.P., Mr. McIntosh, of Renginal, Col. Fraser Tytler, &c.

ON STEAM-CULTIVATION.*

By MR. DAVID GREGG.

It is not my intention in this paper to treat of the mechanical part of the above subject. For although the greatly varying nature of the soils, and circumstances to be dealt with over the country, renders it necessary to have many different adaptations of the apparatus employed, still the machinery has now been so nearly brought to perfection that the farmer has no longer any difficulty in obtaining apparatus suited to his own particular requirements. The means employed to bring about such results as those to which I shall advert can scarcely be considered of that importance which the subject assumed during the earlier stages of steam-cultivation. The points I propose to deal with are:

The advantages to be derived by the farmer from the use of steam in the shape of better crops; tillage operations more economically effected; the lessening of the number of operations required; and, most important of all, work done at precisely the right time, and when it can be done to the greatest advantage.

I shall also advert to the present state of steam-cultivation, and its prospects for the future.

It is asserted by all who have tried spade-husbandry, that the crops obtained under that system are much better than those which can be got from horse-cultivated land; indeed, this is so far the case that although it cost from four to five times as much as horse labour, its adoption has been found no disadvantage where an abundance of labour, at a moderate cost, could be obtained to do the work at the proper time. This is now rendered impracticable by the present state of the labour-market in England. However, the fact of its superiority remains nevertheless indisputable.

The chief feature of advantage in spade-husbandry is the thorough loosening and mixing of the soil, and as this is much better accomplished by steam, it logically follows that crops upon steam-tilled land will be far superior to those grown under horse-culture. And this is borne out by actual experience, the exchange of horse for steam power being generally followed by a marked improvement in the crops, and much greater yield per acre, varying of course with the nature of the soil, but amounting in some cases to two quarter more corn per acre. The reason for this increased pro-

ductiveness can be easily understood; a team of four horses ploughing a 12 in. furrow will leave more than 300,000 footprints per acre; and as these nearly cover the ground, the effect, as every farmer well knows, is to leave a hard subsoil or "pan" beneath the cultivated ground, which becomes worse with every successive ploughing at the same depth. The tractive power that horses are able to exercise upon a plough or other implement is very limited, and is further decreased in consequence of having to convey their own weight over the broken and uneven soil, and also to partly undo the compression caused by the treading of their feet.

If a horse be taken when the land is in a rather plastic state and walked across the track of the steam-plough, and made to travel to and fro transversely on every 10 in. width until a breadth of 6 yards is trodden over, it is then found that if the steam-cultivator has just sufficient steam to perform its work properly before it arrives at the ground so trodden down, it will be completely stopped before it gets through the 6 yards; and, considering the momentum of the fly-wheel, this experiment shows plainly that the power required is something very material, and experience shows one-third additional draught to be required on land that has been trodden down to the same extent as in cultivation by horse power. With steam the case is very different. The engine stands on the headland and hauls the implement to and fro by means of a wire rope. All treading and compression of the soil and subsoil is thereby entirely avoided, and the implement is driven at a much more rapid pace, throwing up the soil to a greater depth, and in a loose state, enabling it to derive full benefit from the influences of the atmosphere. It is found in practice that the rapid motion of the steam-driven implement tends to loosen and aeriate the soil much below the actual depth at which the type or share is running. In horse or ox ploughing the case is just the reverse, as the sole of the plough and the treading of the animals so consolidate the bottom, that the necessary chemical action between soil and subsoil is prevented, and consequently all escape of gas and water. The result of the deep tearing up and loosening of the soil at the proper time by steam is that its temperature is raised, and a much greater quantity of ground is penetrated by air. The air is replaced in the same proportion by water, when rain comes, and this moisture is retained in the cultivated ground as though in a sponge, any superfluous quantity sinking away to the drains beneath, instead of the whole lying for some time on a hard trampled subsoil, as though held in a dish, making the land cold and ungenial.

I am now more particularly referring to heavy land; but a similar result is observable in the case of light land. Light lands are never much damaged by wet; the principal danger is from "burning" in dry weather, but the deep cultivation and loosening of the soil, instead of having it lying on what might be termed a board, causes even light land to retain its moisture in a dry season for a considerable time. The mere question of aerating the soil deserves much more attention than is generally given to it. Mr. Bailey Denton lately wrote an able letter to the *Times*, which forcibly illustrates the importance of this question. He says:

"Within a few miles of the metropolis, on Northpark Farm, Blackheath, Mr. Shepherd has raised a breadth of wheat which any earnest agriculturist will be pleased to see. It is growing on land not naturally fertile, which Mr. Shepherd underdrained at his own cost, and has since cultivated with steam-plough. The yield has been estimated by good judges at an average of 45 bushels per acre. At 8s. per bushel, this will bring 18½ per acre, irrespective of the straw, which may be considered as equivalent to the harvest expenses.

"Adjoining Northpark Farm is some very good wheat growing on similar land, equally well drained and treated, except in the one particular of steam-cultivation. It has been horse-ploughed. This yield may be fairly put at 30 bushels, which, at the same price per bushel, will bring 12½ per acre.

"Within sight of these two instances may be seen some wheat also growing on land similar in character to Mr. Shepherd's, which has neither been drained nor steam-cultivated, the yield of which cannot be estimated at more than 20 bushels to the acre. The return in money, at the same price per bushel, will be 8½ per acre.

"Hence we have within a short drive of London three cases of comparison, which cannot fail to show that by the adoption of deep steam-cultivation on deep drainage the produce from stiff soils may be doubled."

Steam-cultivation improves the crops in another way. If the soil has been thoroughly and deeply loosened at the right period, and has not been consolidated except by its own weight, the roots of the plants have ample liberty to penetrate, until they are stopped by natural causes. In dry seasons the roots are thus enabled to follow the moisture in the ground very much farther than would otherwise be possible, and as no burning can take place until the deepest root has entirely exhausted the moisture around it, the crop is made capable of resisting the effects of drought for a very long time. I believe that the success or otherwise of a crop depends upon the number of cubic feet of soil that the roots are able to penetrate, and I have found that a grain crop

HIGHLAND RAILWAY.
Abstract Note of the Chief Viaducts on the Highland Railway.

Nos. on Plans.	Situation.	Abutments and pier of stone	Ex- treme length.	Height above the bed of river.	Cost.	Cost per lineal foot.	Remarks.
1	Viaduct over the river Tay, at Dalguise.	2 spans of wrought iron, 210 ft. and 141 ft.	615	67	20,895	39 12 0	Built for a single line.
2	" " " " " "	2 spans of 122 ft. each, and 2 of 35 ft.	850	86	11,156	31 17 6	"
3	" " " " " "	2 spans of 137 ft. each, and 2 of 41½ ft.	413½	49	18,772	32 16 7	"
4	Killiercankie viaduct	10 arches of 35 ft. span	608	54	6,720	11 5 0	"
5	Viaduct over the river Tilt, at Blair Athole	1 span of wrought iron 150 ft.	256	40	6,500	25 7 9	"
6	" " " " " "	1 arch 80 ft. span, 2 arches 40 ft. span	274	55	6,100	18 12 8	"
7	" " " " " "	1 wrought-iron span of 80 ft.	148	27	8,298	22 5 6	"
8	" " " " " "	7 arches of 45 ft. span	477	106	10,281	21 9 0	"
9	" " " " " "	1 span of 230 ft. of wrought iron, and 6 side arches of stone and brick, each 80 ft. span	660	74	84,482	52 5 0	Double line.
10	" " " " " "	3 spans of 150 ft. each, of wrought iron	605½	46½	21,430	35 4 4	Single line.
11	" " " " " "	4 arches of 55 ft. span.	871	56	8,620	23 4 8	Double line.
12	" " " " " "	3 arches of 73 ft., and 4 side arches of 20 ft. span	669	40	18,410	20 0 0	Single line.
13	" " " " " "	2 wrought-iron girders, each 126 ft. long, set on a turn-table	540	45	4,718	21 2 0	"
14	Viaduct over the river Conon, in Ross-shire	All stone and at a skew of 45°; 3 arches of 73 ft. span, built in square ribs.	540	45	11,891	21 2 0	"

* Paper read before the British Association at Dundee.

will stand up much better, and is not so easily laid on a deeply cultivated soil as on one that is shallow. From what has been said on this part of the subject, it will be readily conceded that a great improvement in the crops is one of the results that must inevitably follow the use of steam on the land.

At the present time the cost of performing tillage operations by steam is very far from being so low as it should be, or what it eventually will be. In many cases, and especially with machinery working for hire, the very heaviest portion of the work is given to steam, and generally that which cannot well be done by horses. Now, before we can obtain the maximum of cheapness we must cause steam-power to perform all the operations connected with the tillage of the ground; for if, after steam-ploughing a field, horses are taken upon it perhaps two or three times for the purpose of harrowing, or doing other similar work, the ground is of course trodden down, and consolidated again. The consequence is, that the next year it requires much more power to break it up than would otherwise be the case; and not only does it require this extra force, but clod-crushers and other implements have to be applied to it, which would not be required if the treading was avoided. The generality of land if put under steam-cultivation, and kept entirely free from the trampling of animals, would only require one very deep-cultivating operation every fourth or fifth year, and would be kept in such a state as to allow air and moisture and the roots of the crop to penetrate freely, so that the cultivation of the cereal crops in the rotation would only require to be light or surface operations sufficient to receive and cover the seed.

The cost of steam-cultivation has hitherto been greatly increased by the excessive breakages that have occurred to the machinery. These have arisen from two causes—namely, the want of men properly educated to the work, and the deficient construction of the machinery at first employed. These difficulties are now, however, altogether overcome, and with ordinary good management any mishaps of the kind named may be wholly avoided. With regard to the cost of steam as compared with horses, I find, from careful observation, that, including interest on money, depreciation, and repairs, the average yearly cost of maintaining a set of steam-cultivating machinery, doing 2000 acres per year (say 10 in. or 12 in. deep), is under 300*l.*, or 3*s.* per acre. This allows money enough for its replacement in ten years. A good machine of this kind should displace over thirty horses, and of course many horse-implements. Now, the wear and tear of the harness, implements, and the amount of farrier's and other bills in connexion with these thirty horses, with interest and depreciation, will be at least twice as great as the corresponding items chargeable upon the steam tackle. The average price of coals per horse power per day—that is, the cost of the quantity of coals we should have to burn in an engine to get out of it work equal to what one horse could do in a day—is 7*d.* It is quite evident that the daily keep of a horse must cost much more than this. Less than half the number of men also are required to do the same acreage of work, although their wages have to be somewhat higher than those of the ordinary farm-labourer.

Or, to put the case more concisely, a pair of horses in an ordinary plough cannot pull with a force of more than 3 cwt. or 4 cwt. at the most, and a day of this work cannot cost less than 10*s.*; on the other hand, a steam-ploughing engine will give off during the whole day eight or nine times that draught, at a cost of certainly not more than 3*l.* These calculations are per day only; but as the horses have to be kept and fed when they are idle as well as when they are working—which is not the case with the steam-engine—the comparison is manifestly unfair to the latter. The whole of the comparisons should be based on a yearly average; but it is rather difficult to come to a conclusion how many acres a pair of horses can cultivate in a year even supposing them to be exclusively occupied in such work.

Money is saved in another way. After a thorough deep ploughing, or cultivating by means of steam, it is evident that only half the number of after-operations will be required to bring the ground to a sufficient tilth. In heavy land twitch will be found to disappear altogether, as there will be no treading and planting of it by the horses' feet, which has so much effect in undoing the very operation while being performed, and consequently necessitating many successive operations in thoroughly cleansing the land. A steam-driven implement always tends to bring the weeds and rubbish to the top, never buries them. Heavy land is not naturally inclined to grow twitch; and if so much treading and trampling could be prevented, it is the writer's firm opinion that no such thing would grow on it except through gross mismanagement or very light crops. The want of suitable implements has been a drawback to the cheap use of steam in tillage, as farmers have not been able to effect more than a portion of their work by its means.

Although it is no doubt an advantage to be able to do the farm operations more cheaply than by horse power, I look upon this as of minor importance compared with the results referred to in the first part of this paper, and with the increased certainty that will attend the

carrying out of the farming business, about which I shall say more presently.

The cultivation of soil is a business that requires a great amount of care and attention. A very false idea of a farmer's business is conveyed, when it is said that any one is fit for farming; on the contrary, I do not know of any business which requires such minute attention, and such keen observation; and this arises mainly from the extraordinary variations in the climate, weather, and soil, and the great effect these variations have upon the crops. Those persons who most carefully observe the state of their land, and never work it except at proper times, will derive the greatest advantage from it. On a farm under horse-cultivation, however, this is a very difficult task, as the small amount of profit yielded by farming will not allow the number of horses, &c., to be kept that would be necessary to deal with all the land at the right period, and in the most economical manner. This inability to perform the work when the land is in its best condition involves its deterioration, until it can scarcely be considered to be in growing condition, and not unfrequently involves the total or partial loss of a crop. When we reflect that there are only two or three months in the year during which tillage work can be profitably performed, the fact that the horses are sometimes kept going continually, in order not to fall behind-hand with the work, shows that the soil must often be operated upon when it is in a very improper condition. But the person who farms by steam has a powerful and ample force at his disposal, so that he can afford to wait until his land is in a fit state for working; and this force is also an untiring one, which he can work night and day, with relays of men, if necessary. You may often hear farmers complain that they have got behind-hand with their work; and they will point out to you a field, or perhaps two fields, in which the crop has been nearly lost simply because it was put in two or three days later than the remainder, or when the land was in a state unfit for its reception.

This occurs because the farmer is usually obliged to keep his working force of horses down to the narrowest possible limit, and the consequence is, that in some unfavourable seasons he requires twice the power at his disposal to do his work in time. But, as the writer has shown, these irritating and expensive difficulties are almost unknown to the man who farms by steam. Hitherto farming has very rarely been highly successful as a commercial undertaking, and when taken up by commercial men it does not often pay. The reason is, that to effect the different operations required in the best possible way entails an expenditure all the year round which cannot be borne by the profits of farming. As the use of steam develops itself, however, farming will become a business in which a man may see his way with some degree of confidence, and be able to calculate beforehand the cost of each operation, and whether he will gain or lose by it. The season and the weather will have only half the control over the crops and tillage operations that they have at present. But, before these results can be effected, it is necessary that the very cheapest system of cultivation—cheapest, I mean, as regards the cost per acre—should be adopted, that the tillage should be done at a given time, and at a cost not greater than that of the actual day's work. For instance, if, under the present system, a farmer were to take each field consecutively, and just calculate beforehand the cost of the different operations required for cultivating it, under ordinary circumstances, he would probably find that such an estimate would have to be double before it would cover his actual expenditure—and this in consequence of wet days and other contingencies compelling him to keep his teams and men standing idle. Such a state of things in an ordinary mercantile business would be ruinous; and this is the great drawback in all calculations connected with farming—wet days have to be paid for exactly the same as dry ones, and often expenses are running on when real harm is being done to the land. Before, also, we can attain the cheapest system of cultivation, we must have the farms remodelled, in order to admit of engines and machinery being worked in the most profitable way; and, as the writer has before pointed out, that we must have steam implements that will perform every operation required so as to keep horses off the land altogether, and thus lessen the power required to till the ground. The land must be brought into a uniform state, and be consolidated only by its own weight. When these principles are thoroughly carried out, the cost of cultivation will be only one-half of what it is at present, even where steam is partially employed. It is important that the fields should be made of a size to suit exactly the routine of work that the farmer wishes to carry out, and arranged so that all the crops of one kind are together, thus avoiding unnecessary delays and removals. The removal of a number of implements from one field to another entails a loss of time, which should be reduced to a minimum by making the fields as large as possible, consistent with the rotation of crops the farmer intends to follow. Some may argue that, as their farms consist of different kinds of land, they require a particular crop upon each kind; but the writer believes that, when steam is used,

the advantage of having the whole of a crop in one place more than counterbalances any drawbacks of this nature—except, of course, in very exceptional cases; and besides, the fact that steam can work on one kind of land just as easily as another will often remove these objections altogether.

As an example of the advantages of enlarging fields and pulling down old fences, the writer would refer to the case of a gentleman in Essex, Mr. Prout, of Sawbridgeworth, who, on a holding of 450 acres, by pulling down fences and dividing his farm into seven or eight large fields, has gained no less than 16 acres of arable land—land which was formerly occupied by old straggling fences, trees, and watercourses; and this has been done at a cost which is trifling, in comparison with the benefits obtained from the improvements.

The question of roads on a farm has an important bearing on the subject. There is an objection generally made that they take up too much ground, but this is altogether unfounded. The headlands, which are generally trodden down and compressed by horses and carts, require at least twice the cultivation of the other parts of the field, and yield worse crops; there can be, consequently, no profit in their tillage, and the width of a road dividing two fields is of course much less than that of two headlands and the hedge. But, however that may be, by having properly constructed roads on a farm, the cost of taking off the produce is very considerably lessened—say, by 3*d.* per ton on the whole. This would much more than cover the rent of the ground occupied, and prevents any treading on land to be cultivated.

When these and such kindred improvements are carried out, farming will become a business, which any thoughtful and intelligent man may manage with profit, and will be free from most of the vicissitudes which now cause the investment of capital in farming to be looked upon as of so precarious a character. Besides the advantages to the agriculturist, the nation at large will derive great benefit from the increased yield of crops, and also from the fact that the materials to feed the power used in tillage will be drawn from the coal-mines or the forest, instead of being taken from the produce of the fields. We shall not be obliged to import so much corn as hitherto, and a larger per-centage of the crops will be converted into food for human beings instead of food for horses.

In these days of dear labour, a very important point is the reduction in the amount of manual labour required to till the soil, together with the enlightenment of the agricultural labourer, tending to make him use his mind as well as his body. So far as this country is concerned, the state of the labour market is becoming a question which every farmer will have to study; for while the labourer is justly participating in the progress of the condition of people in this country, the rise in labour must materially lessen the former profits, except by employing such machinery as shall considerably diminish the number of men required.

ON THE CONSUMPTION OF FUEL.*

By Mr. WILLIAM PATERSON, C.E.

THE consumption of fuel in the furnaces of land and marine engine boilers, in the best way possible, so that the heat evolved during combustion may be utilised to its fullest extent, has become a question of the deepest importance, since steam power has supplanted nearly all other motive powers, in moving the machinery used in arts and manufactures, propelling vessels, and drawing carriages, and is otherwise extensively used in heating and drying processes; and, according to Sir Roderick Murchison's report, as to the coal produce of foreign countries and England, it appears that the produce of England is 98,150,587 tons per annum, and as there is no doubt but that only a small proportion of that quantity will be used for domestic purposes, it is, therefore, no wonder that the fear of exhausting our coal-fields is apprehended; and, although the industry of the country cannot be stinted in its supply of coal, in order to the conservation of such a valuable article, the next best thing to do is to take all the heat out of the fuel that can be got by proper combustion, and to apply the heat obtained so as to raise the largest quantity of steam, at the most economical pressure, for working with, and thereby obtain the greatest amount of work from the least quantity of coals, and by that means limit the demand, and save money on what is burnt; and as the product of proper combustion is a colourless vapour, the annoyance of having the atmosphere of towns impregnated with black smoke, or unconsumed carbon, would be avoided.

Although it is apparent, from the chimneys of furnaces of some works and vessels not emitting much coloured vapours, that the consumption of fuel is pretty well performed, but whether economically or not cannot be said, it is, however, equally apparent, by the issuing of black smoke, or unconsumed fuel, from many of the chimneys in our manufacturing towns, collieries, and steam vessels, that economy in the consumption of fuel is not yet generally

* Paper read before the British Association at Dundee.

obtained, and that "the time has not arrived when it would be considered a disgrace to produce black smoke."*

Notwithstanding that several treatises on the proper consumption of fuel, and the prevention of smoke, have been published—one of the best of which, with supplement by Dr. William Fairbairn, C.E., appeared in the printed Transactions of this Association—but, of these treatises, there is in some of them too much stress laid on, and argumentation in favour of, some particular view the writer held, or patent he had some pecuniary interest in, which militated against the real essential part of the work, and in all, even the best, the information given is of rather too scientific and technical a nature, and such practical directions are a-wanting, that in a great measure prevents practical men from understanding and applying the information therein afforded.

It therefore occurred to me to make an attempt to supply what is required, and, having no other interest to serve than the advancement of science in that direction, and in no controversial spirit, I have put together such practical observations, suggestions, and rules as may conduce to that end, which, from the experience and observation of thirty years, I have learned and found to be efficacious in consuming fuel by proper combustion, and applying the heat so obtained, and I trust that the present attempt will not altogether prove useless.

To have fuel properly consumed, and the heat evolved therefrom utilised to its fullest extent, is obtained by having the area of the firegrate of a size capable of holding the weight of fuel of the necessary depth, sufficient to raise the steam required, the depth of thickness of fuel on the gratebars or branders being in proportion to the quantity of air that can pass through between the bars and fuel at the rate necessary for perfect combustion in connexion with the method adopted for feeding the furnaces, and that the flues and chimney shall be so proportioned to the area of the firegrate that the products of the combustion shall be carried away at such a rate that a sufficient supply of air may be obtained, and be under control at the furnace.

The second is attained by causing the flame or heat arising from the incandescent fuel to be applied to as large a surface of the boiler as can be got at, when the heat is at the greatest, and the heated air or products of combustion may leave the boiler at the same temperature at which the steam is in the boiler, the boiler being of a form that in the circumstances offers the largest absorbing surface to the heated products of the fuel, and be formed of the best conducting materials, having the least possible quantity of water in the boiler that is necessary for the steam required, accompanied with a sufficient steam space.

To arrive at the proper area of firegrate, it is necessary to know the kind of fuel that is to be burnt therein, and the quantity of steam that has to be obtained from the boiler.

There have been published several excellent analyses of the different kinds of fuel used, but all that is really required may be obtained by consulting the tables given in the excellent reports of experimental investigations on coals for the steam navy, by Sir Henry De la Beche and Dr. Lyon Playfair, and with the tables in these reports will I principally deal in illustrating the process of arriving at the respective areas from firegrate to chimney, and will take, of the tabulated fuels in the reports mentioned, Newcastle Hartley and Fordel Splint, and for 100 lb. of each.

1. To find the cubic feet of oxygen necessary to saturate the carbon of the fuel.

Take the percentage of carbon opposite the fuel in column B, Table 2, (see page 212) multiply it by 2.666, the atomic weight of oxygen that combines with 1 of carbon, and by 11.85, the number of cubic feet in 1 lb. of oxygen; the product is the cubic feet of oxygen required.

Newcastle Hartley. Per cent. of carbon 81.81.

81.81
2.666
218.105
11.85
2584.544 cubic feet of oxygen required.

Fordel Splint. Per cent. of carbon 79.58.

79.58
2.666
212.150
11.85
2513.977 cubic feet of oxygen required.

2. To find the oxygen necessary to saturate the hydrogen of the fuel.

Take the percentage of hydrogen opposite the fuel selected in column C, Table 2, multiply it by 8, the atomic weight of oxygen that combines with 1 of hydrogen, and by 11.85, the number of cubic feet in 1 lb. of oxygen; the product is the cubic feet of oxygen required.

Newcastle Hartley. 5.50 per cent. of hydrogen.

5.50
8
44.00
11.85
521.4 cubic feet of oxygen required.

Fordel Splint 5.50. per cent. of hydrogen.

5.50
8
44.00
11.85
521.4 cubic feet of oxygen required.

3. To find the quantity of atmospheric air that will give off these two quantities of oxygen.

Add the quantities of oxygen required for the carbon and hydrogen of the respective fuels together, multiply the sum by 4.762, the proportion in volume the atmospheric air bears to the oxygen in it; the product is the atmospheric air required.

It may be necessary to mention here that to be strictly correct it would be necessary to deduct from the sum of the two quantities of cubic feet of oxygen the cubic feet of oxygen in the fuel, as shown by the percentage in column F, Table 2; but as it is uncertain the time when the oxygen is evolved from the fuel, and it is rather better to have an excess than a deficiency of oxygen, I considered it not necessary to take that into account.

Newcastle Hartley.

2,584.544 for carbon
521.4 " hydrogen
3,105.944
4.762
14,790.505 cubic feet of air required.

Fordel Splint.

2,513.977 for carbon
521.4 " hydrogen
3,035.377
4.762
14,454.465 cubic feet of air required.

4. To find the economic value or evaporating power of the selected fuel.

Take the number of pounds given in column A, Table 1, multiply them by 100, the product is the weight of water in pounds that 100 lb. of the fuel will evaporate; then divide the last product by the rate of evaporation, column K, Table 1, the product will be the time in hours it would take to evaporate the weight of water which 100 lb. of the fuel could evaporate.

Newcastle Hartley.

Water evaporated, 8.23 lb.
Rate of evaporation, 308 lb.
8.23
100

308)823(2.672 time required.

Fordel Splint.

Water evaporated, 7.56 lb.
Rate of evaporation, 464.9 lb.
7.56
100

464.9)756(1.626 time required.

5. To find the cubical content of 100 lb. of the selected fuel when used as fuel, and the square area of firegrate in inches it will cover at 12 in., 6 in., and 4 in. deep.

Multiply 1728, the inches in a cubic foot of fuel, by 100, and divide the product by the number in column B, Table 1, the quotient is the cubic inches in 100 lb. of the fuel used as fuel; then divide the last result by 12, the square root of the quotient will be the side of the square, in inches, of the area of firegrate covered by the fuel in 100 lb. at 12 in. deep.

For 6 in., square the side found for 12 in., double it, and the square root of the product is the side of the square area of firegrate covered by 6 in. of fuel.

For 4 in., square the side found for 12 in., triple it, and the square root of the product is the side of the square area of firegrate, covered by four inches of fuel.

Newcastle Hartley.

Weight of a cubic foot of coal as fuel, 50.5.

1728
100
50.5)172800(3421.78
12)3421.78

2)285.148=16.886 side of square of 12 in.
23.880 " 6 in.
29.247 " 4 in.

Fordel Splint.

Weight of a cubic foot of coal as fuel, 55.

1728
100
55)172800(3141.818
12)3141.818

2)261.818=16.180 side of square of 12 in.
22.885 " 6 in.
28.025 " 4 in.

6. To find the area in a cubic foot used as fuel to allow air to pass through different kinds of fuel.

Multiply 144, the number of inches in a square foot, by the number in column B, Table 1, the weight of a cubic foot of coal used as fuel, and divide the product by the number in column C, Table 1, the weight of a cubic foot of solid coal, subtract the quotient from 144, multiply the remainder by .666, to give an allowance for clinkering, &c.; the square root of the product is the side of the square in inches of the air-passage, through a square foot of the selected fuel at the branders or fire-bars.

Newcastle Hartley.

Weight of cubic foot of coal used as fuel, 50.5
solid coal, 80.27

144
50.5
144
80.27)7272(90.594
53.406
.666

2)85.568=5.963 side of square.

Fordel Splint.

Weight of a cubic foot of coal used as fuel, 55
solid coal, 78.61

144
55
144
78.61)7920(100.75
43.25
.666

2)28.804=5.366 side of square.

7. To find the rate at which the atmospheric air must pass through the firegrate to burn off the 100 lb. of selected fuel.

Divide the cubic feet of atmospheric air found by Rule 3 by the time in seconds that the 100 lb. of fuel takes to evaporate the quantity of water found by Rule 4, multiply the quotient by the side of the square in inches of firegrate, found by Rule 5, and divide by the side of the square in inches of the air-passage per square foot of fuel, found by Rule 6; the quotient is the rate at which the air must pass through the firegrate per second, to burn off 100 lb. of the fuel at 12 in. deep on bars; if for 6 in. one-half, and if for 4 in. at one-third of that rate.

Newcastle Hartley.

2.672
60
160.32
60
9619.2)14790.505(1.537
16.886

5.963)25.953(4.352 rate required.

Fordel Splint.

2.672
60
160.32
60
9619.2)14454.465(1.502
16.180

5.336)24.302(4.554 rate required.

8. To find the area of firegrate with fuel at 6 in. deep thereon, to raise steam from 212° equal to one nominal horse-power of a condensing engine.

Divide by 60 the pounds of water evaporated by 100 lb. of fuel in an hour, as found by Rule 4; multiply the quotient by 27.648, the cubic inches of water in 1 lb. of water, and by 1669, the cubic inches of steam in one of water, at the pressure of the atmosphere, and by 10, the pounds of effective pressure the steam would have on the piston of a condensing-engine having a good vacuum; divide the product by 12; the quotient will be the number of pounds that could be raised by the steam 1 foot high in a minute; divide this by 44,000, the quotient is the number of horses' power in the steam raised by 100 lb. of fuel at 6 in. thick on the firegrate; then by this number of horses' power divide the area of firegrate covered by fuel 6 in. thick, as found by Rule 5; the square root of the quotient is the side of the square of area of firegrate, with fuel of 6 in. deep for a nominal horse-power of a condensing engine.

Newcastle Hartley. Water evaporated, 8.23 lb.

8.23
100
60)823(13.716
27.648
379.219
1669
632916.511
10
16.886
286.136
2

12)6329165.110

44000)527430.425(11.987)570.272(2)47.674=6.897.

Fordel Splint. Water evaporated, 7.56 lb.

7.56
100
60)756(12.6
27.648
318.364
1669
581419.516
10
16.180
261.792
2

12)5814195.160

44000)484516.263(11.011)523.584(2)47.545=6.895.

9. To find the area of firegrate, with fuel of 6 in. deep, for a nominal horse power of a non-condensing engine, say at 30 lb. of effective pressure on the piston, which will take steam of 50 lb. pressure in the boiler.

Divide by 60 the pounds of water evaporated by 100 lb. of fuel in an hour, as found by Rule 4, multiply the quotient by 27.648, the cubic inches of water in 1 lb. of water, and

* Mr. Fairbairn's answer to Mr. McKinnon before the Select Committee of the House of Commons on the 23rd April, 1845.

by 552, the cubic inches of steam in 1 of water, at 50 lb. pressure, and by 30, the pounds of effective pressure, divide the quotient by 12, the quotient is the number of pounds that can be raised by the steam 1 ft. high in a minute, divide this by 44,000, the quotient is the number of nominal horses' power in the steam raised by 100 lb. of fuel at 6 in. in the firegrate, then by this number of horses' power divide the area of firegrate covered by fuel 6 in. thick, as found by Rule 5, the quotient is the side of the square of area of firegrate, with fuel of 6 in. thick thereon, for 1 nominal horse-power of a non-condensing engine at 30 lb. of effective pressure of steam.

Newcastle Hartley's. Water evaporated, 8.23 lb.

8.23	
100	
60)823(13.716	
27.648	
379.219	
552	16.886
209.328	16.886
80	285.136
12)6279.866	2
44000)523.322(11.893	570.272(2/47.950=6.924 side.

Fordel Splint. Water evaporated, 7.56 lb.

7.56	
100	
60)756(12.6	
27.648	
348.364	
552	16.886
192296.928	16.886
30	285.136
12)5768907.840	2
44000)408742.320(10.925	570.272(2/52.198=7.224 side

The time when smoke is emitted from the chimneys or funnels is when hydrogen is being evolved from the fuel during combustion; and if a sufficient quantity of oxygen cannot be brought in contact with the products of the coal, through the firegrate, at that time, so as to fully saturate both hydrogen and carbon, hydrogen—having a greater affinity for oxygen than carbon, and combining in combustion with it in a much colder state than carbon—lays hold, as it were, of its full equivalent of oxygen first, leaving the carbon set free by it, to combine with the oxygen left, if any, in the proportions which produce carbonic oxide, which is emitted from the chimney as light brown smoke, and the heat evolved in the production of this oxide is not above two-fifths of the heat; if the same amount of carbon had had its full equivalent of oxygen, for although the heat evolved generally is in proportion to the oxygen burned, that law does not hold good in this case, and if little or no oxygen is left, the free carbon goes off in the shape of black smoke, and no heat obtained from the carbon; rather the reverse, it having carried away some of the heat evolved from the combustion of the hydrogen. The process used in the formation of lampblack is a good illustration of how black smoke is produced.

In some instances there is not sufficient oxygen for the complete saturation of the hydrogen alone; in this case the unconsumed hydrogen goes off along with the free carbon, and, if the chimney or funnel be low, will be observed burning in flame at the top.

Instances of the latter kind occur when the combustion is slow—the distillation of the fuel goes on most favourably under slow combustion—the effect of which is, that a great proportion of the oxygen of the atmospheric air gets into combination with the carbon at the top of the firebars, creating a strong heat there, in many cases melting the bars, and roasting and distilling the fuel above, while the oxygen is being exhausted, the product of the distillation going off along with the carbonic acid gas or oxide and nitrogen, the process being, in such cases, the oxygen burning the fuel, a small quantity of oxygen being consumed compared with the quantity of fuel, while in the cases where proper combustion takes place, the largest amount possible of oxygen is consumed compared with the quantity of fuel.

Although a great deal can be effected to remedy the unequal demands of atmospheric air in the furnaces that are stoked by the hand, by a judicious method of stoking. Mr. Watt instituted a very good system by having an extra depth of fuel placed at the furnace mouth, partly on the dead hearth, so that by a partial distillation some of the more volatile products are brought off slowly, and are burnt off along with the incandescent fuel on the area of the grate, that extra thickness at firing being spread over the reduced depth of fuel on the grate, and the principal part of the fresh fuel being, as before, laid at the furnace mouth. Still it is clear that a regular and uniform supply of air into furnaces is not required for complete and economic combustion when the feeding of the furnaces is done by hand. Therefore, when the largest quantity of air required cannot be brought through the firebars, the additional supply can be very well supplied through apertures, having regulators on them, in the furnace doors; or if the furnace or firegrate is long, a supply can be obtained through or at the back of the bridge or flame-wall, the air being conveyed to the bridge in a pipe or pipes having regulators on them; these regulators could be wrought with self-acting cataracts in connexion with the furnace doors.

Ash-pits should be in cross section, the full aggregate

area of the open spaces between the firebars, and should have doors on them with slides to regulate the supply of air, and act as a damper when the heat evolved requires to be retained for a short time.

A sufficient cubic space above the firebars is of great importance to allow the volatile products of the fuel to be properly mixed and combined before being carried away over the flame-wall and forced in amongst the carbonic acid gas and nitrogen of the air consumed, as also to keep that part of the boiler over the furnace from being roasted, as it were, by being too near the incandescent fuel in a white heat.

As an empirical rule, I have found it answer very well to allow an average of 2 cubic feet above the fuel on every square foot of firegrate; this, with the thickness of the fuel, gives an average height the boiler ought to be above the firegrate.

I may remark here that it is always well to allow for a good thickness of fuel being used on the firegrate, it being most economical for raising high-pressed steam; for, as it may be observed, by comparing the sizes of the firegrates required for a nominal horse power of a condensing and non-condensing engine, that they are nearly alike, it is, therefore, evident that working with high-pressed steam is the most economical, inasmuch as a small quantity of high-pressed steam, having the same elastic power as a larger quantity of low-pressed steam, by being wrought expansively, will work with a useful effect two and a half times more than the low-pressed steam.

Of the area over bridge or flame-wall, to insure proper combustion in the furnace, it is imperative that the products of combustion should not pass from the bridge or through the flues at a greater rate than the air comes through the gratebars.

10th. To find the area over the bridge or flame-wall at the end of firegrate.

To the superficial area in inches of the air-passage through a square foot of firegrate per second, by Rule 6, add one-thirtieth part for the increase of volume in the combination of the hydrogen and oxygen, and for other products of the fuel not previously taken into account; and as the temperature of the furnace may be assumed to be fully 1000°, multiply the total volume by 3, the square root of the quotient is the side of the square in inches for the opening over the bridge or flame-wall for every foot of firegrate.

Newcastle Hartley.

5.963	
5.963	
30)35.557	
1.185	
36.742	
3	
2/110.226 = 10.498	side of square required.

Fordel Splint.

5.336	
5.336	
30)28.472	
.949	
29.421	
3	
2/88.263 = 9.394	side of square required.

Of the flues, no part of them should be less in cross section than the area over the bridge or flame-wall; they may with advantage be made somewhat larger, to give space for the deposition of dust, so that the flue at no time may be less than the area over the bridge or flame-wall, and the distance between the chimney and furnace should be as short as possible.

The chimney being the part connected with ordinary furnaces which provides the power to force the required quantity of air into the furnace, it is necessary to have it of such relative proportions and dimensions as, with the heat going to waste from the boiler, will enable it to perform that work.

11. To find the inside capacity of a chimney.

Square the rate in feet of air required to enter the firegrate per second, multiply the product by .002288, the product is the force in pounds with which the air will enter by the air passage in a superficial foot of firegrate, multiply the product by .333, the proportion at least which the air passage between the firebars should bear to the bars, the quotient is the force in pounds exerted on one foot of firegrate.

From the degrees of temperature of the products of combustion entering the chimney, which may be assumed at the temperature of the steam in the boiler, say 212°, subtract the degrees of temperature of the atmospheric air assumed at 60°, divide the difference by 490.8 (1/490.8)

the increment in bulk for every degree of heat Fahrenheit above 32°, add one integer to the decimal found, multiply the sum by 1728; the product is the number of cubic inches of the rarified air in the chimney, equal in weight to the inches in a cubic foot of air outside the chimney; multiply 535.68, the weight in grains of a cubic foot of air at the ordinary temperature, by 1728, and divide by the last product obtained, subtract the quotient from 535.68 grains, the difference is the weight which a cubic foot of rarified air is lighter than a cubic foot of air outside, multiply this by .333, the area of air-passage entering the furnace, divide the weight of force exerted on a foot of firegrate in grains by the last product; the product is the height which a

column of the rarified air will counterbalance the pressure of one foot of area of firegrate.

Newcastle Hartley.

4.852	
4.352	
18.989	
.002288	
04884	
.333	
.0144302	
7000	
101.0105	

212	
60	
490.8)152(.309	
1.000	
1.309	535.68
1728	1728
2261.592)925655.04(535.680	
409.228	
126.452	
.333	
42.108)101.01(2.398	

Fordel Splint.

4.554	
4.554	
20.738	
.002288	
.047450	
.333	
.0158	
7000	
110.60	

212	
60	
490.8)152(.309	
1.000	
1.309	535.68
1728	1728
2261.592)925655.04(535.680	
409.228	
126.452	
.333	
42.108)110.6(2.626	

It, however, should be observed that the inside area of the chimney at the top should nearly equal the area of air passage through the firegrate. As the previous calculations in connexion with the tables showed a much lower rate of air going through the firegrate than ought to obtain for proper combustion—for Dr. Ure, in a paper read before the Royal Society in 1863, stated that he found the aerial products of combustion, from boiler furnaces flew off with a velocity of fully 36 ft. per second—and as these products in that condition follow, apparently, a fixed law, it is a natural conclusion to come to, that if the products of the fuel were supplied with the necessary oxygen at a rate nearly equal to that at which they fly off, more complete combustion would follow, and the full complement of heat be evolved.

12. To ascertain the height of chimney, the current of air through the firebars, the area of firegrate, and the pressure of steam being determined on.

Square the rate required, multiply the product by .002288, then by the area in feet of firegrate multiplied by .333, the product is the pressure of air in pounds on the air-passages of firegrate; multiply this product by 7000 grains, the product is the total pressure in grains; find the difference of weight of a cubic foot of rarified air and a foot of cold air, as by Rule 11; divide the total pressure by this difference, the quotient is the cubic content of a column of air to produce the pressure; divide the quotient by the area of air-passage through the firegrate, the quotient is the height of the chimney; or if a certain height above 100 ft. is determined on, divide by the height, and the square root is the side of the square of the chimney at the top; and if it is for a round chimney, multiply the side of the square by 1.128, the product is the diameter of a chimney of equal area.

Assume the rate of the air required to be 36 ft. per second, the area of firegrate 21 ft., and the pressure of steam at 50 lb., including the pressure of the atmosphere:

36	
36	
1296	
.002288	
2.965	
21	
62.265	
.333	
20.734245	
7.000	
145139.715000	
281	
60	
490.8)221(.450	
1000	
1450	535.68
1728	1728
2505.600)925655.04(535.680	
369.394	
166.286	

166.286)145139.715000(872.831 cubic contents.
21
383
6.993)872.831(124.81 height of chimney.
100)872.831
8.72831)2.953 side of square
1 128
8.330984 diameter of chimney.

It may be mentioned here that it would be well that the minimum height of chimneys should be 100 ft., not that that height is specially required for draught for furnaces; the converse is the case, for in our manufacturing towns several of the tapered chimneys would be far more effective were they reduced so far in height; but it would be beneficial inasmuch as it would admit of the deleterious products of complete combustion emitted from the chimneys being diffused through the surrounding atmosphere before coming near the surface of the earth, to which, from their denseness, they have a tendency to descend.

In regard to boilers generally, the work "Useful Information for Engineers," by Dr. William Fairbairn, C.E., contains, as its title bears, much valuable information. There are, however, a few points on which something may be said.

The quantity of water in a boiler, in proportion to the steam room, has always appeared to me to be too large, when it is considered that even in those having steam of an elastic force above the atmosphere of 105 lb., the relative volume of steam, compared to that of water, is 240 to 1; now as water in the boiler is required for no other purpose than being converted into steam, and is only expended in doing so, apparently, to be strictly correct, these proportions are all that is required, and how a rule could have been thought of allowing one half of the cubic capacity for water and the other for steam is not easily explained.

Mr. Watt so far remedied this defect by concaving the bottom and sides of the wagon and haystack-shaped boilers, and then in placing a flue through them; it was further remedied in the Cornish, and still further in the marine tubular and locomotive boilers; but it does not appear that the bringing of the relative proportions between steam and water nearer each other was the object for which these changes were made, the object being rather to give increased heating or absorbing surface of boiler. It was, however, overlooked that the apparent heating surface obtained from internal flues and tubes was not nearly all effective, for water boils easiest, and raises steam quickest by convection, that is, having the heat applied to the under surface of the boiler, and also when, from the length of the boiler, either by the double or triple run the heated products had to make in connexion therewith, a great proportion of the last run was non-effective by the heat being absorbed before passing there. It is, therefore, necessary that the boilers that have return flues should not be too long, and that if the heated products have three runs of the boiler, the first being an internal flue, the second should be immediately under the boiler.

The Cornish boiler, with the double flue, is an improvement, so far as the flues are concerned, but not as regards the furnaces and flame-wall. In none of the Cornish boilers, even in those with one flue, is there the proper space above the furnace, nor over the flame-wall, to promote perfect combustion.

A boiler, of the Cornish kind, formed something similar to the Butterfly boiler, or, rather, having a firebox like a locomotive, with tubes three times the size of locomotive tubes, and of about 25 ft. long, if the tubes are of iron, the conducting power of copper being to iron as 2.4 to 1, were this kind of boiler so built that the products of combustion could be brought to bear on the under side as well as in the tubes, leaving the boiler at the level of the water-line, it would be effective in raising steam; or, if large flues

the bottom part of the tube, the length of boiler to be from 15 ft. to 18 ft., and the heated products of combustion to pass from the internal to the under side of boiler, split and return by the sides; or another kind of land boiler might be formed of the cylinder form, with egg ends, having the water space lessened by another portion of boiler inside, rising above the water 6 in., the water space between it and the boiler gradually increasing in width up to water-line, and thereby bring the water and steam space nearer in proportion to each other, and were the feed-water caused to impinge on this steam casing, as it may be called, at several points, would promote the proper circulation of the water when in a state of ebullition, which contributes so much to the generation of steam, give a larger space of steam room, and would prevent priming. Studs properly placed would keep the casing in its position. The want of steam room in boilers tends very much to cause the pressure in the boilers to vary, and goes far to assist in some explosions, and were this kind of boiler built in on the hung system, or oven plan, the flue around the boiler being of the proper sectional area, and the exit flue placed at the top of the water-line, the full width of the boiler and side flues, by the depth to give the proper sectional area, equal to the area over the flame-wall. The following advantages would be derived from it, viz., that the boiler would hang always in a body of flame or heat from the incandescent fuel, keeping all the heating surface of the boiler of nearly equal temperature, and the heat would be so applied to the heating surface that the water will receive the heat by convection, none of the heating surface having a downward tendency, and no part of the heating surface would be covered with soot, which is generally the case in the last flue of wheel or three-run flues, this soot acting the part of a non-conductor, preventing even the little heat that is to be got in these parts of a flue from being absorbed and conducted into the water.

In marine boilers, where flues are used, they should not have a longer run than 25 ft., and made narrower at the top, thereby allowing the water space to be wider at the top of the flue, and the nearer the proportion the steam-room and water space are made to their relative proportions they bear in the production of steam so much the better, as the saving of space in steam-vessels is a desideratum.

Much has been said in favour of large furnaces and slow combustion, but my experience has always been that when the furnace was not too large, but sufficient to hold the necessary fuel, the space above the firebars large enough to enable the product of the burning fuel and the oxygen of the air to intermingle properly, the area over the bridge and the flues being of a size sufficient to allow the heat-expanded air and products of combustion to pass over and through at no higher rate than the air came into the furnace, and that the chimney was of sufficient size inside as produced the necessary draught or pressure at the furnace, that the higher the rate the air came into the furnace, if it did not exceed the rate of 36 ft. per second, the more complete was the combustion, and the more work done for the fuel burned. A locomotive running at a high rate of speed is always able to raise the necessary steam required for the extra speed by the sharpness of the draught.

And as to the kind of top, or finish, a chimney ought to have, many fanciful theories are extant, without any good reason for adopting the one instead of the other, for the principal condition for the top of a chimney to be in is to allow the free admission of the rarified air.

This cannot be the case in all states of the weather with some of the forms; for instance, the obelisk tops with centre diaphragms have the drawback of presenting a surface to the wind above the top proper of the chimney, the diaphragm being below that, the draught of the chimney must be impeded by sudden gusts of wind impinging on the diaphragm and forcing itself down the chimney, till overpowered by the ascending current. The best form of top is a plain one, having a splay outwards from the inside aperture, so that if wind strike it will have a tendency to rise upwards and rather assist the ascending current.

The heightening of chimneys has generally been considered as the panacea for all the evils incidental to badly constructed furnaces and smoky chimneys of dwelling houses. The height of a chimney conduces most effect for draught when advantage is to be taken of the chimney, not for combustion, but for ventilation; for it is a fact known well to all bricklayers, that even in the hottest weather, when the air inside the chimney is very cold as compared with the air on the outside, that an ascending current is always in the chimney, and the higher the chimney, the stronger is the current. So great and uniform is a current of ascending air in all high chimneys, that the inference is, that the column of air in the inside can be no denser than the surrounding air at the top of the chimney; if this inference is correct—which I think it is, for on no other theory can the ascending current be accounted for—it does not accord with the present accepted law of the weight of air, which is, that air is like layers of paper lying one above the other, the topmost having merely its own weight, but every layer downwards is bearing the weight of the layers above it, so that at the surface of the earth the bottom layer is supporting a weight equal to 14.7 lb. per square inch. If that law is universal, then the air in the chimney would have the same number of layers, as it were, as there are on the outside, and when in a colder state would rather have been denser than otherwise, and the current downwards rather than upwards. A

case in point is in the railway tunnel in Edinburgh, from Scotland-street to Princes-street (a work with which I was connected), which is 1008 yards long, and is 116 ft. higher at Princes-street than at Scotland-street, but for a considerable length the Scotland-street end of the tunnel is larger in cross section than at any other place; in hot weather, when a larger quantity of rarified air is in the lower end, a strong current of air always descends to Scotland-street.

There is another peculiarity connected with the motion of air in a cold state—that it moves in the reverse way that water does in a syphon: it goes down the short leg and up the long one, and it will do this in a pipe, when all around is still; but the motion is much increased if the long leg is made larger as well as longer. This peculiarity of motion in air being induced in a pipe by it having the form of an inverted syphon, the length of the long leg always being sufficiently high to reach a slightly lighter atmosphere, so as to give as much difference in weight as will overcome the friction, was observed by Dr. Chowne, and he took advantage of it by enrolling a patent for ventilating buildings by introducing syphon-pipes into them. In his description of the patent, he owned he could not account for the action of the air, nor on what principle the motion in the air was induced; neither had he been aware that, by making the long leg larger as well as longer, the effect would be increased, or the working of the patent might have been more successful; but, as it was, it failed.

It is also well known amongst miners that, in sinking a shaft without a brattice wall in it, the smoke of the powder from the shots fired cannot be got rid of, nor pure air obtained to sustain the workmen; but when a brattice wall is put in, and, as is generally the case, one side is a little larger than the other, the ventilation goes on by the air descending the smallest side and ascending the largest side of the divided shaft.

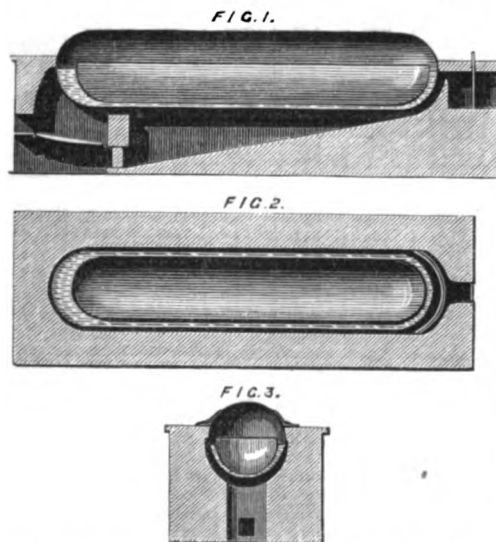
This peculiarity might well be taken advantage of in the mining districts, where good ventilation is so much required, by always having the upcast shaft considerably larger than the downcast; and in the mines where the carburetted hydrogen exists in such quantities, the draught in the upcast might be accelerated, without the aid of a furnace, by having some of the inflammable gas conveyed in pipes to the upcast shaft, and burnt in jets well up in it. This would help to carry away the noxious gas, save fuel, and improve the draught. The heat evolved from the consumed gas would rarify the air very much. Of course the entrance to the upcast shaft should always be equal to the area of the shaft, having sliding doors on it to modify the draught in the mine when required.

I have said that some of the high tapered chimneys would be more effective were they diminished in height so far, and may be illustrated thus: as it is the area of the narrowest part of a chimney multiplied by the height that determines the column of rarified air passing forth from a chimney, a chimney of a sectional area at the top equal to the size of air-passage through the firegrate, as in Rule 12—say having a sectional area of 6.993 ft., the side of the square of 2.644 ft., cubic column 872.831 ft., and height 124.81 ft. But were that chimney to be increased in height another 48 ft., and having a taper of 1 in. in 8 ft., the side of the square at top would be reduced by 1 ft. each way, leaving a sectional area of 2.702 ft., which, multiplied by 172.81, the increased height, only gives a column of rarified air equal to 400 ft. as against 872.831 ft.

In conclusion, it is of the utmost importance that even the workmen who are engaged in erections where currents of air or gases are concerned should have removed from them the notions with which they are generally imbued as to the laws which govern these currents, and should be made acquainted with their nature and laws, for in many cases workmen, seeing that the instructions they receive, or the plans they are working to, are the reverse of the notions they have held during life, "that a contracted throat is conducive to a good working furnace," they will have a little of their own will in the matter, and not to allow, as they think, the work to be spoiled altogether, they contract some part (I am recording what I have experienced myself). The work is completed, and the result of the working is found not to be what was anticipated, and is only made right when the contracted part is removed.

I have been long impressed with the idea that some such work as this had taken place in forming the air-passages where some of the apparent failures took place in the ventilation of the House of Commons. When I had the opportunity of hearing the description of the working of the process of the ventilation of that building, as illustrated by a model in Dr. Boswell Reid's class-room, the system appeared perfect, but if by any means the apertures or air-passages through which the air of the respective temperatures had to pass were not in proportion to the densities of the air, perhaps the larger were given for the cold air and the smaller for the heated, or both might be equal, either of which conditions would destroy to a certain extent the proper ventilation.

In the system for ventilating rooms by having an aperture with valve on it leading into the chimney of the room, the vent linings above the aperture should be 1 in. diameter larger than those below, and kitchen chimney vent linings should be fully two-thirds larger than for rooms, and no cans should be put on vents of a less size than the vent linings.



were preferred to the tubes, they might be made oval, supported along the centre of the inside with three rows of vertical pipes, these being larger in diameter at top than at

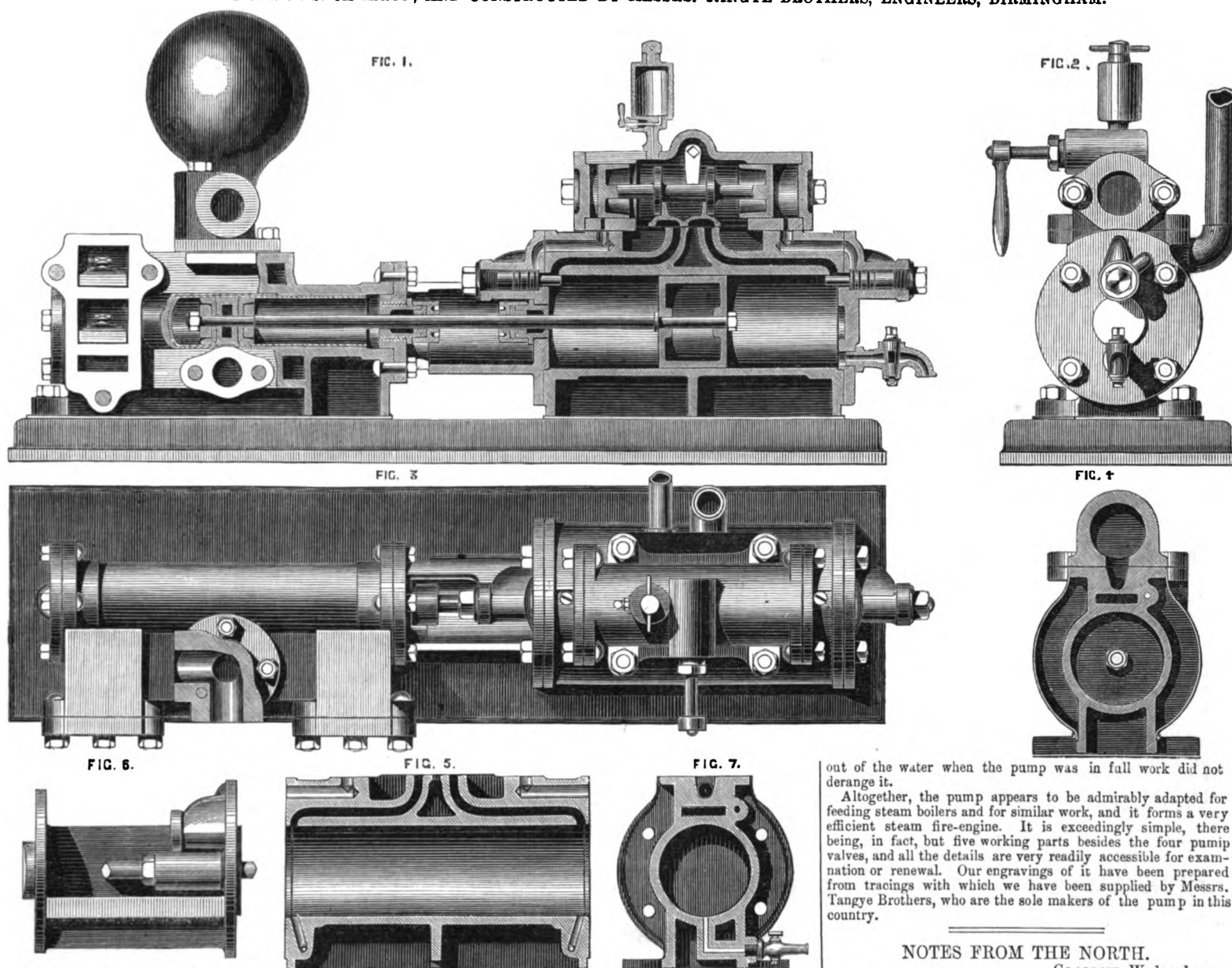
THE COMBUSTION OF FUEL.

TABLES REFERRED TO IN MR. PATERSON'S PAPER, PAGE 209.

No. I. SHOWING THE ECONOMIC VALUES OF DIFFERENT COALS.											No. II. SHOWING THE COMPOSITION OF AVERAGE SAMPLES OF THE COALS.									
NAMES OF THE COALS EXPERIMENTED UPON.	Economic evaporating power or number of lb. of water evapo- rated from 212° by 1 lb. of coal.	Weight of 1 cubic foot of the coal as used for fuel.	Weight of 1 cubic foot as calcu- lated from the density.	Rate of B to C, or of the econo- mical to the theoretical weight.	Difference per cent. between theoretical and economical weight.	Space occupied by 1 ton in cubic feet (economical weight).	Results of experiments on cohesive power of coals per centage of large coals.	Evaporating power of the coal after deducting for the combustible matter in the residue.	Weight of water evaporated from 212° by 1 cubic foot of coal.	Rate of evaporation or number of lb. water evaporated in an hour.	LOCALITY OR NAME OF COAL.	Specific Gravity of Coals.	Carbon.	Hydrogen.	Nitrogen.	Sulphur.	Oxygen.	Ash.	Per centage of Coals left by each Coal.	
WELSH COALS.											WELSH COALS.									
Craigola	9.35	60.166	81.107	.742	34.80	37.23	49.30	9.66	581.20	441.48	Craigola	1.30	84.87	3.84	0.41	0.45	7.19	3.24	85.50	
Anthracite (Jones and Co.)	9.46	58.25	85.786	.679	47.26	38.45	68.50	9.70	565.02	409.37	Anthracite	1.375	91.44	3.46	0.21	0.79	2.58	1.52	92.90	
Oldcastle Flery Vein	8.94	50.916	80.42	.633	57.946	43.99	57.70	...	455.18	464.30	Oldcastle Flery Vein	1.289	87.68	4.89	1.31	0.09	3.39	2.64	79.80	
Ward's Flery Vein	9.40	57.433	83.85	.685	46.00	39.00	46.50	10.60	508.78	529.90	Ward's Flery Vein	1.344	87.87	3.93	2.02	0.83	included in ashes.	7.04	...	
Binea Coal	9.94	57.08	81.357	.702	42.53	39.24	51.20	10.30	587.92	486.95	Binea Coal	1.304	88.66	4.63	1.43	0.33	1.03	3.96	81.10	
Llangennech	8.86	56.93	81.85	.695	43.76	39.34	53.50	4.20	523.75	376.22	Llangennech	1.312	85.46	4.20	1.07	0.29	2.44	6.54	83.60	
Pentrefellin	8.72	57.72	81.73	.705	40.17	38.80	46.50	8.98	518.32	381.50	Pentrefellin	1.31	88.72	4.50	0.18	...	3.24	3.36	82.30	
Duffryn	10.14	53.22	82.72	.643	58.43	42.09	56.20	11.80	540.12	409.32	Duffryn	1.358	85.52	3.72	trace.	0.12	4.55	6.09	85.00	
Mynydd Newydd	9.52	56.33	81.73	.689	45.09	39.76	53.70	10.59	536.26	470.69	Mynydd Newydd	1.326	88.26	4.66	1.45	1.77	0.60	3.26	84.80	
Three-quarter Rock Vein	8.84	56.388	83.60	.674	48.26	39.72	52.70	...	498.46	486.86	Three-quarter Rock Vein	1.31	84.71	5.76	1.56	1.21	3.52	3.24	74.80	
Cwm Frood Rock Vein	8.70	55.277	78.299	.706	41.648	40.52	72.50	9.35	480.90	379.80	Cwm Frood Rock Vein	1.34	75.15	4.93	1.07	2.85	5.04	10.96	62.50	
Cwm Nanty-gros	8.42	56.00	79.859	.701	42.60	40.00	55.70	8.82	471.52	404.16	Cwm Nanty-gros	1.255	82.25	5.84	1.11	1.22	3.68	6.00	68.80	
Resolven	9.53	58.66	82.354	.713	40.39	38.19	35.50	10.44	535.02	390.25	Resolven	1.32	79.33	4.75	1.38	5.07	included in ashes.	9.41	83.90	
Pontypool	7.47	55.70	82.35	.676	47.845	40.216	57.00	8.04	460.07	250.40	Pontypool	1.32	80.70	5.66	1.35	2.39	4.88	5.52	64.80	
Bedwas	9.79	50.5	82.60	.671	63.565	44.32	54.00	9.99	494.39	476.96	Bedwas	1.32	80.61	6.01	1.44	3.50	1.50	6.94	71.70	
Ebbw Vale	10.21	53.30	78.81	.676	45.98	42.26	45.00	10.64	544.19	460.22	Ebbw Vale	1.275	89.78	5.15	2.16	1.02	0.39	1.50	77.50	
Porthmawr	7.53	53.00	86.722	.614	62.70	42.02	60.00	7.75	401.34	347.44	Porthmawr Rock Vein	1.39	74.70	4.79	1.28	0.91	3.69	14.72	63.10	
Colehill	8.00	53.00	80.483	.658	51.85	42.26	62.00	8.34	424.00	406.41	Colehill	1.29	73.84	5.14	1.47	2.34	8.29	8.92	56.00	
Thomas's Merthyr	10.16	53.00	82.29	.628	55.26	42.26	55.50	10.72	538.48	520.80	Thomas's Merthyr	1.30	90.12	4.33	1.00	0.85	2.02	1.68	86.53	
Nixon's Merthyr	9.96	51.70	82.29	.638	59.16	43.32	64.50	10.70	511.93	431.40	Nixon's Merthyr	1.31	90.27	4.12	0.63	1.20	2.53	1.25	79.11	
Hill's Plymouth Works	9.75	51.20	84.78	.603	65.68	43.74	64.00	10.18	539.20	431.60	Hill's Plymouth Works	1.35	88.49	4.00	0.46	0.54	3.82	2.39	82.25	
Aberdare Co.'s Merthyr	9.73	49.80	81.73	.603	65.78	45.43	74.50	10.27	479.68	489.50	Aberdare Co.'s Merthyr	1.31	88.28	4.24	1.66	0.91	1.65	3.26	85.83	
Gadley Nine-foot Seam	9.56	54.80	83.67	.658	51.75	40.87	70.00	10.46	523.88	517.30	Gadley Nine-foot Seam	1.33	86.18	4.31	1.09	0.87	2.21	5.34	86.54	
Neath Abbey	9.38	59.30	83.57	.709	40.92	37.77	50.00	9.65	556.23	546.10	Neath Abbey	1.31	89.04	5.05	1.07	1.60	...	3.55	61.42	
Gadley Four-foot Seam	9.29	51.60	82.79	.623	60.44	43.41	68.50	10.73	479.36	400.00	Gadley Four-foot Seam	1.32	88.56	4.79	0.88	1.21	...	4.88	88.23	
Llynvi	9.19	53.30	80.35	.663	50.56	42.02	...	9.58	429.82	399.50	Llynvi	1.28	87.18	5.06	0.86	1.33	2.53	3.04	72.94	
Rock Vawz	7.68	55.00	80.21	.685	45.83	40.72	65.50	7.88	422.40	397.50	Rock Vawz	1.29	77.98	4.39	0.57	0.96	8.55	7.55	62.50	
LANCASHIRE COALS.											LANCASHIRE COALS.									
Balcarras Arley	8.83	50.50	78.17	.646	54.79	44.35	76.00	9.09	445.91	454.10	Balcarras Arley	1.26	83.54	5.24	0.98	1.05	5.87	8.32	62.89	
Blackley Hurst	8.81	48.00	78.90	.608	64.37	46.60	65.00	9.00	422.88	500.80	Blackley Hurst	1.26	82.01	5.55	1.68	1.45	5.28	4.05	57.84	
Blackbrook Little Delf	8.29	51.00	78.16	.652	53.25	43.92	61.50	8.58	422.79	440.40	Blackbrook Little Delf	1.26	82.70	5.55	1.43	1.07	4.89	4.31	58.48	
Rushy Park Mine	8.08	47.00	80.04	.687	70.81	47.65	67.00	8.35	379.76	419.10	Rushy Park Mine	1.28	77.76	5.23	1.32	1.01	8.99	5.69	56.66	
Blackbrook Rushy Park	8.02	55.60	80.15	.689	44.93	40.50	80.50	8.26	443.50	481.20	Blackbrook Rushy Park	1.27	81.16	5.99	1.35	1.62	7.20	2.68	38.10	
Johnson and Wirthington's	8.01	50.00	80.10	.624	60.20	44.80	69.00	8.16	400.50	454.50	Johnson and Wirthington's	1.28	79.50	5.15	1.21	2.71	9.24	2.19	57.52	
Rushy Park	7.98	52.60	84.07	.625	59.82	44.85	75.50	8.16	419.74	435.00	Rushy Park	1.35	80.47	5.72	1.27	1.39	8.33	2.82	56.26	
Laffak Rushy Park	7.90	50.80	80.10	.634	57.37	44.13	80.00	8.23	401.32	435.00	Laffak Rushy Park	1.28	82.26	5.47	1.25	1.48	5.64	3.90	66.09	
Balcarras Haigh Road	7.70	48.30	76.80	.628	59.00	46.37	95.00	8.06	371.91	381.10	Balcarras Haigh Road	1.23	79.23	6.08	1.18	1.43	7.24	4.84	60.33	
Cannel (Wigan)	7.44	51.10	78.61	.650	53.83	43.83	70.00	7.58	380.18	431.50	Cannel (Wigan)	1.26	83.90	5.66	1.40	1.51	5.53	2.00	57.84	
Balcarras Lindsay	7.21	49.00	79.11	.619	61.44	45.71	44.50	7.35	353.29	487.50	Balcarras Lindsay	1.26	74.21	5.03	0.77	2.09	8.69	9.21	55.90	
Balcarras Five-foot	6.32	51.60	81.73	.631	58.39	43.13	82.00	6.62	326.11	362.70	Balcarras Five-foot	1.31	72.86	4.98	1.07	1.54	8.15	11.40	56.15	
Sir John Johnson and Wirthington's	9.39	52.10	78.86	.360	51.36	42.99	...	9.80	489.21	351.20	Sir John Johnson and Wirthington's	1.26	85.58	5.31	1.26	1.32	4.39	2.14	65.13	
Newcastle House (Tanfield)	8.23	50.50	80.27	.629	58.95	44.35	78.50	8.65	415.61	308.00	Newcastle House (Tanfield)	1.29	81.81	5.50	1.28	1.69	2.58	7.14	64.61	
Hedley's Hartley	8.16	52.00	81.79	.635	57.28	43.07	85.50	8.71	424.62	306.80	Hedley's Hartley	1.31	80.26	5.28	1.16	1.78	2.40	9.12	72.31	
Bate's West Hartley	8.04	50.80	78.17	.649	53.87	44.13	69.50	8.26	408.43	406.80	Bate's West Hartley	1.25	80.61	5.26	1.52	1.85	6.51	4.25	...	
Buddle's West Hartley	7.82	50.60	77.11	.656	52.29	40.09	80.00	8.01	395.69	413.30	Buddle's West Hartley	1.23	80.75	5.04	1.46	1.04	7.86	3.85	35.60	
Hastings's Hartley	7.77	48.50	78.04	.621	60.90	46.18	75.50	7.93	376.84	404.50	Hastings's Hartley	1.25	82.24	5.42	1.61	1.35	6.44	2.94	...	
Carr's Hartley	7.71	47.80	78.23	.611	68.66	46.86	77.50	8.13	368.53	344.30	Carr's Hartley	1.25	79.83	5.11	1.17	0.82	7.86	5.21	60.63	
Davidson's West Hartley	7.61	47.70	78.36	.608	64.27	46.96	76.50	7.83	362.99	402.90	Davidson's West Hartley	1.25	83.26	5.31	1.72	1.38	2.50	5.84	59.49	
North Percy Hartley	7.57	49.10	78.29	.627	56.45	45.62	60.00	7.72	371.68	423.50	North Percy Hartley	1.25	80.03	5.08	0.98	0.78	9.91	3.22	57.18	
Haswell's Coal Company's	7.48	49.50	79.36	.623	60.32	45.25	79.50	7.85	373.66	291.80	Haswell's Coal Co.'s Steam-	1.27	83.71	5.30	1.06	1.21	2.79	5.93	61.38	
Steamboat Wallsend	7.42	50.40	78.79	.629	56.32	44.44	63.50	7.66	373.93	451.10	Steamboat Wallsend	1.26	78.01	4.74	1.84	1.37	10			

CAMERON'S DIRECT-ACTING STEAM PUMP.

DESIGNED BY MR. A. S. CAMERON, AND CONSTRUCTED BY MESSRS. TANGYE BROTHERS, ENGINEERS, BIRMINGHAM.



We give, above, engravings of a new steam pump designed and patented by Mr. A. S. Cameron, and the manufacture of which has been recently taken up in this country by the well-known firm of Messrs. Tangye Brothers, of Birmingham. In our illustrations, Fig. 1 is a longitudinal section, Fig. 2 an end elevation, Fig. 3 a plan, and Fig. 4 a transverse section, whilst the remaining figures show some variations in the construction, to which we shall refer presently.

The steam and pump cylinders, it will be seen, are placed in a line with each other, and they are connected by a distance piece, the end flanges of which form the covers for both cylinders. The steam cylinder is made with a double set of steam passages, one pair of these passages leading from the slide-valve face to the ends of the cylinder in the usual way, and the other pair extending from near the ends of the steam-chest to the inner ends of small cylindrical chambers formed one on each cylinder cover. Each of these chambers is fitted with a piston valve, which closes an opening in the cylinder cover, these valves being, except when moved by the piston, kept against their seats by the pressure of steam on their backs, the outer ends of the valve chambers being placed in free communication with the steam-chest by small passages, not shown in Fig. 1.

The main slide-valve covers the exhaust port and one pair of steam ports, and it is made of the section shown in Fig. 1, so that when it is moved to the right, steam is admitted into the right-hand port, and *vice versa*. In the engravings the valve is shown in the position it occupies when steam is being admitted into the left-hand port, the other port being placed in communication with the exhaust. On the back of the valve are a pair of lugs which fit between two collars formed on a spindle, which connects, and, indeed, is cast in one piece with, a pair of plungers which work in the cylindrical portions forming the ends of the valve-chest, and into which the second pair of steam-ports open. The plungers do not fit their cylinders tightly; but are made so that they allow a small amount of leakage to take place past them, the steam thus passing being shut in when either plunger travels beyond the port, and thus forming a cushion to check the motion of the valve. In case the engine should stop in such a position that both steam-ports are closed by the valve, a rocking-shaft, worked by an external handle, is provided, this shaft carrying a finger, as shown in Fig. 1, by which the valve can be shifted. When the pump is at work,

this rocking shaft remains stationary, as the valve does not move far enough to touch the finger.

The action of the apparatus is very simple. Supposing all the parts to be in the positions shown in Fig. 1, the piston will, when steam is turned on, move from left to right. On arriving at the end of its stroke it will strike against the spindle of the valve on the right-hand cylinder cover, and force it off its seat, thus placing the second right-hand steam passage in communication with the right-hand end of the cylinder, and, consequently, owing to the position of the main valve, in communication with the exhaust. This being the case, the pressure is removed from the back of the right-hand plunger connected with the main valve, and the pressure of the steam on the inner side of the plunger then forces the latter to the right, the slide-valve being of course carried with it. This movement admits steam to the right-hand end of the cylinder, and places the left-hand end in communication with the exhaust, and the piston then performs its stroke from right to left, when the operations we have described are repeated at the other end of the cylinder.

The pump cylinder—which, as we have already mentioned, is placed in a line with the steam cylinder, and is connected with it by a distance piece—is lined with brass, and the piston, which is packed with a pair of cupped leathers, as shown in Fig. 1, is also of brass. The pump is double-acting, and the valves are arranged so that they are very readily accessible. The valve seats, which are of brass, are turned, and then placed in a mould and the valve-chest cast round them. The valves are of brass, with india-rubber faces let into them, a system of construction which is found to answer well.

In the pumps more recently constructed, Messrs. Tangye have introduced the slight modifications shown in Figs. 5, 6, and 7. Of these, Figs. 5 and 7 show the addition of a couple of pet-cocks to the steam cylinder, whilst Fig. 6 represents an alteration in the distance-piece between the steam cylinder and pump-barrel, this distance-piece, as well as the piston-rod stuffing-box, having been made longer to enable the gland to be more readily tightened up.

One of the pumps which we have described was exhibited in action by Messrs. Tangye at the recent show of the Royal Agricultural Society at Bury St. Edmunds; and it worked admirably, the valve arrangement acting perfectly at all speeds. Even the somewhat severe test of raising the suction-pipe suddenly

out of the water when the pump was in full work did not derange it.

Altogether, the pump appears to be admirably adapted for feeding steam boilers and for similar work, and it forms a very efficient steam fire-engine. It is exceedingly simple, there being, in fact, but five working parts besides the four pump valves, and all the details are very readily accessible for examination or renewal. Our engravings of it have been prepared from tracings with which we have been supplied by Messrs. Tangye Brothers, who are the sole makers of the pump in this country.

NOTES FROM THE NORTH.

GLASGOW, Wednesday.

Harbour and Graving-dock Accommodation: Glasgow and Greenock.—The annual accounts just made up and published by the Clyde Navigation Trustees show some striking facts regarding the extension of the harbour at Glasgow, and the deepening of the river to such an extent, that where it was fordable on foot within the memory of persons still living, vessels of 2000 tons burthen can now float with ease, and where smacks of 150 tons burthen were formerly *neaped*, the Black Prince ironclad passed over in safety, as also do merchant ships of 20 ft. water-draught to and from every quarter of the globe. Since the year 1770 no less a sum of money than 4,304,666*l.* has been spent in deepening the river and giving increased harbour accommodation, but, of course, the greater part of this sum has been expended during the present generation. In the year 1771 the income from harbour dues only amounted to 1044*l.*, and it was then that efforts were first made to improve the navigation and harbourage. In 1780 the income was 1515*l.*, and at the end of each succeeding twenty years, and in 1867, it was as follows:

1800	...	...	3,319 <i>l.</i>
1820	...	...	6,328 <i>l.</i>
1840	...	...	46,536 <i>l.</i>
1860	...	...	97,983 <i>l.</i>
1867	...	...	131,892 <i>l.</i>

The sum for 1867 was an increase of 6104*l.* over that of the preceding year. Then, again, as regards the Customs' revenue, in 1812 it was quite nominal, being returned at 3124*l.*, while there is every prospect that at the close of the present year it will amount to a million pounds sterling.

With such a traffic as these numbers indicate it is really surprising that the Clyde Trustees have never yet been able to boast of a graving dock of their own. This condition of things is to be remedied forthwith, the trustees having at their last meeting sanctioned the construction of such a dock at a cost of 60,000*l.*, upon ground which is the property of the Trust. The affairs of the Trust are in such a buoyant condition, that the debt of upwards of 1,500,000*l.* gives them little or no consideration, and this expenditure of 60,000*l.* is sanctioned without a murmur.

The Greenock Harbour Trustees have also been giving earnest consideration to the question of graving-dock accommodation, and several discussions have taken place amongst them regard-

ing the propriety of purchasing ground and constructing such a dock upon it at a total expenditure of 80,000*l*. The sanctioning of this expenditure is, in the mean time, postponed until the exact condition of the harbour finances is known; but the proposal is only postponed, not rejected, and there is scarcely any room to fear that it will not be adopted at an early date.

The China Trade.—Steam versus Sails.—The screw-steamer *Ajax*, 1500 tons, has just arrived in London from Shanghai, in 68 days, with a cargo of tea and silk. The time of this passage is about 30 days shorter than that of the homeward voyage of the sailing China clippers last year. The *Ajax* belongs to Mr. Alfred Holt, a Liverpool shipowner, and was built for him, along with the *Achilles* and *Agamemnon*, by Messrs. Scott and Company, of Greenock. Much interest is attached to this voyage, as it is believed to afford a settlement of the question of steam ships as against the clipper sailing ships in the China trade.

The Gunpowder Trade.—The fact that the manufacture of gunpowder is carried on to a very great extent in several places around the Firth of Clyde was referred to in my "Notes," I think, on a former occasion. There does not seem to be any falling off in the trade, judging by the following facts: During the past month of August the quantity of gunpowder shipped at the Tail of the Bank—which is a sort of roadstead in the Firth, opposite Greenock—amounted to 346,416 lb. The largest individual shipment was per steamer *Maceon*, for Genoa, and consisted of 100,000 lb., the remainder going to Africa, Brazil, Penang, &c., in quantities ranging from 25,000 lb. to 58,000 lb.

The New Steamer *Siberia* and the *Cunard Fleet*.—The magnificent screw steamship *Siberia*, of 2500 tons and 300 horse power, built and engined by Messrs. J. and G. Thomson, of Glasgow, for Messrs. Burns and McIver, of the British and North American Royal Mail Steam Packet Company, has just been having a trial of her machinery and steering gear. This is the second steamer built this year for the *Cunard* fleet, and a third is on the stocks. Since the year 1852 there have been built on the Clyde for this company no fewer than thirty-six large screw steamers and three paddle steamers. Previous to 1850 they had twelve paddle steamers built for them, making in all fifty-one steamers, of 90,000 tons. Twenty of these vessels have been sold, but there are still upwards of thirty in the fleet, of fully 60,000 tons.

Shipbuilding at Port Glasgow.—Messrs. McIntyre, shipbuilders at this seaport, have contracted with a London firm to build for them an iron ship of 1800 tons register. This will be the largest vessel built by these enterprising shipbuilders, and will be the first keel laid down in their new yard. Messrs. Robert Duncan and Co. have just launched another ship of 800 tons register for the Albion Shipping Company, of Glasgow, the managing owners of which are Messrs. Patrick Henderson and Co. She is named the *Helen Burns*, and is the seventeenth ship belonging to the Albion Shipping Company, and the third built by Messrs. Duncan and Co. for them during the last ten months. Besides these, there have been built or bought for this company during the last six years other ten ships, some being Clyde built, some Aberdeen built, and three colonial built; and Messrs. Duncan and Co. are building another ship of 800 tons. The ship just launched has the following dimensions: length of keel, 185 ft.; breadth of beam, 32 ft.; depth of hold, 19 ft. 9 in. All the ships of this fleet are engaged as New Zealand liners.

STEAMSHIP PERFORMANCES.

Report on the Condensation and Analysis of Tables of Steamship Performance, as published in the Years 1857, 1858, 1859, 1860, 1861, and 1862, by JOHN SCOTT RUSSELL, C.E., F.R.S., WILLIAM FAIRBAIRN, C.E., LL.D., F.R.S., THOMAS HAWKLEY, C.E., F.G.S., JAMES R. NAPIER, Marine Engineer, F.R.S., and W. G. MACQUORN RANKINE, C.E., LL.D., F.R.S.*

THE British Association possesses a large collection of records of the performance of steam-ships, accumulated in the course of many years, and printed in the reports of previous meetings, but in a form so bulky and cumbersome as seriously to interfere with their utility for practical and scientific purposes. At the Nottingham meeting in 1866 it was resolved to entrust the committee, whose names are given above, with the duty of condensing and re-arranging the data contained in those records, in order to bring them into a more compact and useful shape. That has been done in the present report, according to a method of which the leading principles may be summed up as follows:—All results belonging to any special theory, and all quantities calculated by inference, or ascertained otherwise than by direct measurement, are excluded from the condensed tables; vessels for which certain essential data are wanting are excluded (the essential data being such as the principal dimensions, the displacement, the kind of propeller, the speed, the indicated horse power, &c.); the vessels inserted in the condensed tables are divided into groups, according to their full speed, and very numerous groups are subdivided according to the displacement; an uniform arrangement of the data is adhered to as far as practicable; and the tables are drawn up in such a form as to be printed in octavo pages.

Condensation and Analysis of the Tables on Steamships' Performance, as published in the years 1857, 1858, 1859, 1860, 1861, and 1862.

The condensation is performed in the following manner:

1. Summary of Tables as published in the years 1857-1862.
2. Condensed Table of Merchant Paddle Steamers. Table I.
3. Condensed Table of Merchant Screw Steamers. Table II.
4. Condensed Tables of Men-of-war, forming four groups. Tables III., IV., V., and VI.

Summary of Tables, as published in the years 1857-62.

"1857, Appendix A.—Tabular comparison, the old, the present, and proposed measurement for tonnage; an analysis of ships and steamers, their proportions, displacement, weight, and resistance; engines and steam-power, and result, of speed realised."

This Table is of little or no use for analysis, for this reason, that of the few steamers of which the displacement, area of mid-hip section, and speed are given, no indicated horse power has been returned, and *vice versa*. Some of the ships have been mentioned in the condensed Tables, but their quantities have been given as taken from other Tables.

"Table A.—Summary of returns, showing the performance of the Chester and Holyhead Company's steam-vessels *Anglia*, *Cambria*, and *Scotia*, and the consumption of coal between Holyhead and Kingstown, under certain conditions taken at standard tests."

"1858, Appendix II.—Table showing the difference which exists between the 'register tonnage' of vessels, and the 'tons weight' of cargo actually carried in the trade and navigation of the United Kingdom with foreign countries and British possessions in 1852, 1853, 1854, and 1855, deduced from returns of the Board of Trade."

This Table gives the imports and exports during the above years of tons weight carried from and to the following countries: Russia, Sweden and Norway, Prussia, France, Holland, Austria, Greece, Turkey, and many others.

"1859, Appendix V., Table I.—Return of the performance of the Chester and Holyhead Company's steam-vessels, under trial for a standard test."

These Tables give the consumption of coal and indicated horse power for a certain speed of ship. The quantities of the telegraph have been repeated in another Table, and will be found in the condensed Tables of this report, with the same indicated horse power. Of the other three steamers, the performances have been given in this report under ordinary circumstances.

"Appendix V., Table II.—Copy of a return laid before a Select Committee of the House of Commons. See Blue-Book on Dublin and Holyhead Mail Service, 1853, Appendix, p. 176. A return of the speed and consumption of fuel of the steamboats under regulated conditions of time, pressure, and expansion, for the undermentioned periods."

This Table contains the same ships as Table I., Appendix V., giving a time of passage, average rate of speed, weight on safety-valves, proportion of steam in cylinders, and the total consumption of coals.

"Appendix V., Table III.—Chester and Holyhead Railway, Steamboat Department, 1857. A return of the speed and consumption of coal, under regulated conditions of time, pressure, and expansion, for the undermentioned period (namely, three months, from January 1 to March 31, 1857)."

"Appendix V., Table IV.—Chester and Holyhead Railway, Steamboat Department. A return of the speed and consumption of coal of the steamboats, under regulated conditions of time, pressure, and expansion, for the undermentioned period (namely, from April 1 to June 30, 1857)."

"Appendix V., Table V.—Chester and Holyhead Railway, Steamboat Department. A return of the speed and consumption of coal of the steamboats, under regulated conditions of time, pressure, and expansion, for the undermentioned period (namely, from July 1 to September 30, 1857)."

"Appendix V., Table VI.—A return of the speed and consumption of coal of the steamboats, under regulated conditions of time, pressure, and expansion, for the undermentioned period (namely, from October 1 to December 31, 1857)."

"Appendix V., Table VII.—Chester and Holyhead Railway, Steamboat Department. A return of the speed and consumption of coal of the steamboats, under regulated conditions of time, pressure, and expansion, for the undermentioned period (namely, from January 1 to March 31, 1858)."

"Appendix V., Table VIII.—Chester and Holyhead Railway, Steamboat Department. A return of the speed and consumption of coal of the express and cargo boats, under regulated conditions of time, pressure, and expansion, for the undermentioned period (namely, from April 1 to June 30, 1858)."

"Appendix V., Table IX.—Chester and Holyhead Railway, Steamboat Department. A return of the speed and consumption of coal of the express and cargo boats, under regulated conditions of time, pressure, and expansion, for the undermentioned period (namely, from July 1 to September 30, 1858)."

"Appendix V., Table X.—Chester and Holyhead Railway, Steamboat Department. A return of the speed and consumption of coal of the express and cargo boats, under regulated conditions of time, pressure, and expansion, for the undermentioned period (namely, from October 1 to December 31, 1858)."

"Appendix V., Table XI.—Chester and Holyhead Railway, Steamboat Department. Consumption of coal for the six months ending June 30, 1858."

"Appendix V., Table XII.—Chester and Holyhead Railway, Steamboat Department. Consumption of coal for the six months ending June 30, 1858."

"Appendix V., Table XIII.—A return showing the number of years run before the *Anglia*, *Cambria*, *Scotia*, and *Hibernia* had new boilers; number of miles run, and consumption of coal per mile, with and without raising steam, banking fires, lying at Kingstown and Holyhead; steam pressure in boilers."

"Appendix V., Table XIV.—Chester and Holyhead Railway, Steamboat Department. A return of passages made by the steamboats in 3½ hours, &c."

This is only a return of two steamers, the *Anglia* and the *Scotia*, and only giving on two journeys the highest and lowest steam-gauge in the cylinder, and the expansion proportion in the cylinder.

"Appendix V., Table XV.—Chester and Holyhead Railway, Steamboat Department. Mileage run, and expenses per mile, of the passenger boats in the years 1849 and 1856, 1857, 1858."

"Appendix VII., Table I.—Result of experiments with the yacht *Undine*, July 6, 1858, on the measured mile at Greenhithe."

"Appendix VII., Table II.—Result of experiments with the yacht *Undine*, July 29 and 30, 1858."

"Appendix VII., Table III.—Result of experiments with the yacht *Undine*, October 26, 27, and 28, 1858."

"Appendix VII., Table IV.—Experiments with the yacht *Erminia*, 12th October, 1858, in Stokes Bay."

This Table does not give indicated horse power nor displacement.

"1860, Appendix I., Table I.—Table showing the results of performances at sea, and on the measured mile, of seventeen vessels of the Royal Navy, of twenty-two vessels in the Merchant Service, and of two vessels of the United States Navy; together with the particulars of their machinery."

This Table contains data of the Chester and Holyhead Railway boats, as mentioned in former reports; the quantities therefore given in this Table have been selected for this report. But in taking the dimensions of the ships, former printed Tables have been compared in order to be correct.

"Appendix I., Table II.—Results of performances of the steam-ships in the service of the Messageries Impériales of France during the year 1858."

It is to be regretted that no dimensions whatever of these ships have been given; they have therefore been left out of this report.

"Appendix II., Table I.—Chester and Holyhead Railway, Steamboat Department. A return of the speed and consumption of coal of the express and cargo boats, under regulated conditions of time, pressure, and expansion, for the undermentioned period (namely, from January 1 to December 31, 1859)."

"Appendix II., Table II.—Chester and Holyhead Railway, Steamboat Department. Chester and Holyhead steamboats' consumption of coal for the six months ending 30th June, 1859."

"Appendix II., Table III.—Chester and Holyhead Railway, Steamboat Department. Chester and Holyhead steamboats' consumption of coal for the six months ending 21st December, 1859."

Tables II. and III., Appendix II., are a repetition of what has already been given in Table I., Appendix II., with the exception of the total consumption of coal for the six months, which may be found, however, by multiplying the coals consumed per trip by the number of trips. They contain eight ships, the *Anglia*, *Cambria*, *Scotia*, *Telegraph*, *Hibernia*, *Hercules*, *Ocean*, *Sea Nymph*.

"Appendix IV.—Tables showing the ratios between the indicated horse power and the grate, the tube, the other heating and total heating surfaces, and the indicated horse power; also between the grate and heating surfaces and between the indicated horse power and the coal consumed."

This Table contains two ships of the United States Navy, the same as have been mentioned in Appendix I., Table I., nineteen vessels of the Royal Navy, whose quantities also are mentioned in other Tables, and nineteen vessels of the Merchant Service, among whom are the *Anglia*, *Cambria*, *Scotia*, *Telegraph*.

"Appendix V.—Description of the hull, engines, and boilers of the United States sloop *Wyoming*. Table I. Performance of United States steam-sloop *Wyoming* under steam alone. Table II. Performance of United States steam-sloop *Wyoming* under steam and sail."

"Supplementary Appendix.—Table showing the trial performance of the steam-vessels *Lima* and *Bogota* when fitted with single-cylinder engines, and after being refitted with double-cylinder engines. Also the sea performances of the same vessels under both these conditions of machinery, and on the same service."

This Table has also been embodied in Table II. of printed report, 1861.

"1861, Table I.—Return of performance of H.M. vessels, furnished by the Admiralty."

"Table II.—Showing the results of the performance of six of H.M. vessels under various circumstances."

Of these six vessels, namely, the *Chesapeake*, the trial under steam has been returned in this report. The *Flying Fish*—of the three trials no indicated horse power has been given, one trial only giving the displacement, but not the speed, they have therefore been left out of this report. The *St. George*—the trial under steam alone has been returned in this report; and of the *Clio* and *Sphinx* no actual measurements of ship are given, they have therefore not been returned in this report.

With regard to Table I. of the *James Watt*, no speed was given; of the *Virago* no speed was given; the *Hydra*—this vessel made two trials, of which the first the speed was not to be depended on, and in the second the indicated horse power was not returned. The *Centaur*—no speed given. The *Industry*—no area of midship section nor displacement given. The *Diadem*—six trials have been returned, two with common screw, and four with Griffiths's screw; the first of these trials, of the 16th of April, 1858, has been repeated in later Tables. As a comparison, there are given in this report two results of performances of this vessel in the condensed Tables, one with the common screw and one with Griffiths's screw, and inserted these quantities

* British Association, 1867, Section G.

in their place, according to their speed and displacement. Of the Flying Fish a number of trials have been given in different Tables; but the trial with the common screw has been reported in the condensed Tables. Of the Marlboro', the trial of June 2, 1858, has been repeated in later Tables, and will also be found in the condensed Tables, where the quantities of the boilers are mentioned. Of the Bullfinch, seven trials are recorded with different propellers; the trial of the 20th of March, 1858, has been returned in this report. The Doris, of the seven trials here given, the latest of June 3, 1859, with Griffiths's screw, has been repeated in later Tables, and also given in the condensed Tables of this report. Of the Renown, the two trials of the 15th and 16th of March, 1858, have been repeated in later reported Tables. The quantities of these trials will also be found in this report, because they are the results under the same conditions of draught of water and displacement. Tables I. and II. have been separately condensed, because of the quantities of the boilers being there mentioned.

"Table III.—Performance of H.M.S. Victor Emmanuel at sea."

"Table IV.—Return of seven trials on the measured mile in Stokes' Bay of H.M.S. Victor Emmanuel."

"Table V.—Return showing the results of performance of eighteen vessels in the merchant service under various conditions."

It is from this Table that most of the quantities have been reported.

"Table VI.—Chester and Holyhead Railway, Steamboat Department. A return of the speed and consumption of coal of the express and cargo boats, under regulated conditions of time, pressure, and expansion for the undermentioned period (namely, from the 1st January to 31st March, 1860)."

"Table VII.—Chester and Holyhead Railway, Steamboats. Consumption of coal for the twelve months ending December 31, 1860."

"Table VIII.—City of Dublin Steam Packet Company. A return of the average time of passage and consumption of coal of the mail steamers for six months, ending June 30, 1860."

"Table IX.—City of Dublin Steam Packet Company. A return of the average time of passage and consumption of coal of the mail steamers for three months, ending September 30, 1860."

"Table X.—Résultats de la navigation des paquebots des services maritimes des Messageries Impériales pendant l'année 1859."

No dimensions of these ships have been given, and have therefore been left out of this Report.

"Table XI.—Résultats de la navigation des paquebots des services maritimes des Messageries Impériales pendant l'année 1860."

Of these ships also no dimensions have been given, and have therefore been left out of this Report.

"Appendix, Table XII.—Return of the average passages of mail packets, and consumption of coal for six months, ending 31st March, 1861."

"Appendix, Table XIII.—Steamship Leinster, on trial from Holyhead to Kingstown, April 4, 1861."

"Appendix, Table XIV.—Steamship Ulster, on trial from Kingstown to Holyhead, April 5, 1861."

Of these trials the ship's draught of water nor displacement have been recorded.

"1862. Table II.—Return of the particulars of the dimensions of twenty vessels in H.M.'s Navy, with the results of their trials upon completion for service."

The major part of this Table had been repeated in Table VI. of this volume, and those that have not, such as the Racehorse, Adventure, Dart, Glasgow, Orpheus, Octavia, Warrior, and Bacchante, no area of midship section nor displacement has been recorded.

"Table III.—Results of the performances at sea, and when on trials of H.M.S. Colossus, St. George, and Arrogant."

Of these steamers also no area of midship section, displacement, nor indicated horse power has been recorded.

"Table IV.—Results of the trials of H.M. screw-ships, officially tabulated by the Admiralty in 1850."

"Table V.—Results of the trials of H.M. screw-ships, officially tabulated by the Admiralty in 1856."

"Table VI.—Results of the trials of H.M. screw-ships, officially tabulated by the Admiralty in 1861 (being a continuation of Tables IV. and V.). Steam Transport Service, Tables VII., VIII., IX., X., XI., XII., XIII., XIV., XV., and XVI. (the last five Tables being summaries of the Tables VII. to XI.) show the results obtained from vessels employed in transport service during the latter part of the Russian war, showing the respective values of the several steamships, classified according to the nature of the employment, or the special character of the duties required to be performed; and giving, in addition, the cost of moving each ship 1000 miles, &c."

"Table XVII.—Royal (West India) Mail Packet Company. Southampton to St. Thomas, distance 3622 miles."

"Table XVII. (continued).—Royal (West India) Mail Packet Company. St. Thomas to Southampton, distance 3622 miles."

In these Tables, namely, Table XVII. and Table XVII. (continued), no draught of water nor area of midship section have been given; these Tables give the speed of the ship and consumption of coals at that speed, under various conditions of the state of the hull of five steamers, viz., the Seine, Tasmanian, Atrato, Shannon, and La Plata.

"Table XVIII.—Royal (West India) Mail Packet Company. Summary made from the Tables of diagrams from indicator and working of the engines belonging to the various ships included in the return furnished of the performances from Southampton to St. Thomas, between June 3, 1861, and June 17, 1862, as given in the preceding Tables."

"Table XVIII.A.—Table of diagrams from indicator and working of engines, showing the manner in which the summaries in the above Table are obtained."

In both Tables no particulars of ship are given.

"Table XIX.—Return of particulars of the dimensions of the Peninsular and Oriental Steam Navigation Company's Steamship Moulton, with tabulated statement showing the results of her performance as compared with six other vessels in the same service."

"Table XX.—Table of results of the performances of sixty-eight vessels of the Imperial and Royal Austrian Lloyd's Steamship Company."

No particulars of ship nor indicated horse power has been returned in this Table.

"Table XXI.—Table of experiments with H.M. gunboat Stork."

No area of midship section nor displacement has been given.

"Table XXII.—Eight logs of voyages of the Great Eastern."

Of the eight logs only three are returned with the indicated horse power, and these two have been used in the condensed Tables."

"Table XXIII.—Dimensions and abstract of performances of the Pacific Steam Navigation Company's new paddle-wheel steamships Peru and Talca."

No particulars of wheels nor immersion of floats have been returned.

"Table XXIV.—Abstract log of, and notes upon, the performances of the African Royal Mail Company's steamship McGregor Laird."

"Table XXV.—Notes on the performance of the North German Lloyd's Company's steamship Hansa."

"Table XXVI.—Log of the Earl of Durham's sailing yacht Beatrix, on her recent Mediterranean voyage."

This forms the summary of all the Tables published up to 1862, and the following has been the method adopted by the committee in condensing the Tables:

1. All results belonging to any special theory, and all quantities calculated approximately by inference, or ascertained otherwise than by direct measurement, to be excluded from the condensed Tables.

2. Vessels for which any of the essential data (marked E in the annexed Table) are wanting to be excluded.

3. The remaining vessels to be divided into groups, according to their speed on trial; for example,

Group 1, between 5 and 7 knots.

" 2, "	7 "	9 "
" 3, "	9 "	11 "
" 4, "	11 "	13 "
" 5, "	13 "	15 "
" 6, "	15 "	17 "
" 7, "	above 17 knots.	

4. Groups that are very numerous to be divided into subgroups, according to displacement, viz.:

Subgroup A, below 125 tons		
" B, between 125 and 250 tons		
" C, "	250 "	500 "
" D, "	500 "	1000 "
" E, "	1000 "	2000 "
" F, "	2000 "	4000 "
" G, "	4000 "	8000 "
" H, "	8000 "	16000 "
" I, "	above 16000.	

5. Results of trials at low speeds, or "half-boiler power," to be placed in the group proper to the speed.

6. In the following sketch of the arrangement of a table, each vessel of a group or subgroup occupies a column, and the several data for each vessel appear in a series of lines. The data consists of twelve essential items marked E (without which no vessel should be admitted) and twenty-one others, making thirty-three in all; so that pages of about forty lines will hold the tables, which may thus be printed in octavo.

7. Where trials of performance under sail have been recorded, supplementary tables may be added.

Proposed arrangement of Table for a given group or subgroup.

Group No. . . . , speed between . . . and . . . knots.

Subgroup No. . . . , displacement between . . . and . . . tons.

- E. Name of vessel (or reference numbers) | | |
- E. Length on loadwater-line, in feet.
- " of forebody.
- " middlebody.
- " afterbody.
- E. Breadth, extreme immersed, in feet.
- E. Depth of immersion, mean, in feet.
- Immersed midship section in square feet.
- E. Displacement, tons of 35 cubic feet.
- Mean immersed girth, feet (from actual measurement, and not otherwise).
- Material and state of skin.
- Co-efficient of fineness of water-lines, displacement $\div (L \times \oplus)$.

PROPELLERS.

- E. Description (paddle, common or feathering, screw, Smith's, Woodcroft's, Mangin's, Griffith's, &c., jet propellers).
- E. Radius (for common paddles to outer edge; for feathering paddles, to journals; for screw, to tips of blades) in feet.
- Number of blades or paddles.
- E. Pitch of screw (if not uniform, state extreme and mean pitches), in feet.
- Aggregate mean length of screw blades (along axis).
- Immersion (of upper and lower edges of paddle or screw), in feet.
- Area (pair of paddles; screw disc, deducting boss; pair of jet nozzles), in square feet.
- E. Speed of vessel in knots (of 6076 ft.).
- Speed of propellers (measured for common paddles at outer circumference, feathering paddles at journals; screw, mean pitch $\times$ revolutions), in knots.

ENGINES.

- Description (single, double, treble; single cylindered, double cylindered; condensing, non-condensing, geared, not geared, &c.).
- Final volume of steam per revolution of propeller, in cubic feet.
- Steam cut off at (decimals of final volume).
- E. Revolutions of propeller per minute (paddle or screw).
- Steam effective pressure, lb. per inch.
- E. Indicated horse power.

BOILERS.

- Total capacity, in cubic feet.
- Heating surface, in square feet.
- Firegrate area, in square feet (including dead-plate and bars).
- Pressure during trial (lb. on the square inch).
- E. Fuel consumed; description and weight, in lb. per hour.
- Remarks and cross references.

So far as it was possible, the above arrangement has been followed up and carried out; but a quantity of the items mentioned have never been returned in the printed Tables. Such items were therefore cancelled. Further, all quantities that had to be calculated, such as the coefficient of fineness of water-line, speed of propellers, area of a pair of floats, when they were not given in the printed Reports, have been omitted from the condensed Tables, and other quantities inserted in their stead, such as diameter and number of cylinders, length of stroke, speed of piston in feet per minute, &c., which of all ships nearly have been returned.

Paddle-steamers, screw-steamers, and men-of-war have been separately condensed, and grouped according to speed and displacement.

In condensing the Tables of the men-of-war ships, there are vessels of which some nineteen trials were returned. The mean of the majority of trials with the same draught and the same propeller have been returned in this Report.

Vessels of which the logs were given separately, such as the Victor Emmanuel, Wyoming, Macgregor Laird, Great Eastern, have been placed in the condensed Tables according to their speed and displacement.

The material and state of skin have but once been returned, and only of five ships; but no mention was made in those Tables of area of midship section and other essential data for analysis, that item has therefore been left out of the condensed Tables.

The diameter of the paddle-wheel, as given in the condensed Tables, is the diameter as returned in the printed Reports, and must not be confounded with the effective diameter of the wheel. In only a few cases the effective diameter has been returned, and upon these quantities even very small dependence can be placed. For example, in Table V., Report 1861, the diameter of paddle-wheel of the Delta is 26 ft., and the effective diameter is given as 22 ft.; the Lima has the same diameter of wheel, but the effective diameter is given as 25.16 ft. Both are feathering wheels, and there is only a difference of 1.5 ft. in the width of the float, the Delta having a float 4.5 ft. broad, and the Lima a float of 3 ft. broad.

The depth of immersion on trial means the immersion of the bottom of the float beneath the surface of the water.

Steam cut off at (dimensions of final volume) this quantity has very seldom been returned, and has therefore been omitted from these Tables.

Instead of effective pressure of steam, the pressure of steam in the cylinder, the pressure from the vacuum, and the pressure in the boilers are here given as they have been returned in former Reports.

All vessels of which the indicated horse-power, displacement, or any of the essential data were not returned, have been left out of this Report. For example, of the Oneida no displacement was returned; of the Erminia, no length and breadth of ship; of the Emerald, no length, breadth, nor area of midship section; of the Candia, no area of midship section; of the Nubia, no draught of water, nor area of midship section, &c. Nor could these quantities be ascertained, there being no lines of any ship in hand.

When the condensed Tables were finished, it was intended to give a theoretical discussion of the ships according to the different methods of the following gentlemen: J. Scott Russell, Esq.; W. J. Macquorn Rankine, Esq.; J. R. Napier, Esq.; and T. Hawksley, Esq.; but it is proposed to make that a separate and subsequent operation.

TABLE I.—MERCHANT PADDLE STEAMERS.

Groups of Speed	4. Between 11 and 13 knots.										
	3. From 9 to 11 knots.										
	F. Between 2000 and 4000 tons.	D. Between 500 and 1000 tons.				E. Between 1000 and 2000 tons.					
Subgroups of Displacement...	La Plata.	Anglia.	Admiral.	Cambria.	Cambria (lengthened).	Callao.	Valparaiso.	Lima.	Lima.	Bogota.	Bogota.
Name of Vessel											
Length, in feet... ..	284	187.83	$\left. \begin{matrix} F=84 \\ M=54 \\ A=72 \end{matrix} \right\} 210$	197.75	237	232	232	251	251	250	250
Breadth, in feet	40.5	26.16	32	26.16	26.16	29	29	30	30	30	30
Mean draft of water, in feet... ..	19.09	9	7.5	8.87	9.31	11.12	11.67	11.5	12.15	11.91	
Area of immersed midp. sec., sq. ft.		186.25	214	201.1	200.03	280	308	302	321	302	
Displacement, in tons of 35 cubic ft.	3809	620	820	840	980	1150	1220	1345	...	1410	
Mean immersed girth, in feet		...	31.43								
Material and state of skin	...	...	Iron painted; clean.								
ENGINES.											
Description	Side lever.	Pat. doub. cyl.	Double cylind.	Side lever.	Side lever.	Pat. doub. cyl.	Pat. doub. cyl.	Doub. cyl.	Side lever.	Pat. doub. cyl.	Side lever.
Number of cylinders	2			2	2	4	4	4	2	4	2
Diameter of cylinder, in inches	103	48.5	$\left\{ \begin{matrix} 76.5 \\ 48.5 \end{matrix} \right\}$	73.5	73.5	$\left\{ \begin{matrix} 2 \text{ of } 90 \\ 2 \text{ of } 52 \end{matrix} \right\}$	$\left\{ \begin{matrix} 2 \text{ of } 90 \\ 2 \text{ of } 52 \end{matrix} \right\}$	$\left\{ \begin{matrix} 2 \text{ of } 90 \\ 2 \text{ of } 52 \end{matrix} \right\}$	73	$\left\{ \begin{matrix} 2 \text{ of } 90 \\ 2 \text{ of } 52 \end{matrix} \right\}$	73
Length of stroke, in feet	9	4.5	4.25	5	5	5	5	5	6	5	6
Number of revolutions per minute...	12.31	25	24	23	20.25	24	24	24	22.5	22	
Nominal horse power...	876	330.52	...	392.10	392.10	320	320	320	400	320	400
Indicated horse power	...	816.07	744	995.35	837.34	1050	800	1160	1300	1100	1300
Pressure of steam in boiler, in lb.	14.82	14	25	14.5	14	26	22	26	16.5	26	
Pressure of steam in cylinder, in lb.	...	8.9	19	9.4	5.65	23	16	21	12.5	23	12.50
Pressure from vacuum	...	11.12	...	10.2	10.41	9.5	11	11	11.5	10	11.5
PROPELLER.											
Description	Radial fixed.	Mod. Morgan's	Feathering.	Mod. Morgan's	Common.	Feathering.	Feathering.	Feathering.	Ordinary.	Feathering.	Ordinary.
Diameter, in feet	36	24.5	20.5	23	25	26	26	26	26	26	27.5
Length of paddle, in feet	10.5	9.5	7	7	8	8.5	8.33	8.16	8.5	8.5	8.5
Breadth of paddle, in feet	3.16	3.67	3	4	2.16	3.08	3.16	3	2.5	3.08	2.5
Number of paddles	28	12	11	16	52	12	10	12	24	13	24
Depth of immersion, in feet	...	5.16	...	5.83	3.33	4	3.5	4	...	4	
Speed of vessel, in nautical miles..	10.79	12.96	12	12.2	12.23	12.9	11.53	12	13	12.5	12.75
BOILERS.											
Description	Tubular.	Tubular.	...	Tubular.	Tubular.	Tubular.	Flue.	Tubular, superheated.	Tubular.	Tubular.	Tubular.
Length, in feet... ..	22.5	17	...	10.5	10.5	12.5	11	12.08	11	12.5	11
Breadth, in feet	$\left\{ \begin{matrix} 14 \\ 11 \end{matrix} \right\}$	11	...	9.75	9.75	12.5	11	12.5	11	12.5	11
Depth, in feet	$\left\{ \begin{matrix} 18 \\ 14.6 \end{matrix} \right\}$	15	...	18	18	12.5	11	12.5	11	12.5	11
Steam-room, in cubic feet	4240	300	...	...	...	1600	390	1600	1450	1600	1450
Water-room, in cubic feet	5125	...	...	...	...	2000	720	2000	2520	2000	2520
Number of furnaces	24	12	...	12	12	6	6	6	12	6	12
Number of boilers	4	2	...	4	4	2	2	2	4	2	4
Grate surface, in square feet	616	160	100	165	450	140	130	136	252	140	252
Total heating surface... ..	16947	4508.44	...	6134	6893	3940	2530	3336	7655	3340	7652
Consumption of coals, in lb., pr. hr.	8149	5580	2206	5760	5241	2240	2464	3024	6720	2240	6720
WEIGHTS.											
Total of engines, in tons	495.5	...	210 with bolrs.	117	117	220	200	220	220	220	220
Each wheel	37.5	22	...	23.5	11.95	26	25	20	16	26	11
Boilers without water	219	40.97	...	66	83	60	34	60	80	60	80
Water in boilers	131	35	...	60	63	40	36	40	70.5	40	70
Reference to Report	1860	1860	1860	1860 & 1861	1860 & 1861	1860 & 1861	1860	1860 & 1861	1860 & 1861	1860 & 1861	1860 & 1861
By whom supplied	Royal Mail Co. log.	Admiral Moorsom.	Dr. Rankine.	...	...	Messrs. Randall & Elder.	Messrs. Randall & Elder.	Messrs. Randall & Elder.	...	...	
Remarks	Moderate wind and tide.	Fair wind; fair tide; moderate sea.	...	Wind light.	Moder. breeze; variable tide; comparatively smooth sea.	Lgt. hd. wind; variable tide; light head sea.	Light wind; alternate tide; no sea.	...	...	Wind abeam; variable tide; short beam sea.	

TABLE II.—MERCHANT SCREW STEAMERS.

Groups of Speed	3. Between 9 and 11 knots.				4. Between 11 and 13 knots.			
	A. Under 125 tons.		C. Between 250 and 500 tons.		F. Between 2000 and 4000 tons.			
	Subgroups of Displacement		C. Between 250 and 500 tons.		F. Between 2000 and 4000 tons.			
Name of Vessel	Midge.	Penelope.	Undine.	Lancefield.	Macgregor Laird.	Candia.	San Carlos.	Leonidas.
Length in water-line, in feet	53.75	74.33	{ FB=70 } { AB=50 } 125	{ F=62 } { M=8 } { A=75 } 145	245	281	192	208
Breadth (extreme), in feet	12.67	12.75	25	28	30	38.9	30	29.12
Mean draft of water, in feet	4	4.08	10.16	8	17.16	18.75	11.83	7.75
Area of immersed midship section, square feet	40	32	154.33	157	440	280	280	207
Displacement, in tons of 35 cubic feet	45	46.5	294	359	2035	2520	700	810
Mean immersed girth, in feet	..	..	37.84	27.64	..	..	..	..
Material and state of skin	..	..	Iron painted.	Iron painted.	..	..	..	..
Engines.								
Description	Inverted.	High pres. inver.	Inverted direct.	Inverted.	Inverted geared.	Trunk.	Patent doubl. cyl.	Vert. invert. cyl.
Number of cylinders	1	2	..	2	2	2	4	2
Diameter of cylinders, in inches	16	11.5	24	28	62	70.75	53 and 31	40
Length of stroke, in feet	1.33	1	1.25	2.5	3.16	4	2.92	2.5
Number of revolutions, per minute	160	..	101.74	84	34.9	..	47.5	78
Nominal horse power	25	20	60	60	200	450	120	100
Indicated horse power	100	93	167.09	200	550	1415	500	340
Pressure of steam in the boilers, in lb.	60	45	15.8	..	{ Average. 28 lb. }	..	50	..
Pressure of steam in the cylinder, in lb.	..	..	12.29	..	..	..	47	11.45
Pressure from vacuum	..	..	..	..	..	..	11	..
Propellers.								
Description	4	..	..	Gaining pitch.	..	..	10.5	8.83
Diameter, in feet	4.67	4.25	7.83	8	..	15.5	13.33	18
Pitch, in feet	9	10.5	11.25	16 to 17	..	20	Variable.	1.83
Length in line of shaft	1.5	.67	1.33	..	..	3.33	2	3
Number of blades	3	3	..	3	..	2	2	2
Boss, diameter in feet	96 x 1.16	.71	1.25	..	..	2.2	2.5	2
Depth of immersion at bottom	5.24	4.67	9.50	10	..	..	11	8.08
Speed of vessel, in nautical miles per hour	10.53	10.85	9.26	9.6	9.5	9.26	11.75	11.7
Number of revolutions, per minute	160	146	101.74	84	..	36	48	78
Boilers.								
Description	Cyl. mult. tub.	Tubular.	Tubular.	Chamb. 2, upright water tubes.	Tubular.	Lamb's patent.	Spiral flue.	Tubular.
Length, in feet... ..	9	8.06	12.25	9	..	15.5	12.5	9.5
Breadth, in feet	6.67	5.25	8	13	..	9.5	24	7.61
Height, in feet... ..	6.67	5.25	9	13	..	13	..	11.42
Steam-room, in cubic feet	70	38.05	456	..	..	..	750	225
Water-room, in cubic feet	140	86.45	..	..	..	..	800	1460
Number of furnaces	1	1	4	2	..	16	1	4
Number of boilers	1	1	1	1	2	4	1	2
Grate surface, in square feet	19.8	13.062	45.17	48	96	266	76	70
Total heating surface, in square feet	326.8	311.302	989.17	1278	4200	7922	2276	2274
Consumption of coals, in lb. per hour	280	336	..	672	..	..	1176	1204
Weights.								
Total of engines, in tons	2.5	2.7	10.3	..	..	..	70	24
Total of boilers, in tons	5.5	3.9	17.75	..	..	..	55	23
Total of water in boilers	5.75	2.5	6.5	..	..	..	27	21
Propeller	.35	.15	.85	..	..	..	1.6	1.35
Reference to Reports... ..	1861	1861	1859 and 1860	1861	1862	1861	1860	1861
By whom supplied	J. W. Dudgeon.	Messrs. Morrison and Co.	Duke of Sutherland & J. Scott Russell.	Professor J. M. Rankine.	Royal African Mail Company.	Messrs. Rennie and Son.	Messrs. Randolph and Elder.	Morrison and Co.
Remarks	Gale N.E.; heavy head- and beam- sea.	Moderate wind; no sea; with and against tide.	..	Moderate sea; quarter ebb; favourable tide.	..	..	..	Topgall breeze; moderate swell; last of flood; first of ebb.

Groups of Speed	4. Between 11 and 13 knots.				5. Between 13 and 15 knots.			
	C. Between 250 and 500 tons.		D. Between 500 and 1000 tons.		C. Between 250 and 500 tons.			
	Subgroups of Displacement... ..		D. Between 500 and 1000 tons.		D. Between 500 and 1000 tons.			
Name of Vessel	Guayaquil.	Mavrocordato.	Colombo.	Pera.	Thunder.	Ceylon.	Tasmanian.	Great Eastern.
Length in water-line, in feet	195	221	313	{ F=158 } { A=142 } 300	240	{ F=140 } { A=160 } 300	322	{ F=330 } { M=120 } { A=230 } 680
Breadth (extreme), in feet	30	32.75	37.25	42.08	30	41	39	23.62
Mean draft of water, in feet	11.71	15.75	18.25	18.25	14	18.25	19.08	23.71
Area of immersed midship section, square feet	260	444	618	592	842	582	577	1678
Displacement, in tons of 35 cubic feet	840	1963	2487	2972	1000	2940	3376	1678
Mean immersed girth, in feet	..	..	..	58	..	61	..	1678
Material and state of skin	..	..	..	Iron painted.	..	..	..	1678
Engines.								
Description	Pat. double cyl.	Vert. inv. cyl.	Beam geared.	Trunk.	Vertical dir.	Inv. dir.	Trunk inverted.	Horizontal direct.
Number of cylinders	4	2	2	2	2	2	3	4
Diameter of cylinders, in inches	53 and 31	48	72	70.75	55	72	68	84
Length of stroke, in feet	3	2.5	5.5	4	3	3	3.5	4
Number of revolutions, per minute	50	49	26	32.5	56.5	61.3	52	38.58
Nominal horse power	120	160	450	450	210	450	550	1600
Indicated horse power	600	545	1528	1414	924	2040	2800	4656
Pressure of steam in the boilers, in lb.	62	15	18.25	..	13	20	19	16.75
Pressure of steam in the cylinder, in lb.	46	..	21.8	..	13	..	10.55	19
Pressure from vacuum	12	..	..	..	12	..	12.75	13
Propellers.								
Description	10.5	14.75	15	15.5	15	16.5	17.83	24
Diameter, in feet	12	17	18	21	21	24	33.5	44
Pitch, in feet	2.5	2.16	3.61	3.67	4	4	3.75	4
Length in line of shaft	2	3	3	3	2	3	3	4
Number of blades	1.67	2.25	..	2.16	..	..	..	..
Boss, diameter in feet	11	15.75	18	..	15.67	..	19.25	..
Depth of immersion at bottom	12	11.19	12.46	12.556	14.5	13.34	14.25	14.28
Speed of vessel, in nautical miles, per hour	104	49	78	65	56.5	61.3	52	38.58
Boilers.								
Description	Pat. spiral flue.	Tubular.	Lamb's sht. flue.	Lamb's patent.	Tubular.	Lamb's sht. flue.	Tubular.	Tubular.
Length, in feet... ..	12	9.5	16	17	17.5 and 21	18	{ 4 of 14.54 } { 2 of 18.16 }	18.5
Breadth, in feet	12	11.83	10	9	9.16	10	13.75	17.5
Height, in feet... ..	24	13.29	17	12	15	14	8.87	14
Steam-room, in cubic feet	1000	415	2250	..	780	..	3957	..
Water-room, in cubic feet	1200	1165.4	..	..	1714	..	9375	..
Number of furnaces	1	6	16	16	8	20	26	72
Number of boilers	1	2	4	4	2	4	6	6
Grate surface, in square feet	74	111.3	340	327	214.6	450	510	..
Total heating surface, in square feet	2274	3543.4	8992	8839	4796	9450	12058	15859
Consumption of coals, in lb. per hour	1120	2128	4054	..	1456	..	8400	16161
Weights.								
Total of engines, in tons	70	51	263	..	96	..	390	..
Total of boilers, in tons	30	42	119	..	56	136	201	500
Total of water in boilers	25	26.42	101	..	49	64	150	..
Propeller	2.3	4.15	8	..	4	7	14	86
Reference to Reports	1861	1861	1861	1861	1861	1861	1860	1862
By whom supplied	West India Mail Company.	Messrs. Morrison and Co.	P. & O. Co.	Messrs. Rennie & Son.	J. W. Dudgeon.	Messrs. Hum- phrys & Tennant.	Messrs. A. and J. Ingila, Glasgow.	J. Scott Russell and logs of G. E.
Remarks	Light wind; heavy sea.	Calm; no sea; tide in favour.	..	Wind strong, S.S.W.	Calm; no sea; 1 mile against tide.	..	Fresh breeze; flood 2 runs; ebb 2 runs.	..

TABLE III.—MEN-OF-WAR (GROUP 1).

Groups of a Speed	...	...	...	...	...	1. From 5 to 7 knots.												
Subgroups of Displacement	...	...	...	...	...	B. Between 125 & 250 tons.	D. Between 500 and 1000 tons.			E. Between 1000 and 2000 tons.			F. Between 2000 and 4000 tons.					
Name of Vessel	...	...	...	...	...	Minx.	Plumper.	Wasp.	Cruiser.	Meteor.	Glatton.	Massa- chusetts.	Amphion	Cornwallis.	Hastings.	Blenheim	Hawke.	Ajax.
Length in water-line, in feet	...	...	...	...	...	131.02	140	188.33	160	172.5	172.5	156.25	177	177.08	176.87	181.23	176.08	176
Breadth (extreme), in feet	...	...	...	...	...	22.08	27.5	83.83	31.92	43.92	45.20	32	43.16	49.08	48.5	48.5	48.46	48.54
Tonnage, builder's measurement	...	...	...	...	...	303	490	970	753	1469	1535	...	1474	1809	1763	1832	1753	1761
Mean draft of water in feet	...	...	...	...	...	4.16	12.58	12	13.41	7.2	8.5	15.67	19	21.37	20.83	21.12	21.37	22.21
Area of immersed midship section, square feet	...	...	...	...	...	59	252	302	828	310	379	405	546	736	725	738	757	790
Displacement, in tons of 35 cubic feet	...	...	...	...	...	145	679	970	998	1346	1640	1361	2025	2718	2730	2790	2808	3013
ENGINES.																		
Description	...	...	...	...	...	H. H. P.	V. gear'd	V. os.	H. geared.	H. H. P.	H. H. P.	D. Ac.	Hor.	H. Tr. H. P.	H. H. P.	Hor.	H. Tr. H. P.	Hor.
Number of cylinders	...	...	...	...	...	2	2	2	2	2	2	2	2	2	2	2	2	2
Diameter of cylinders in inches	...	...	...	...	...	9.18	27	34	28.06	26.01	25.5	24.875	48	30.02	30	52	30	55
Length of stroke, in feet	...	...	...	...	...	.75	2	2.75	2	2	2	3	4	2.5	2.5	3	2.5	2.5
Number of revolutions per minute	...	...	...	...	...	196	54	58.58	49	139	127	44.39	45	96	78	43	89	521
Weight per square inch on safety-valve, in pounds	...	...	...	...	...	55	14	11	10	60	62	...	10	60	65	10	50	10
Nominal horse power	...	...	...	...	...	10	60	100	60	150	150	...	300	200	200	450	200	450
Indicated horse power	...	...	...	...	...	86.5	127.3	236.2	123.7	529.6	693.4	162.54	592.2	572.8	597.3	938.4	500	930.6
PROPELLER.																		
Diameter, in feet	...	...	...	...	...	4.08	8.69	11	9	6	6.21	10.5	15	12	12	16	12	16
Pitch, in feet	...	...	...	...	...	8.55	6.10	13.5	6.67	12.5	14	16	21	9.5	12.29	20	9.5	18.42
Length in line of shaft	...	...	...	...	...	.57	1.16	2	1.12	...	2.27	2	2.5	1.57	1.92	3.33	1.57	3.08
Immersion at bottom, in feet	...	...	...	...	...	2.33	6.42	4.75	7.83	4.5	5.16	18.33	...	14.75	14	...	14.08	12.57
Number of revolutions, per minute	...	...	...	...	...	196	109.08	58.58	98	139	127	44.39	45	96	78	43	89	52
Speed of ship, in knots per hour	...	...	...	...	...	5.441	6.381	6.976	6.295	5.77	4.5	5.616	6.75	5.8	6.702	5.816	6.525	6.83
Speed of propeller	...	...	...	...	...	6.888	6.568	7.801	6.445	17.139	17.539	...	9.321	8.996	9.457	8.483	8.340	9.447
Slip in knots per hour	...	...	...	...	...	1.447	.187	.825	.150	11.369	13.039	...	2.571	3.196	2.755	2.667	1.815	2.617
Slip, per cent.	...	...	...	...	...	21.01	2.85	10.58	2.33	66.33	74.35	...	27.58	35.53	29.13	31.4	21.76	27.70
Speed ² × $\frac{1}{D^3}$ ÷ indicated horse power	...	...	...	...	...	260.4	514.1	434	661.7	112.4	49.8	...	283.5	250.7	365.4	154.7	420.6	270.5
Speed ² × $D^{\frac{1}{3}}$ ÷ indicated horse power	...	...	...	...	...	...	157.6	140.8	...	...	...	...	...	...	...	...	...	...
Wind	...	...	...	...	...	...	No. 3.	No. 4.	Calm.	...	...	Mod. brze.	...	...	...	...	No. 2.	Light.
Sea	...	...	...	...	...	...	...	...	...	...	...	Moderate swell.	...	Smooth water; a little swell.	...	...	...	Smooth.
Remarks	...	...	...	...	...	...	...	...	...	...	...	...	Rigged & fully equipped.	...	...	Rigged & partially equipped.	...	...
Reference to Reports	...	...	...	...	...	1862	1862	1862	1862	1862	1862	1860	1862	1862	1862	1862	1862	1862

TABLE IV.—MEN-OF-WAR (GROUP 2).

Groups of a Speed	2. Between 7 and 9 knots.													
Subgroups of Displacement	B. Between 125 & 250 tons.	C. Between 250 and 500 tons.		D. Between 500 and 1000 tons.										
Name of Vessel	Teazer.	Cygnets.*	Swallow.	Ariel.	Wrang- ler.	Viper.	Torch.	Lynx.	Reynard.	Lyra.	Rifleman.	Panta- loon.	Hornet.	Nimrod.
Length in water-line, in feet... ..	130	145.08	189	139	160	160	145	160	147.67	139	150	151	160	200
Breadth (extreme), in feet	21.79	25.42	27.92	27.92	25.33	25.33	25.33	25.33	27.83	27.83	26.57	29.08	31.87	30.16
Tonnage, builder's measurement	296	428	486	486	477	477	425	477	518	485	486	677	753	851
Mean draft of water, in feet... ..	5.25	9.14	10.25	10.79	10.42	10.46	11.37	10.83	10.92	12.20	11.54	13.08	13.37	10.75
Area of immersed midship section, square feet	82.9	168	180	195	198	199	224	209	222	239	233	263	312	253.5
Displacement, in tons of 35 cubic feet	205	893	455	500	546.5	550	557	586	604	638	678	798	937	969
ENGINES.														
Description	V. os.	Hor.	Hor.	Hor.	Hor.	Hor.	Hor.	Hor. trunk.	Hor.	Hor.	V. os. geared.	Hor.	Hor.	Hor.
Number of cylinders	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Diameter of cylinders, in inches	27.06	32	25.5	25.5	40.5	40.5	32	=35.1	28	25.5	34	38	38.06	58.06
Length of stroke, in feet	2.5	1.5	1.75	1.75	2	2	1.5	1.67	2	1.75	2.75	2	2	2.25
Number of revolutions per minute	51.5	82	76.5	82	63.33	66	91.75	80	56	84	35.57	100	78	60.625
Weight per square inch on safety-valve, in pounds	9	21	20	20	20	20	20	20	14	20	10	20	20	20
Nominal horse-power... ..	40	80	60	60	160	160	80	160	60	60	100	150	100	350
Indicated horse-power	128.2	162.6	164.6	190.1	224.6	267.3	280.7	222.1	153.6	227.1	166.5	483.75	411.4	383.1
PROPELLER.														
Diameter, in feet	5	9	9	9	11.08	11	9	11	8.92	9	9	10	10	11
Pitch, in feet	7	12.01	10.87	11	15	15	13.08	9.75	7.25	11	8.42	12	15.46	20.5
Length in line of shaft	1.16	1.97	1.81	1.81	2.52	2.57	2.25	2.42	1.33	1.83	1.45	2.29	1.96	3
Immersion at bottom, in feet	...	4.96	5	4.83	4.33	4.57	6.25	4.92	...	6.33	6.5	6.5	7.08	4.75
Number of revolutions, per minute	192.09	82	76.5	82	63.33	66	91.75	80	112	84	89.64	100	78	60.625
Speed of ship, in knots per hour	7.685	8.677	7.429	7.647	8.012	8.8	8.843	7.033	7.3	7.45	7.15	8.934	8.744	8.818
Speed of propeller	13.263	9.833	8.206	8.897	9.371	9.765	11.841	7.694	8.009	9.114	7.441	11.837	11.893	12.259
Slip, in knots per hour	5.578	1.156	0.777	1.250	1.359	0.965	2.998	0.661	0.709	1.664	0.291	2.903	3.149	3.441
Slip, per cent... ..	42.05	11.76	9.47	14.05	14.50	9.88	25.32	8.59	8.85	18.26	8.91	24.52	26.48	28.07
Speed ² × (D ÷ indicated horse-power	293.4	674.9	448.4	458.7	453.4	507.3	553.1	527.4	562.2	435.2	511.5	387.6	507	453.8
Speed ² × D ^{1/3} ÷ indicated horse-power	...	215.5	147.4	148.2	153.08	171.1	166.8	109.7	...	134.9	...	126.8	155.6	175.3
Wind	...	No. 2	No. 5.	...	...	Light breeze.	No. 3 to No. 4.	No. 4.	...	...	...	No. 3.	No. 2.	No. 3 to No. 4.
Sea	...	...	...	...	...	...	...	Moderate swell.	...	...	...	Smooth.	...	...
Remarks	Not rig- ged; fine stern.	...	...	...	...	...	...	...	Rigged and fully equipped.	...	Fully rigged & ready for sea.	...	...	...
Reference to Reports	1862	1862	1862	1862	1862	1862	1862	1862	1862	1862	1862	1862	1862	1862

* Half boiler power.

(To be continued.)

THE EBBW VALE IRONWORKS.

ALTHOUGH not geographically within the principality, but in Monmouthshire, the beautiful vale of the Ebbw is as thoroughly Welsh in its population and pursuits as any part of Glamorganshire. In its lovely scenery it far surpasses that of any of the narrower neighbouring valleys to the west, but is in its turn surpassed by other valleys to the east, that of Pontypool, the Wye, and so on to the great valley of the Severn itself. A stranger to the district, journeying for the first time above Crumlin—with its tremendous viaduct spanning the sky like a vast yet most delicate ivory carving, so unreal does it seem in its aerial lightness—would least expect to come upon iron-works and collieries at the single spot which appropriates the name of the whole of the long valley—Ebbw Vale.

It is nearly a hundred and seventy years since Abraham Darby, a Quaker, commenced the founding of cast-iron pots in Bristol. He afterwards established the ironworks at Coalbrookdale, his grandson erected there the first cast-iron bridge ever built, and his lineal descendant, bearing the same name, founded the Ebbw Vale Iron Company, which, although no single one of its many separate establishments is the largest of its kind in England, is, nevertheless, the largest iron-making firm in Christendom. It has furnaces and mines miles and miles away from Ebbw Vale. Indeed, at that particular part of the valley which bears this name there are but four blast-furnaces, although there are three more about a mile down the river, at a place named Victoria. Then there are four, one of them the highest (72 ft. 3 in.) in Wales, at Sirhowy, by Tredegar, three miles to the west, four more at Pontypool, and six at Abersychan, twelve miles off. There are thus twenty blast-furnaces belonging to the company, and these made, in the year 1865, a total cast of 165,812 tons of pig iron, while the mills turned out 100,066 tons of rails and finished iron, and the collieries brought to bank nearly a million tons of coal, or exactly 986,575 tons. Altogether, the company has employed 15,000 people. Since it was formed into a limited-liability undertaking, and its profits have been publicly reported, these have been returned, in one year, at nearly 200,000*l.* Candour compels us to say that in this period of dulness the works are doing nothing like this, pecuniarily; but iron-making has always been a speculative business, and its turn of luck must come again.

The Ebbw Vale Company have large tracts of freehold property underlied with iron-stone, and they have iron mines also in the Brendon hills, in Somersetshire, whence is brought excellent spathose ores, white and brown, which make a pig from which good Bessemer steel may be made. With this ore the high furnace at Sirhowy, 72 ft. 3 in. high and 18 ft. in the boshes, makes 250 tons of pigs weekly. This ore is used also for settling the puddling furnaces, all the cinder from which is calcined and returned to the blast furnaces, where its silica is corrected by the argillaceous ores of the Monmouthshire district. The furnaces at Ebbw Vale also make each 250 tons weekly. Unlike Dowlais and Rhymney, where raw coal is used in the blast furnaces, that of Ebbw Vale is so far bituminous as to require coking.

The mechanical engineer has much to see at the company's various works. Besides the remarkably fine fitting and smiths' shops at Ebbw Vale, among the finest and best fitted with tools which we have seen anywhere, there is the largest blowing-engine ever made, with 6 ft. steam-cylinder and 12 ft. blowing-cylinder, both of 12 ft. stroke, the steam-cylinder being larger than that of the Merthyr Guest engine at Dowlais, while the blowing cylinder is of the same dimensions. This engine has had to be in great part reconstructed since it was put up by the makers. The fly-wheel shaft, weighing 8 tons, was forged in Cornwall, under a 25 cwt. single-acting steam-hammer, and split not long after it had been put to work. The fly-wheel ran 1½ in. out of truth sideways, and was found to be of insufficient weight. The plummer blocks, also, were too light. We gave drawings and full particulars of this engine in *ENGINEERING* a year ago (Sept. 7th, 1866), and we may say that the new shaft, forged by the Millwall Company, has journals 20 in. in diameter and 3 ft. long, where those of the old shaft were 16 in. by 2 ft.; the new plummer blocks weigh 10 tons each, where the old blocks weighed 3; and the new fly-wheel, 30 ft. in diameter, has 40 tons in the rim, 18 tons in the boss, and 24 tons in the eight arms, besides the 8½ ton shaft and 4½ ton crank, making 95 tons of revolving weight. When the new engine is again (if it be not already) at work, it will blow four large furnaces with 4 lb. blast.

Several of the blowing-engines of the company are of the Neath Abbey Company's make, having no fly-wheels, but the old-fashioned plug-rod valve-gear. One at Sirhowy has a 5 ft. steam-cylinder and 8 ft. blowing-cylinder, and 8 ft. stroke; and another at Victoria has a steam-cylinder of the same size and stroke, and a blowing-cylinder of 122 in. To both these engines smaller supplementary blowing-cylinders have been added, these being worked from the beam at half stroke. These engines work easily and quietly at a good rate of speed, 23 double strokes or 368 ft. of piston per minute.

Although we have spoken of the Ebbw as a river, it is but an insignificant stream, and does not furnish sufficient water for condensing the steam from the great number of engines employed at the various works. Considerable care is taken, therefore, to secure reasonable economy of fuel. The waste heat from both the puddling-furnaces and mill-furnaces is led off in flues to the boilers outside, and the steam-cylinders of the engines are everywhere carefully covered in with brickwork. This, for horizontal engines, presents an unusual appearance to the engineer accustomed, possibly, to ornamental lagging. Excellent draught is provided to the fires, the stack at Victoria being 198 ft. high and 12 ft. square.

The three-high blooming-mill has a steam-cylinder and piston to lift the bloom to the upper rolls. The favourite mill for blooming, however, is White's continuous mill, originally brought out at Dowlais, although not now used there. We described this in our second article upon Dowlais, and may repeat here that the one at Ebbw Vale has worked continuously for three years day and night, that it saves the labour of three men, and that it turns out a hotter and sounder bloom, requiring less re-heating, than the ordinary mill, whether with two rolls or three high.

A somewhat remarkable piece of steam-engineering at Ebbw Vale is a single horizontal engine of 24 in. cylinder and 1 ft. stroke, working direct upon the shaft of an 8 in. guide-mill, used for rolling wire-rods down to ¼ in. diameter. This engine, which has worked day and night for three years, was working, when we saw it, at 240 revolutions, but in rolling wire-rods it is driven at 300 revolutions, or 600 ft. of piston, per minute. It is bedded on masonry 18 ft. thick, and care has to be taken to prevent any thumping. One peculiarity of this engine is that it has but a single flat guide under the piston-rod, the cross-head simply resting upon, but not embracing or fitting into it. The pressure is always in one direction, as the engine cannot be reversed; and the single guide is preferred to two. The only other instance we know of a high-speed guide train being driven direct with an engine on the same shaft is that at Llynvi, where there is an overhead engine with 20 in. cylinder and 1 ft. stroke used in this manner.

We saw Spence's compound in use for protecting some of the steam-pipes, but it was failing grievously, coming off in patches.

Coal-washing is extensively practised for the small stuff, which was formerly lost; and this makes excellent coke—so good, indeed, that it is used in the furnaces making pigs for Bessemer steel. Many of our readers know of Bourdon's coal-washing machine, brought to this country years ago by James Morrison, now of Ferryhill, in Durham, and who made a fortune by its aid, and in a manner wholly unexpected by the northern coal-owners. It is this machine, of which the patent has run out, that is used at Ebbw Vale, and which is now being started at Dowlais. It is of exceeding simplicity. The fine coal—and it is all the better if ground under edge-runners, although this additional labour is not often undertaken—is raised by a Jacob's ladder to the top of the washing-tanks, and led by separate spouts into each of the four compartments. These are of cast iron, about 4 ft. square, open at the top, and hopper-bottomed to permit the escape of the slate and heavier matters. The compartments are kept nearly full of water, which is churned up and down through the coal by means of four 30 in. pistons working with a 4 in. stroke in as many open-topped cylinders at the side, one piston to each compartment. The shale, pyrites, &c., soon settle to the bottom by their greater weight, and are let off at intervals by opening a valve, some of the water escaping and more being then added. One combined machine, with four pistons and washing-tanks, is worked by a small engine, and is attended by two men and six girls. It will wash 200 tons in 12 hours, at a cost of less than 8*d.* per ton, all told, the wages amounting to hardly 15*s.* a day. What was once wasted is thus converted, when coked, into most valuable fuel, the coke from washed coal slack being purer than that from the large coal of the same pits

inasmuch as most, if not all, the sulphur is washed away.

The company has many coal pits; that at Abercarn being one of the finest in the kingdom. It is 300 yards deep, and is 22 ft. by 16 ft. all the way down. The winding engines are a pair with 48 in. cylinders and 8 ft. stroke, winding a flat rope on a 20 ft. drum. The cages have two stories, and on one occasion no less than 1330 tons of coal were wound out of the pit in 12 hours. The workings extend 1400 yards from the bottom of the pit; and for 1000 yards there is an underground tramway, with wagons drawn by a pair of 20-inch cylinder engines of 3 ft. stroke, and worked at a high rate of speed. A visitor to the pit, not long since, was actually whisked along this line at the rate of 20 miles an hour, but the regular rate of working is hardly one-third this speed. This colliery was once ventilated by a huge Nasmyth fan; but this has been long since removed, and furnace ventilation, maintained by an enormous fire, adopted in its place. The coal is tolerably bituminous; but the air is good, and the men work with naked lights. The Ebbw Vale coal, according to Playfair and Delabecche's experiments, had the very highest evaporating power of any coal tried, being 10.21 lb. of water evaporated from 212 deg. by one pound of coal. Only Thomas's Merthyr and the Duffryn coals came near this. It is a rather lighter coal than some of the others in the same district, contains about 90 per cent. of carbon, yields 77½ per cent. of coke, contains about 1 per cent. of sulphur, and burns with remarkably little ash.

We have said nothing of the Bessemer Steel Works at Ebbw Vale. They are admirably built of stone, well clear of the other portions of the works, and close beside the railway. Their erection was commenced by Mr. Moon, the son of the chairman of the London and North-Western Railway; but their present design and the arrangement of the plant was completed by Mr. E. Windsor Richards, the engineer of the Ebbw Vale Company. At present but two 5-ton converters and a small experimental converter have been put down; but the buildings are arranged to hold more. The whole plant was constructed by Messrs. W. and J. Galloway and Sons, of Manchester.

The visitor to Ebbw Vale can hardly fail to leave it without regret. Not even at Coalbrookdale does so much natural beauty look down upon great ironworks and collieries. Almost in the midst of the works are the park-like garden and plantation surrounding the Ebbw Vale House, now used by the directors as a private hotel for themselves and their visitors. Further back, along the hill-side, is the town of workmen's houses, commodious and neat, indeed almost elegant as you look at them, with the emerald background of the wooded hills beyond. The church, a recent work, is, architecturally, of beautiful design, and there is a well-supplied and well-supported reading-room, a museum, &c. Beyond the town there is a little world of rural beauty, within which, hidden among the trees, is the home of the managing director, the inheritor of a name of which all in England may be justly proud—Abraham Darby—a name well befitting the founder of the largest iron-making firm in the whole world.

AUSTRALIAN COAL.—The Dutch Indian Gaslight Company reports that the management in Batavia made a trial last year of Australian coal for the purposes of the company's manufacture. The result was not unsatisfactory; but the management was obliged, nevertheless, to fall back upon English coal, in consequence of the absence of regular navigation services between Batavia and Australia.

THE EASTERN COAST.—Her Majesty's ship Porcupine, Captain Calver, R.N., left the eastern coast last week, having completed a survey of the coast from Covehithe Ness to Orford Ness, upon which she has been employed for the last two months. Many interesting and important changes have been found to have occurred since the last survey was made, nearly half a century since. The shoals have altered in form and extent, while the sea has made considerable inroads upon the coast, particularly at Covehithe, Southwold, Dunwich, and between Aldborough and Orford Ness. A new fish-market and wharves have been nearly completed at Great Yarmouth. The market is 750 ft. long by 40 ft. wide, with a landing-wharf of the same width between it and the quay. The market is covered with a roof resting on 148 iron pillars; the roof on the east side is lighted with 36 skylights, 10 ft. by 36 ft. each, the west front being open. Along the eastern side are offices for fish salesmen, telegraph clerks, &c. The whole cost of the works has been about 12,000*l.*

THE DISTINGUISHED MEN OF SCIENCE.—Many of our readers who possess the fine and interesting print bearing the above title will regret to learn of the death of its engraver, Mr. William Walker, who died, ripe in years, on Saturday last, at his residence in Margaret-street, Cavendish-square. Mr. Walker executed many important engravings from his own designs, but that to which we have referred, containing fifty figures, drawn from authentic portraits, and grouped by John Gilbert, of the most distinguished men of science, engineers, and mechanicians living in England at the beginning of the present century was among the most remarkable. Mr. Walker spent six years upon this work, and laid out 5000*l.* upon it before receiving any return.

COTTON MACHINERY.

(For Description, see opposite page.)

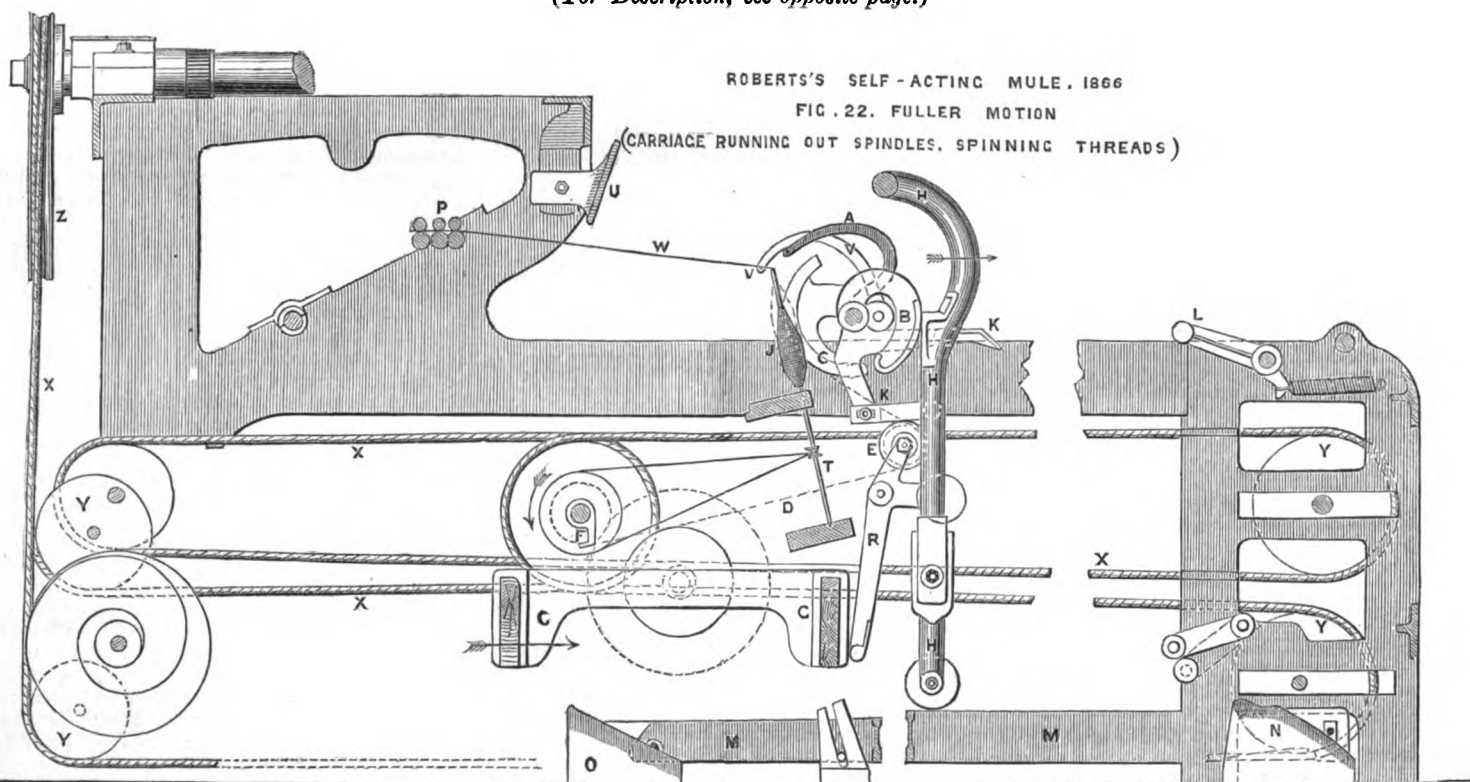


FIG. 1. ARKWRIGHT'S SPINNING MACHINE, 1769.

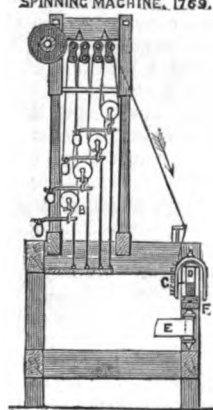


FIG. 2. HARGREAVES' SPINNING JENNY, 1770.

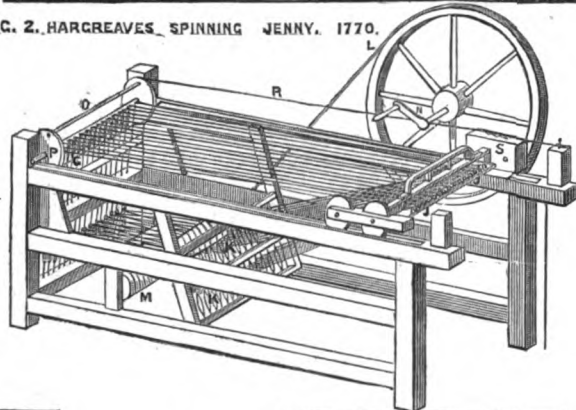
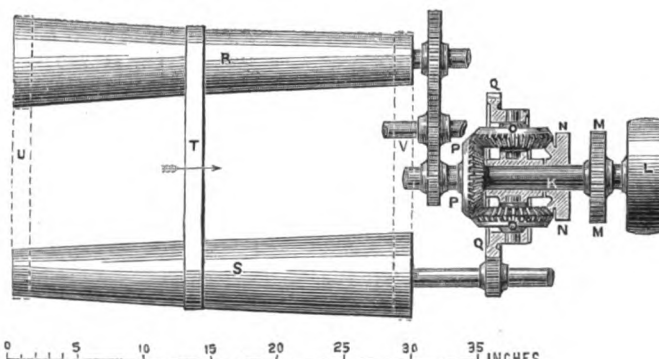


FIG. 18. HOLDSWORTH'S DIFFERENTIAL MOTION, 1826.



EATON'S BACKING.

FIG. 19.

OFF MOTION, 1818.

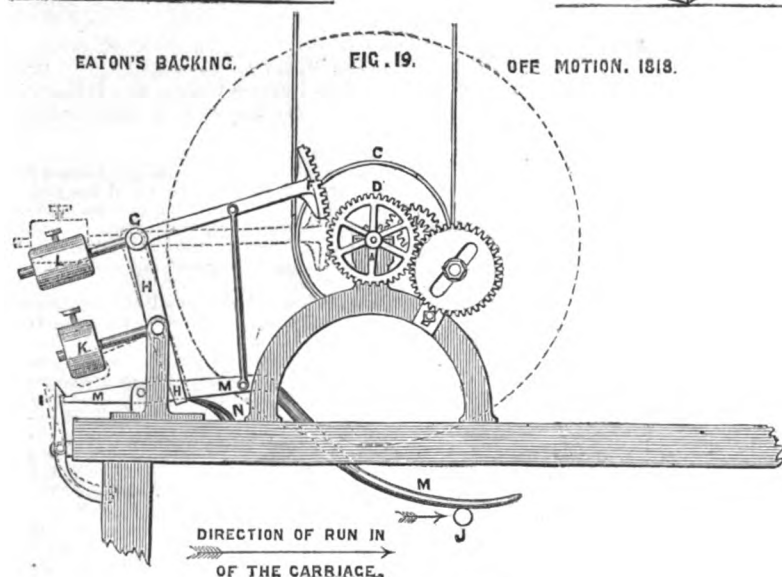


FIG. 20.

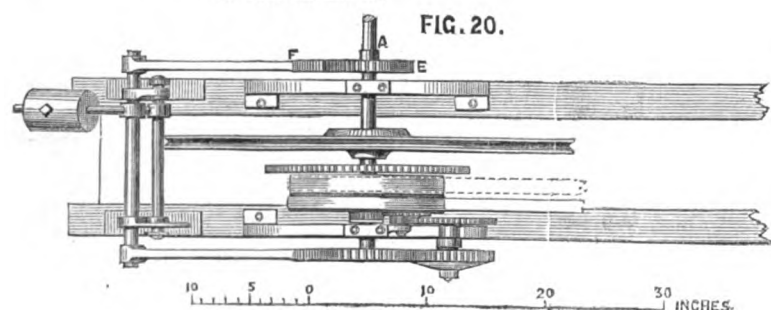
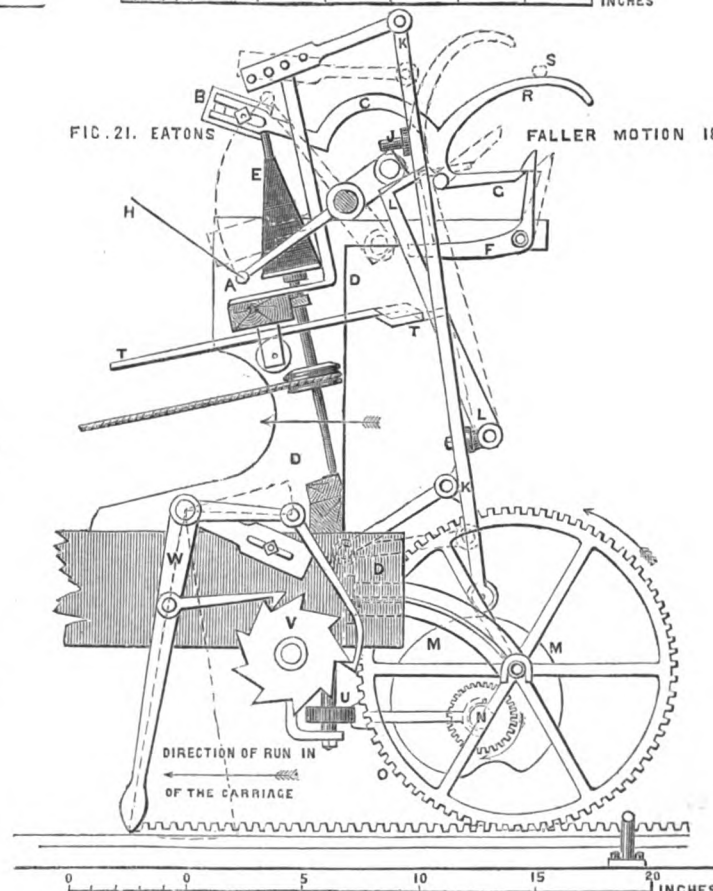


FIG. 21. EATON'S

FALLER MOTION 1818



ON MACHINERY FOR THE PREPARING AND SPINNING OF COTTON.*

By Mr. JOHN PLATT, of Oldham.

THE object of the present paper is to trace the principal mechanical steps by which the application of machinery to cotton spinning has been developed, and which have led to the completion of the present elaborate machines, so remarkable for the perfection of the results produced by them. The modern machines are, in fact, formed of a combination of numerous highly ingenious contrivances, which have been successively designed to meet the special difficulties of dealing by machinery with so delicate and irregular a material as the raw cotton fibre.

The process of spinning involves three essential and distinct operations:

First, *Drawing*,—in which the fibres of the raw material are drawn out longitudinally, so as to lay them all parallel with one another, and overlapping at the ends; as is done by the fingers of the hand-spinner for forming a continuous sliver out of the short fibres lying irregularly in the bundle that is tied upon the distaff.

Second, *Twisting*,—in which the sliver previously formed is twisted into a roving or thread, for giving it longitudinal tenacity by increasing the lateral friction between the fibres; as is done by the hand-spinner by twirling the bobbin on which the portion of thread already twisted has been wound.

Third, *Winding*,—in which each portion of the thread, after it has been sufficiently twisted, is wound upon the bobbin.

In the application of machinery to the performance of these operations, the great difficulties experienced have arisen from the irregular character of the cotton fibre on the one hand, and, on the other, from the unyielding action of machinery, which has to take the place of the delicate feeling of the fingers in hand-spinning, whereby the spinner is enabled to accommodate the action continually to the variations in the material. It is a point of special mechanical interest, however, to note at how early a period in the application of machinery correct ideas were developed as to the principles of action in the important successive steps: so correct, indeed, that they have remained unaltered in principle to the present time, although many highly ingenious improvements in detail have subsequently been effected.

It appears that the credit of the first invention of the spinning machine is due to Lewis Paul in 1738, little more than a century ago, all spinning having been previously done by hand. In his first machine the raw cotton was passed through a succession of pairs of rollers, each pair running faster than the preceding, so as to draw out the sliver of cotton longitudinally to any degree of fineness required. The machine thus accomplished only the drawing process, leaving the sliver so formed to be twisted and wound afterwards by hand. The great feature of this invention was that the important principle of drawing by rollers running at different speeds was thus established at the outset, to supersede drawing by the fingers in hand-spinning; and this mode of drawing has been adhered to ever since as the fundamental principle in the preparation of fibrous materials for spinning.

In 1748 Paul further invented a carding machine, for carding or combing the raw cotton in preparation for the drawing-rollers. It consisted of a number of flat parallel cards fixed upon a table with spaces between them; and, the teeth of the cards being all bent in the same direction, the cotton was carded by being drawn over them by hand by means of an upper flat carding-board set with teeth bent in the opposite direction. In another arrangement this flat upper card was replaced by a horizontal carding cylinder, made to revolve by hand; and the lower carding table was made concave to fit the underside of the cylinder. When the cotton was sufficiently carded, it was taken off each card separately by hand by a needle-stick, and then connected into one entire roll or lap.

In 1758 Paul further improved his original machine by rendering it capable of performing the two other processes of twisting and winding requisite to complete the operation of spinning by machinery; and he constructed a spinning-machine having a circular frame containing fifty spindles. The cotton was drawn by rollers, as in his previous machine, and the sliver was delivered from the rollers to a bobbin upon each spindle, by means of an arm or flier fixed upon the spindle; and the spindle being so contrived as to go faster than the bobbin, the sliver was thus twisted into thread by the flier, before being wound upon the bobbin.

Although the two mechanical principles, which have formed the basis of all subsequent spinning machinery, namely, the drawing rollers running at different speeds, and the differential motion of the flier and bobbin, were thus originated by Paul, it does not appear that his machines were ever practically successful; and Arkwright's spinning-machine in 1769, shown in Fig. 1, page 220, appears to have the merit of being the first that was brought into successful operation. This machine cannot be called more than an improvement in detail upon Paul's, as the principles of the two were the same; and it is difficult to imagine that Arkwright had not seen Paul's machine. The success

of the later machine may be attributed to its superiority both in workmanship and in the material employed, the earlier machine having been composed almost entirely of wood.

The four pairs of drawing rollers, A A, Fig. 1, were made of brass and steel, and geared together by pinions; the bottom rollers were covered with wood and fluted, and the top ones were covered with leather, and pressed down upon the bottom rollers by the weighted cords and pulleys, B B. The sliver delivered by the rollers was then twisted into a yarn or roving by the flier, C, and wound upon the bobbin, D. The differential motion of the flier and bobbin, by which the two operations of twisting and winding were effected, was exactly the same that is still employed for the same purpose, only the motion was obtained by different means. If the flier and bobbin both revolved at the same rate and in the same direction, no winding would take place, and the effect would be confined to twisting the sliver into a roving. On the other hand, if only the flier revolved and the bobbin were stationary, all the motion would wind and also twist, but only a single twist would be put into the sliver for each coil wound on the bobbin. But if the bobbin rotates slower than the flier, the twisting is effected at just so much slower rate than the twisting as the two speeds are made to approximate. This was accomplished in Arkwright's machine by the simple means of a friction brake upon the bobbin, D, the bobbin being loose upon the spindle, and dragged round by the thread, whilst the flier, C, was fast upon the spindle, and driven direct by the driving-strap, E, below. The friction-brake to retard the bobbin was made by a worsted cord passed round a groove in the whirl, F, at the bottom of the bobbin, and tightened by hand to the required adjustment by a screw-pin securing the end of the cord. The drag put upon the bobbin by this friction-brake also put a stretch upon the roving, and caused it to be wound tight on the bobbin in solid layers instead of in loose coils. In the arm of the flier, C, were fixed a number of hooks, under which the roving was passed; and the winding on the bobbin was done in successive steps, by stopping the bobbin and shifting the roving successively from one hook to the next on the flier, as no idea had yet been originated of giving the bobbin a vertical motion upon its spindle so as to guide the roving on regularly in winding.

In 1770 Hargreaves invented the spinning jenny, shown in Fig. 2, page 220, the principle of which is identical with that of the present spinning machinery. It thus presents a remarkable instance of a correct perception respecting the best mode of working having been attained at so early a stage in the application of machinery to a new purpose. The operation of spinning into threads the rovings produced by the machines already described, or by the modern improved machines similar in principle, comprises the two processes of twisting and elongating the roving to form it into a thread, and then winding the spun thread into the form of a "cop" upon the same spindle by which the spinning or twisting has been performed. These two processes still continue to be effected in essentially the same manner as in Hargreaves's spinning jenny.

The twisting of the thread is effected by causing the spindles G, Fig. 2, to revolve, as though for winding up the thread, but allowing the thread to slip off the free end of the spindle once in each revolution. For this purpose the thread is led off from the top end of the spindle at an angle so much greater than a right angle that its tendency to wind in a spiral brings it to the top extremity of the spindle in each revolution, causing it to slip off the end of the spindle at each successive revolution; and the top of the spindle is shaped conical to facilitate the slipping of the thread off the end. The result is that the thread is twisted one turn by each revolution of the spindle, without disturbing or interfering with the portion of spun thread already wound up into a cop on the lower part of the spindle. The crossbar, J, carrying the guiding eyes through which the several threads pass, rests at each end on a carriage that runs along the side framing of the machine; and before the commencement of the spinning by the spindles, G, the crossbar is first drawn backwards from the spindles by hand through about one-third the length of the machine, drawing off a continuous supply of roving from the bobbins, K, below, which are free to turn on their bearings. The clasp, H, is then pressed down tight upon the crossbar J, holding the rovings fast, and the spindles, G, are set in motion, twisting the lengths of thread between the spindles and the crossbar; and during the twisting the crossbar is gradually drawn backwards by hand to the end of the machine, thus producing the required elongation of the threads by tension during the spinning, as is done in the case of hand-spinning by the weight of the bobbin or spindle hanging from the twisting thread. The spindles, G, receive their motion from the drum, M, driven by the driving pulley, L, which is turned with the right hand by the handle, N, while the left hand draws back the crossbar, J, by means of the handle upon the clasp, H.

When the crossbar, J, has been drawn back to the extreme end of the machine and the spinning of the threads has been completed, they are then wound up on the spindles by depressing them all simultaneously to the lower portion of the spindles by means of the "faller wire," O, which is brought down upon the threads by the rotation of the discs, P P, in the direction of the arrow. The rotation of the discs is effected by tightening the cord, R, which runs along the side of the machine, and they are turned back again by a counterbalance weight for raising the faller wire when

the cord is released; the cord passes round three horizontal pulleys on the top of the carriage, S, and is tightened for depressing the faller wire by a transverse sliding movement being given to the middle pulley by means of a hand lever, which is worked by the left hand whilst holding the clasp on the crossbar, J. The threads being depressed by the faller wire, the further rotation of the spindles now causes the threads to be wound up in cops upon the spindles, the sliding crossbar, J, being pushed forwards gradually by hand as the winding proceeds, until it again reaches the spindles, when it is ready for beginning the spinning of a fresh length of rovings. During the winding of the threads already spun between the spindles and the crossbar, J, this length of the threads is secured and separated from the untwisted rovings beyond the crossbar by the pressure of the clasp, H, which is kept pressed down tight upon the threads.

On the completion of the spinning, however, of each length of the threads, and before the change can take place from spinning to winding, it is necessary first to unwind the short spiral of thread extending up from the top of the cop previously wound to the top extremity of the spindle. This spiral is unavoidably formed at the commencement of the twisting, before the thread can reach the point where it ceases to wind and begins slipping off the end of the spindle at each revolution; but if this portion of thread were not entirely removed before the faller wire, O, is lowered at each time of changing from twisting to winding, an irregular and loose accumulation of thread would take place upon the upper end of the spindle, spoiling the form of the cop, and interfering with the proper slipping-off action in twisting. The motion of the spindles has therefore to be stopped and reversed for a few turns when the twisting is finished, to unwind these few spiral coils; and this was done in the spinning jenny by the spinner stopping the driving wheel, L, and then giving it a partial turn backwards by hand, for "backing off" the thread, before driving forwards again for winding thread on the spindles.

This backing-off motion and the faller wire are identical with those now in use in the modern spinning-machines, the only difference being that they are now made self-acting. In winding the cop each successive layer of thread is so regulated that a conical form is given to each end of the finished cop, in order to prevent the thread from getting loosened upon it at the ends in subsequent handling; while, at the same time, the crossing of the thread in the alternate spiral layers gives firmness to the cop, and still allows the thread to be afterwards drawn off it, when required for use, either by slipping off the end, as in a shuttle, or by unwinding the cop on a spindle. In the spinning-jenny this shape of cop was obtained by regulating the winding of the thread by means of the cord, R, acting upon the discs, P P, raising and lowering the faller wire, O, during the winding, so as to guide the thread upon the spindle as required for producing the desired shape of cop. The same shape of cop and mode of guiding the thread on are still adhered to in the present spinning-machines; but the whole of the movements are now effected entirely by self-acting machinery.

Further improvements in the preparatory processes of carding and roving were introduced by Arkwright, in 1775 which may be said to include the principal features contained in the carding and roving machines now used. The cotton delivered from the preliminary machine was formed into a roll or lap, for supplying a continuous fleece of cotton to the carding-cylinders, the carding operation being repeated until the irregular mass of fibres in the raw material had been combed straight and laid parallel in the fleece of cotton with a sufficient degree of uniformity to allow of proceeding to the subsequent operations. Comb-plates, worked backwards and forwards by cranks, were also added for combing off the cotton in a continuous fleece from the "doffer" or taking-off cylinder of each of the carding-machines. The sliver delivered from the last carding process was passed between a pair of rollers for the purpose of consolidating it by the pressure of the rollers after the loosening action of the doffing comb-plate; and it was then coiled down into a can.

The doubling and drawing process employed at this stage of the manufacture was also introduced by Arkwright at the same time, the object being to intermingle the fibres more completely in the sliver, and thereby render it more uniform in quality, ready for twisting into a roving. For this purpose two, or generally more, of the slivers from the carding-engine are passed side by side through a series of pairs of drawing rollers, each pair in succession being made to run faster than the preceding; and the last pair of rollers runs as many times faster than the first pair as there are slivers doubled together, so that the single combined sliver delivered from the rollers is drawn down to the same size or weight per foot as one of the original slivers. The doubling and drawing operation is usually repeated three times, and the ultimate sliver so prepared is then ready for the roving-frame, in which it is again drawn and twisted and wound upon a bobbin.

In the roving-frame Arkwright now effected an important advance upon his previous machine, shown in Fig. 1, by introducing the new principle, which has since been adhered to, of driving the bobbin and the spindle independently by separate motions, instead of letting the bobbin be simply dragged round by the thread as previously described. At the same time he also introduced the conical regulating-drum, for reducing the speed of the bobbin in proportion as its diameter was increased by the thickness

* Paper read before the Institution of Mechanical Engineers on the occasion of their meeting at Manchester, in August, 1866. Some of the figures referred to in this paper are given on page 220; the remainder will appear, with the conclusion of the paper, next week.

of the coils of roving wound upon it, so as to avoid increasing the tension upon the roving, as would be the case if the speed of the bobbin were uniform, since the spindle and flier are driven always at a constant speed. This mode of regulating the speed of the bobbin by a conical drum is the same that is still employed in the modern machinery, with modifications only in the mode of application. There appears reason also to believe that the rising and falling motion of the bobbin upon the spindle, for winding the roving on the bobbin in regular coils by a continuous vertical movement of the bobbin, was also introduced by Arkwright at the same time, although no description is given by him of the manner in which this was accomplished; but in the drawing illustrating the series of improvements introduced by him at that period, the flier upon the spindle is shown with a single eye for delivering the roving upon the bobbin, instead of the succession of hooks fixed on the arm of the flier in the previous machine, Fig. 1, for winding the roving on in a succession of steps; and a sufficient space is also left in the drawing for allowing the required amount of vertical movement of the bobbin. The invention of this principle of lifting and lowering the bobbin upon the spindle during the winding, which is employed in all the present machines, has not been traced by the writer to any earlier date than these final improvements introduced by Arkwright in 1775.

By thus making special machines for each process in the preparation of the material for spinning, Arkwright effected a most important division of labour; and the factory system, already introduced in the silk manufacture, became rapidly extended in consequence.

In the preparation of cotton the improvements introduced from time to time in each particular section of the machinery employed have been so numerous and so varied that only a slight reference can be made to them in this paper under their respective heads, in the hope that they may be made the subjects of special papers by some of the members at future meetings.

Opening.—The first process in the preparation of the raw cotton was known as "willowing," and took its name from the willow switches formerly used for beating or opening the tufts of cotton by hand. A number of small parallel cords were stretched tight and close together on a horizontal frame, so as to form a sort of table, upon which the cotton to be opened was laid; and the cotton being then beaten with switches made of willow rods kept smooth for the purpose, the fibres of the cotton remained on the cords, whilst the sand and seeds fell through between. Some of the best descriptions of sea-island cotton are still batted in this way, for the finest counts of yarn. Several attempts were made to work the willow beaters by machinery, but they have all been superseded by opening and scutching machines on the modern principle, having revolving cylinders to act as beaters. The most primitive of these is known as the Oldham Willow, and has a revolving cylinder about 36 in. diameter, set with spikes placed in parallel rows, and revolving against a grid of bars set with similar spikes: the cotton is fed upon the grid, and beaten for a longer or shorter time according to its condition, and an exhausting-fan is employed for taking away the sand and bits of dried leaves beaten out. This machine is now used only for separating hard lumps of cotton in bales packed too tightly, and for cleaning cotton waste and the refuse cast out by other cleaning-machines.

Fig. 3 shows a section of the cotton-opener in use at the present time for the purpose of opening out the fibres of the cotton after it has been pressed in the bales, and for extracting the sand, dried leaves, and other impurities imported with it, the object being to do this without entangling or injuring the fibre. The crude cotton from the bales is spread by hand upon the endless travelling lattice, A, which conveys it underneath the iron guide-roller, B, with longitudinal ribs on its surface to the pair of fluted feed-rollers, C. These are pressed together by the weighted lever, D, and deliver the cotton to the picker cylinder, E, set with twelve rows of teeth, which are spaced so that the teeth follow one another spirally round the cylinder, as shown in the plan, Fig. 4. The tufts of cotton being gripped tight between the rollers, C, are caught by the tips of the teeth on the cylinder revolving in the direction of the arrow, and are thus torn open and dashed by the teeth against the circular grid, F, formed of angular bars set with spaces between them, which allow the dirt disengaged by the beating action to fall through. A perforated plate, G, forms the remainder of the casing of the cylinder on the underside, allowing the dust to drop through while the cotton passes over it. The picker cylinder delivers the cotton against the teeth of the beater, H, which has four rows of teeth, similar to those on the picker, E. Here the cotton is further beaten, and passed over a circular grid and perforated plate; and the beater cylinders being covered in at the top by a sheet-iron casing, the current of air produced by their revolution wafts the light fleece of cotton forwards over the straight grid, J. It is whilst the cotton is thus floating in the air that the heavier impurities, loosened by the beaters, drop out and fall through the grid, J, into the dust-box. The cotton then passes between the two wire-gauze cylinders, K, which serve as fine sieves, the interior of the cylinders being exhausted by the fan, L; by this means the more minute particles of dust remaining in the cotton are sifted out, and discharged by the fan through the aperture, M, thereby keeping the rooms where the machines are at work perfectly free from dust. There is thus a continual deposit of impurities taking place throughout the whole passage of the cotton through the machine, from the

feed-rollers, C, to the wire cylinders, K. In the drawing only two beater cylinders, E and H, are shown; but the machines are more generally made with four cylinders, for cleansing the cotton more effectually, the two additional beaters being provided with four rows of teeth, the same as the second cylinder, H. From the wire cylinders the loose cotton is collected again, and consolidated into a fleece by the fluted stripping-rollers, I, running close to the cylinders, K, but not touching; and these deliver it to the travelling lattice, N, which discharges it ready to be taken to the next process of scutching, a lap machine being sometimes attached so as to form the fleece into a lap or roll for supplying the scutcher. The beater cylinders, E and H, run at about 1000 revolutions per minute; the feeding lattice, A, travels at 6 ft. per minute, which is also the surface speed of the feed rollers, C; and the surface speed of the wire cylinders, K, the stripping rollers, I, and the delivery lattice, N, is 60 ft. per minute.

Scutching.—The scutching-machine now in use for further beating and cleansing the cotton delivered from the opener is shown in Fig. 5, having also combined with it the lap machine for forming the fleece of cotton delivered from the scutcher into a roll or lap. The cotton from the opener is supplied to the scutcher upon the travelling feeding-lattice, A, and in order to produce a uniform fleece for the further processes it is necessary at this stage to regulate the quantity fed into the scutcher, which is effected in two ways. In feeding by hand the tedious method of weighing the cotton supplied has to be resorted to, so as to distribute a uniform weight of cotton over each foot of length of the feeding lattice, which, together with the feed rollers, C, is driven at a uniform speed. But in the improved mode of feeding by laps, B, supplied from a lap machine in connexion with the opener, the top feed roller is allowed to rise and fall according to the variations in the thickness of cotton fed in, and the amount of its vertical movement multiplied by means of levers is employed to regulate by a self-acting arrangement the speed at which the feeding-lattice and rollers are driven. By this means an almost uniform supply of cotton is fed to the beater, H, which is composed of three plain bars, as shown in the plan, Fig. 6, and is driven at about 1250 revolutions per minute. The cotton is beaten as before against the circular grid, F, and perforated plate, G, and the current of air from the beater wafts it forwards over the straight grid, J, to the wire cylinders, K, exhausted by the fan, L, the action being exactly the same as in the opening-machine. The rollers, I, which strip the dust cylinders, deliver the fleece to a set of four calender rollers, O, placed over one another, so that the cotton in passing through them receives three compressions, which consolidate it into a kind of felt; the surfaces of the calender rollers are kept clean by rubbers of iron covered with flannel, which are pressed in contact with them.

The lap machine, for coiling the fleece into a roll or lap, has two fluted driving rollers, P, P, running in the same direction, as shown by the arrows; and the lap resting in the channel between them is driven by contact, and wound upon the iron rod, R, guided in a vertical groove at each end. For tightening and closing the coils of the lap, the rod, R, was weighted in the former machines by a heavy weight suspended from the ends of the rod, and it was then necessary to lift the whole of this weight at each time of changing the lap; but this is now effected by the friction-brake, S, pressing against a friction-wheel on the shaft, T, on which are pinions gearing into the vertical racks, U, and these racks carry rollers at the top, bearing down upon the ends of the rod, R, in the lap. By this means, as each successive coil is wound upon the lap, the brake, S, slips and allows the lap to rise; and when the lap is completed, the brake is released by a treadle, and the racks are lifted clear by the hand-wheel on the shaft, T, so as to allow the finished lap to be removed. The driving-pin, V, from which the calender rollers, O, receive their motion, is held up in gear by the lever, W, supported by a catch; and when the lap is finished this catch is released by a tappet upon the pinion, X, which is driven from the bottom calender roller, the speed of the pinion being so reduced that one revolution of it corresponds to the size of lap required to be made. The catch being released allows the driving-pin, V, to fall out of gear, whereby the calender rollers, O, are stopped; and the lap rollers, P, continuing to revolve, break off the fleece ready for removing the finished lap from the machine. By changing the pinion, X, carrying the tappet, the size of lap made by the machine can be varied as desired.

The scutcher shown in Fig. 5 is a single machine, and it is usual to pass the cotton first through a double scutcher of similar construction, but having a second set of feed-rollers with beater and wire cylinders, running at a higher speed; the second pair of wire cylinders and stripping-rollers are driven three times as fast as the first pair, so that they deliver a fleece of one-third the thickness first supplied to the machine. Three of the laps from this double scutcher are then fed into the single scutcher shown in the drawing, as at B B B, Fig. 5, being spread upon the surface of the feeding-lattice, A, in three layers on the top of one another, so as to present to the feed-rollers a uniform fleece equal in thickness to that fed into the first scutcher. By thus doubling the laps the fibres are more thoroughly mixed, and the fleece is thereby made more uniform in thickness.

Scutching-machines having a revolving beater composed of two plain bars describing a circle of about 14 in. diameter, were introduced about 1810; and these machines contained also a travelling feed lattice, two pair of feed rollers, and a second travelling lattice for conveying the beaten cotton underneath a perforated revolving cylinder, the interior of

which was exhausted by a fan. The cotton passing through this machine was delivered in a loose fleece; and a few years later a lap machine was added for coiling the fleece into a lap. Other improvements have gradually been introduced up to the present time, as regards both design and workmanship: the cylinders and beaters have been put in perfect balance so as to revolve steadily at the high speed required, and the forms of teeth on the cylinders have been arranged for greater strength and greater facility of construction; stronger and simpler gearing has been employed, improvements have been made in the form and construction of the bearings of the beaters and other quick revolving shafts, so as to ensure more efficient lubrication, and airtight dust-boxes have been added with movable doors for facility of cleaning; and the self-acting arrangements have been introduced for stopping the machine when a given length of fleece has been delivered, and for regulating the rate of feed according to the thickness of the cotton supplied, so as to dispense with the previous plan of weighing the cotton in feeding. Thus by successive improvements through a long series of years the difficulties which originally presented themselves in the successful adaptation of machinery to cotton-cleaning have been overcome; the cotton can now be perfectly cleaned without injury to the fibres, and the laps are produced uniform in length, breadth, and thickness of fleece, and so thoroughly felted that they uncoil at the carding-engine in the next process without any derangement of the felted fleece.

(To be continued.)

PERMANENT WAY ACCOUNTS.

TO THE EDITOR OF ENGINEERING.

SIR,—Your present investigations into permanent way accounts seem to afford a fit opportunity for discussing a practice which has lately obtained, to some extent, among both English and foreign railway companies, viz., that of inserting in their specifications for rails clauses requiring the manufacturer to guarantee for a certain number of years, varying from three to seven, the soundness of the rails supplied, i.e. (quoting from a specification recently issued):

"The manufacturer is to enter into a contract that he will, when called upon by the railway company's engineer to do so, during the time over which this guarantee extends, deliver, free of all charge, at some place to be agreed upon, a new rail, of as good quality and make as those contemplated in this specification, for each rail which shall have become crushed, bruised, broken, or seriously injured on either of its heads, from any cause whatever (accident alone excepted); and, should any rail so supplied in lieu of an injured rail become injured as above described at any time during the continuance of the guarantee, the contractor shall deliver a rail as above to replace it, or, in default, the railway company shall be at liberty to replace it, at the cost of the contractor, with a rail which will fulfil the conditions of this specification."

It is usually understood, but seldom expressed in the specifications, that rails laid between distance signals at stations are exempted from the guarantee.

Now, the "mortality tables" of iron rails given in Mr. Price Williams's pamphlet, and in your articles, are not based upon theory, but upon most carefully compiled returns extending over a great number of years, and they show that, although the average life of iron rails taken all over the kingdom may be from twenty-seven to thirty years, yet that upon the main lines of the Great Northern Railway 5 per cent. of iron rails last only from three to five years, and 50 per cent. last eight years or under, and no doubt the experience of other lines is very similar.

It follows, then, that a manufacturer supplying rails for a main line which are guaranteed for seven years may not unreasonably expect to be called upon during that period to replace nearly 50 per cent. of the rails delivered. Taking the normal cost of the new rails at 77. per ton, and the value of the old rails (after deducting loss of weight and expenses of carriage) at 34., his obligation is equivalent to 35s. to 40s. per ton. But will railway companies pay this extra sum? No. In the face of their own statistics they persuade themselves that a manufacturer can make rails to last almost any given time by bestowing corresponding care upon his work, and think that from 5s. to 10s. per ton is a sufficient premium for the guarantee, while the manufacturer knows the highest premium he can get, and either declines to tender or speculates upon the chances of being called upon to fulfil his obligation.

It is obvious that the liability involved will be estimated by manufacturers lightly or seriously, according to their position and prospects. To directors of limited companies whose business it is to declare present dividends and leave future troubles to their successors, and to managers of concerns where even the beginning of the end is to them apparent, the liability will seem a small matter; while to firms of another class, who are working their own property, and mean "holding on," its money value may be over-estimated.

I confess to viewing this question from the manufacturers' point of view; but from the other side it appears to me equally unsatisfactory. Supposing the value of the guarantee to be correctly appraised, the system benefits neither the railway company nor the manufacturer. As a matter of fact, it is generally estimated at much below its real value; but then ironmasters and iron companies, with these obligations upon them, have failed, and have transferred their works, leaving the railway companies in either case without remedy. Disputes, too, have arisen, which have been difficult if not impossible to settle equitably, and other evils have resulted from the system; and it is within my knowledge that while some railway companies have lately, for the first time, bought guaranteed rails; others which have had some years' experience of its working are abandoning the system altogether.

It seems to me that, in buying guaranteed rails, railway companies make dear bargains, and that, in selling guaranteed rails, ironmasters dabble with the business of an insurance office, and enter upon speculations which should form no part of their legitimate trade.

I am, yours obediently,
London, September 11, 1867. A. G. B.

LITERATURE.

Irrigation in Spain. By J. E. ROBERTS, C.E. Spon.

If we remember rightly, there is a Spanish proverb—and, if not, there ought to be—which says:

Con Agua, Arena, Sol, y Semilla,
El hacer Paraíso, es cosa sencilla;

which may be thus translated:

With Water, and Sand, and Sun, and Seed,
Paradise-making's an easy deed.

Mr. Roberts has put forth a very pleasant little pamphlet, full of valuable information on the general statistics of Spanish irrigation, and which yet reads like a book of travels in lovely lands. And it is especially valuable to capitalists with hoarded wealth seeking for employment and finding none, now that for the time being it is scared away from railways, owing to the dearth of the true business faculty amongst railway managers. The first of all human wants is food, and therefore the production of food is the most certain of all human industries, albeit it may not always yield the largest percentage of profit; but, like all the industries which are either new or have been neglected, food-making offers abundant opportunities for profitable speculation, as well as food-selling. And food-making in sunny climes and healthy atmosphere possesses a charm and stimulus to vitality which can never exist in close factories. Sitting down under the shade of one's own fig-tree is a pleasure the more appreciated the more it is tried; and bubbling water under a bright sky is the sweetest of all music. Cold climates have their charms; but the dwellers under the pine-trees cannot live upon fir-cones, and Spain, Australia, and California give us the finest wheat grain. Spain, Italy, and Southern France are countries for irrigation, as much so as Algeria, and therein the most certain of all mortgages on land would be the erection of irrigation works, giving not only a first charge, but the means of liquidating the mortgage in more senses than one.

The world in the state of wilderness is very beautiful, but in the process of winning it from the wilderness, for the purposes of utility, its beauty may nevertheless be retained. The mountains in all their beauty may be utilised as well as the valleys. In arid Upper Peru the stony hills are scarped into steps by dwarf walls filled in with earth, over which trickling streams, led from the distant snows of the Andes, pass in zigzags and nourish fruit-trees and vegetables, giving shade and greenery that charm the senses amidst murmuring waters. From Valparaiso, in Chili, south to Cape Horn, is a land of rain; north, towards Peru, it is a land of drought; but the snow gives constant streams, which run uselessly into the Pacific Ocean, unless utilised by the hand of man.

Amongst the rich Spaniards ruined by the revolution in Chili was Don José Montes. All his apparent wealth and valuable estates were taken from him, but, in consideration of his becoming a good patriot, he was allowed to remain in the country, and retain a dry valley of considerable extent, which, for want of water, produced nothing useful. He had some hoarded means left; and when peace came, he set to work and cut an irrigation canal of considerable length along the centre of the mountains, to lead the water from a stream flowing from the Andes, a few leagues south of Copiapo. After the lapse of some years, the water flowed over his valley, and enormous crops were produced. But there was no market, for there was no road open to a population, and Copiapo valley supplied its own people; and although a sufficiently good sea-port was at the mouth of the valley, the laws against smuggling, inherited from Spain, prohibited its use. So all Don José could do with his crops was to let the people who grew them eat them, while he had leisure to think.

In the neighbourhood of the valley there was an old gold mine, worked by the early conquerors, but long abandoned, from the usual cause—"se dio en agua"—"it went into water." Therefore Don José set his tenantry to work to dig an adit through the mountain-side to drain off the water. It was done successfully, and the quartz veins were once more laid open, a tropic mill erected to grind the ore with mercury; and the valley was rented out in lots, and the miners were paid wages, and the result of the whole was that a transportable commodity was obtained in the shape of gold. All things went on swimmingly for three years, when *se dio en agua otra vez*—the mine went into water once more: the adit was too high. Poor Don José was at his wits' end; for calculation showed him that cutting a new adit was impracticable. Once more his teeming brain was at work to plan a pump, and it was the most marvellous pump we ever recollect

to have seen. It had thirty-eight buckets, and was worked by animal power. Each bucket held about six gallons, formed of a goat-skin, taken off whole and kept open by internal hoops. It was attached to the shoulders of a man or woman of Red Indian cross, whose business it was to creep down a circular hole (the worked-out mine-vein) about 3 ft. in diameter, and dive into a well, and then ascend through a similar hole to the adit, stoop down to empty the bucket and then descend for more; all the buckets following in succession, each bucket working about two hours' stretch, and constantly bathed in cold water. The mine was again at work, producing gold, and the pumping went on day and night, Sundays and all; and Don José informed us that if by any chance it were stopped for a week it would not be practicable to get the water under again, as he could not increase his pump-power.

Mr. Roberts informs us on the authority of Don Juan de Ribera, that water supply increases the value of land tenfold. Land worth 6*l.* per acre becomes worth 60*l.* when irrigated. There are various means of irrigation, as weirs cross rivers, carrying the water into canals; water-wheels or *norias*, worked by the stream or by horses; wells worked by windmills; reservoirs formed in the hills, and leading down into the hills—a kind of horizontal wells.

Under the town of Gerona there is a large extent of garden land, which is irrigated by a canal from the river Ter. This river also waters many hundred acres of *huertas* which lie between the tower of Toruella and the Mediterranean Sea. These gardens are irrigated by three canals, which were originally made for mill-races, but their owners now derive a considerable revenue from irrigation, although the water is dealt out very sparingly during the summer months, their first consideration being a sufficient supply to keep the mill-stones going. Each canal has a weir constructed somewhat similarly to those on the river Ebro, namely, by heaping a number of large blocks of stone together; and in some cases a rough attempt at pitching appears to have been made. These watercourses are of modern date, and a large amount of money must have been expended on them; for the chief object of the engineer who planned them appears to have been to spare no expense. One canal has a tunnel of over three thousand yards in length, two-thirds of which could have been avoided, for an open cutting would not have exceeded fifteen feet in depth.

We think Mr. Roberts has overlooked the value of a tunnel in saving the water from evaporation. In India it is a common thing to lead water from great distances in artificial underground channels.

The canals in the Rioja always follow the contour of the country, winding and twisting about utterly regardless of the radius or shape of the curves.* The side slopes in cuttings are always very steep, often being less than $\frac{1}{2}$ to 1; and yet they stand very well. Nearly all *barrancos*, or natural watercourses, in Spain, have vertical sides.

The Moorish or Roman engineers who carried out these works must have been practical men. They always, when possible, avoided deep cuttings, and seem to have altogether set their faces against large embankments, as no doubt their experience told them how expensive and treacherous they are. They cared not about long straight and graceful curves, but they followed the contour of the country, and their work, which has served its purpose well, appears to have been done at the least possible cost.

Of course in all countries the natural supply of fresh water must be from the atmosphere in the form of rain or snow. These must be stored up in hill caverns or in spongy bogs, and the snow more or less under the shade of trees, or they will rapidly run away. And the trees are an important means of attracting rain and of modifying the subsequent evaporation by the sun's heat. Irrigation channels should, as far as possible, be covered, for two reasons: first, to prevent evaporation; and secondly, to prevent the growth of weeds. When they cannot be covered, the edges should be planted with trees to afford shade as much as possible.

Irrigation is destined to play a much greater part in the world's future than it has done in the past; not the mischievous flooding, such as that of the Rhône, which puts part of France under water by avalanches of snow from the Alps, when the green forests have been cut down, which sheltered the snow in past times, and made it a perennial supply for a navigable river, and which forests will have to be restored and preserved as the fountain-head of irrigation for lands that lie below them. There are countries of almost continuous rain—such as the archipelago of Chiloe, where irrigation may be dispensed with; but, as a general rule, countries that require draining also require irrigating, none more so than England, when continuous hot weather occurs. The present beautiful greenery

* The fall of these canals is very slight, and consequently the velocity is small.

is owing to the peculiar rains previous to August, almost like artificial irrigation. In the natural condition of the country, the surplus rain of one period of the year is hoarded in bogs and swamps. We are draining artificially, and we shall have to replace those bogs and swamps by artificial reservoirs, whose waters we may distribute at our pleasure.

Years back our Consul in Egypt, Mr. Salt, made experiments in boring for water in deserts of sand, and ascertained that almost everywhere, at from 50 to 100 ft. in depth, there was an under-sand sea of fresh water. The oases are simply low levels where the water crops out, and makes the surface green. Wherever the water can be raised to the surface by means of bored wells, seed sown will produce vegetation, and the shifting sands will be fixed and evaporation checked. It is therefore quite within possibility that the time will come when the Arabian deserts will be reclaimed, and the intense heat of the day moderated, as well as the cold of the night, a large portion of the world's surface gained for human uses, and the climate of Southern Europe rendered more equable in temperature. Meanwhile, we recommend such of our readers as may feel an interest in increasing our food supplies to study the pamphlet put forth by Mr. Roberts.

RECENT PATENTS.

THE following specifications of completed patents are all dated within the year 1867; and that year should be given in ordering them, at the annexed prices, from the Great Seal Patent Office, Chancery-lane.

(No. 48, 8*d.*) Carl Friedrich Claus, of Middlesboro'-on-Tees, patents a method of raising brine from deep bore holes. According to this plan a diaphragm, or cover is fixed air-tight in the bore-hole, either at the top or some distance down it, and through this diaphragm is passed a pipe leading to the bottom of the bore. A second pipe is also attached to the diaphragm, and by means of this second pipe *aërostatic* pressure is applied to the surface of the brine, which is thus forced up the first-mentioned pipe and delivered at the surface. The details of working on this system are fully described in the specification.

(No. 51, 1*s.*) Robert Robinson, of Preston, patents a method of varying the speed of shafting. This consists of an arrangement of friction gearing connecting that portion of the shaft of which the speed is to be varied with that which is driven at a constant speed. Each portion of the shafting carries a friction pulley, these pulleys being of equal size and being both clipped between a pair of friction discs which revolve with their surfaces parallel with the line of the shafting. The two pulleys bear against the friction discs on opposite sides of the centres of the latter: and if the point of the discs upon which they bear are equally distant from the centre, the two portions of the shafting (which are in line with each other) of course revolve at equal speeds. The shafts of the friction discs, however, revolve in bearings carried by a frame which can be moved, by means of a screw, parallel to the shafting, and the centre of the discs can thus be brought nearer to either the one or the other of the friction pulleys, and the speed transmitted from one portion of the shafting to the other varied.

(No. 56, 8*d.*) William Jeremiah Murphy, of Cork, patents making the bore of rifle cannon with three spiral ribs in place of grooves, and fitting the projectiles so that they are carried by these ribs clear of the remainder of the bore of the gun. The substitution of ribs for grooves is not new.

(No. 58, 8*d.*) William Thomas Sugg, of Vincent Works, Vincent-street, Westminster, patents various improvements in the details of apparatus for lighting railway trains with gas. The various points claimed are too numerous for us to describe them here.

(No. 60, 10*d.*) Henry Doulton, of High-street, Lambeth, patents improvements in pottery kilns. The kilns are so far constructed in the usual manner, that the goods to be burned are stacked in a chamber arched over at the top, and having a number of fire-places arranged round it; but the draught from these fires, instead of passing up through the openings in the arched roof of the chamber in the usual way, is caused to pass downwards through a perforated floor, into a flue formed against the exterior of the drying chamber, and leading up to the top of the funnel.

(No. 61, 1*s.* 4*d.*) James Petrie, of Rochdale, patents an arrangement of cut-off gear for horizontal steam-engines, and a form of metallic piston having a solid portion fitting the cylinder combined with expanding part. The arrangement of the cut-off-gear could scarcely be clearly described without reference to drawings.

(No. 69, 10d.) Edward Thomas Hughes, of 123, Chancery-lane, patents, as the agent of Pierre du Rieux and Edouard Roettger, of Lille, an ingenious arrangement of differential pumps, of which we shall probably give an engraving in our next number.

(No. 70, 6d.) Edwin Marcus Chaffee, of Providence, U.S., patents introducing pieces of india-rubber between the plates of ordinary steel elliptical springs, the object being to allow the plates to "play" without rubbing on each other. We much doubt if this plan will be found satisfactory in practice.

(No. 75, 10d.) Isaiah Kendrick, of Walworth, patents an arrangement of movable grate for steam boilers. This grate is formed of a number of blocks of firebars, which are slowly forced along T-iron guides by means of a pushing arrangement placed in front of the boiler. The blocks, on arriving at the inner end of the furnace, pass under a bridge, by which the fuel is stopped, and then fall down into the ashpit, from which they are withdrawn by the stoker to be replaced on the guides at the front of the furnace and again pushed in in their turn.

(No. 76, 10d.) James Howard and Edward Tenney Bousfield patent improvements in their well-known tubular boiler. These improvements, which refer to use of internal tubes for promoting the circulation, and to the method of connecting the vertical and transverse tubes, were described in our account of the boiler on pages 181 and 182 of the third volume of *ENGINEERING*.

ELECTRIC INDUCTION.

In the course of a paper on "The Electric Induction of Mr. Hooper's Insulated Wires, compared with Gutta-Percha Insulated Wires, for Telegraph Cables," read before the British Association at Dundee, Section A, by Mr. William Hooper, the author referred to the relation existing between the different properties of insulated wires arising from induction. He showed by an extensive series of experiments that an intimate connexion exists between the effects of electrification and electro-static induction, and that the penetration of electricity into the substance of an insulator, when measured by the residual discharge, is a function of the electro-static capacity, and not simply of resistance. He has also shown that the effects of electrification are increased nearly in the same proportion as the interior inductive action is reduced.

The results render it extremely probable that in rapid signalling through long circuits, as by "waves," the rate of transmission attainable is not increased or diminished in the simple proportion of the electro-static capacities, but in a ratio compounded of it and the interior resistance to inductive action.

This is a matter of serious consideration, for the interior induction, unlike the surface induction, is not reduced by an increased thickness of insulator, which points strongly to the practical advantage derivable from Mr. Hooper's dielectric over gutta-percha in every respect for induction. These results are verified by Mr. Latimer Clark, Mr. Varley, Professor Sir W. Thomson, and Mr. Fleeming Jenkin.

So much superior is Hooper's dielectric to gutta-percha for insulation, that, taking the core of the electric telegraph cable connecting Ceylon with India as an illustration, at 76° Fahrenheit, the temperature at which cores are tested, it would require a core nearly 2 ft. diameter of gutta-percha to equal .38 in. diameter of Mr. Hooper's insulator (that is, 200 lb. of Hooper's insulator is equal to 576,000 lb. of gutta-percha), the same conductor being used in each, to obtain the same degrees of insulation.

PRESSURE OF FIRE-DAMP IN MINES.

In the Chemical Section of the British Association at Dundee, Mr. G. Ansell gave a very interesting explanation of the "apparatus for indicating the pressure and amount of fire-damp in mines," of which we gave an illustrated description in this journal some months ago. The idea embodied in the machine was founded on the law of diffusion announced by Mr. Graham, that gases diffuse in the inverse proportion to the square root of their densities, or, more popularly, that light gases diffuse more rapidly than heavy ones. Mr. Ansell here showed, by experiment, that when a tube closed at one end by plaster of paris is filled with common coal gas, the lighter part of the compound is rapidly diffused through the plaster, as is at once seen by the yellow flame and slight explosion which ensue on bringing a lighted match close to the closed end. Hence, Mr. Ansell said, his proposition. In a pit the case is the reverse of that of the tube. There the gas is ready to escape into the galleries, and the apparatus must therefore be modified to suit the varying circumstances. The essential parts of the apparatus may be described as consisting of an alarm-bell and a telegraph needle, the former being rung and the latter deflected by an electric current, which is set in motion by the action of the dangerous gas. The means by which this is effected consist of an iron cup, on which is fixed a disc of white Sicilian marble, standing on a U tube, which contains a quantity of mercury. The marble here represents the plaster which closed the end of the tube in the first experiment, and through it the dangerous gas is diffused. As it does so, the mercury is

pressed up into the other extremity of the tube, completes the previously broken circuit, and an alarm is given by the ringing of the bell and the deflection of the needle. When the apparatus is intended to indicate a sudden eruption of gas, marble five-eighths of an inch thick should be used. When there is a slow accumulation of gas, rising to 10 per cent. (10½ being the most explosive), the apparatus detects it, and points out the danger. Again, when it is wished to give warning to a man who had left the pit that gas had accumulated in his absence, marble one-fourth of an inch thick is used, and the danger is indicated as before. Mr. Ansell stated that he had used the instrument in the Monkland pits at Airdrie, where it had been also used independently by Mr. Mowie, with results a statement of which was handed in, but not read. He mentioned, however, an incident, interesting as showing the value of the apparatus. It had been fitted up in the upper part of a gallery where Mr. Ansell and Mr. Mowie were unable to detect any gas. The instrument gave the alarm, and Mr. Ansell remarked that in this case it must be incorrect; but on elevating a light into the upper current, an explosion followed, showing that gas had indeed been there. Mr. Ansell went on to say that when gas was known to be present, it was of great importance to learn whether the percentage is increasing or diminishing. This he has accomplished by means of a modification of the aneroid barometer. Mr. Ansell thought that he would be able to improve his apparatus by substituting such a corrugated metallic chamber as that in the aneroid for the column of mercury which was used to make connexion between the poles of the battery.

Professor Anderson believed that this was the first attempt to apply the law of diffusion to practical purposes, and it was certainly of the highest importance. In the hands of workmen delicate apparatus was apt to be misused, and this was the only ground for fear.

Mr. Ansell replied that Mr. Mowie had put the apparatus into the hands of workmen who had found not the slightest difficulty in using it.

This Professor Anderson regarded as most satisfactory. Mr. Bell, Newcastle, feared that the very nature of the work of a colliery, which would necessitate the perpetual movement of the apparatus, might impede its use by the workmen; but thought that, in the hands of the coal viewers, it might be turned to good account, as the accidents most feared by coal-owners were those in which the atmosphere of a whole gallery or a portion of one is polluted. This apparatus might be applied to prevent such wholesale catastrophes.

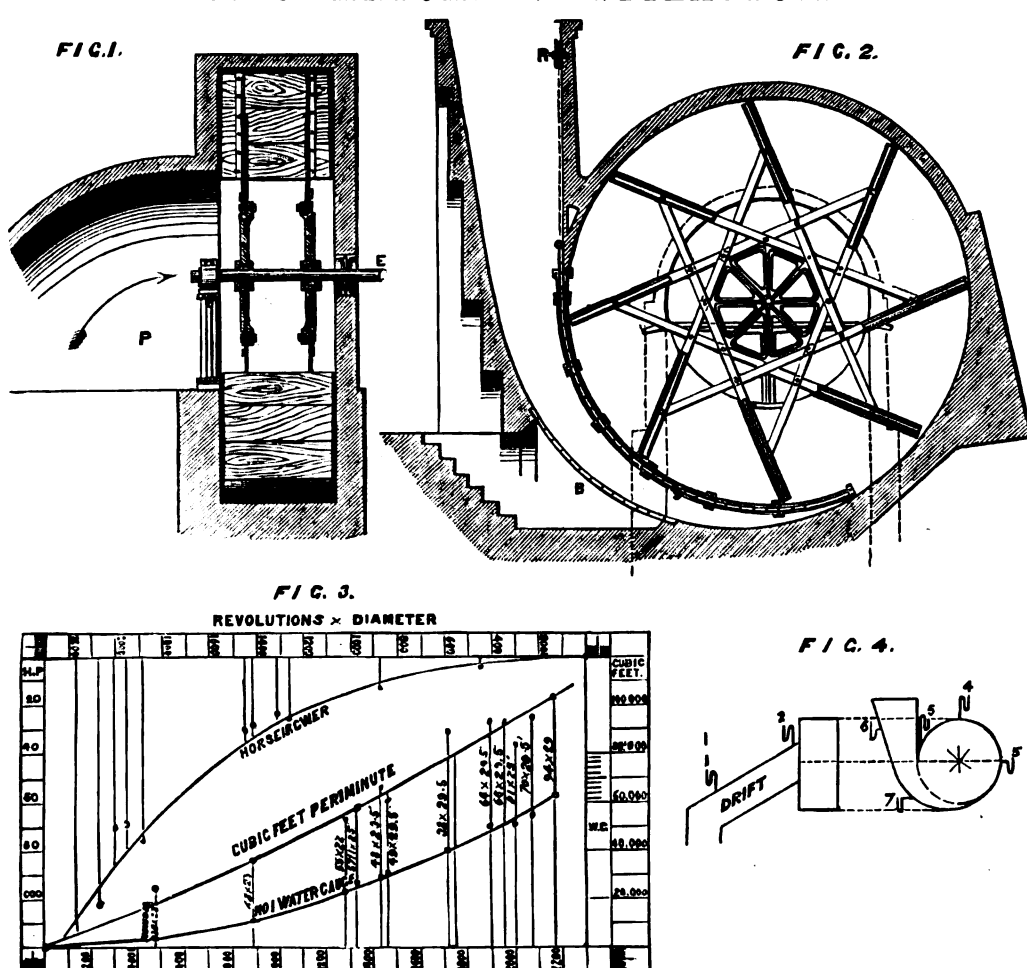
ROLLING THE 15 IN. PLATE.

THE plate was not quite ready at the time appointed, and during the short interval of delay the works were inspected. It is almost impossible to describe the aspect of Cyclopean activity which they presented. The huge space of lofty workshops, covering more than 23 acres of ground, were, above, all dim with smoke, below, all dazzling with the blinding glare and heat of furnaces. Everywhere ponderous flywheels were spinning round with a loud hum through the gloom, everywhere steam-hammers were falling with a shock upon the solid earth that made the walls vibrate, and people near them jump under the tremendous concussion. No place seemed free from steam or flame or melted iron. The dark nooks would suddenly become bright as furnace doors were lifted and emitted their long light-looking flames of dazzling white vapour, and disgorged a mass of seething metal, which men, almost clad in light steel armour, wheeled away and shot under the steam-hammers, the first stroke of which sent jets of melted iron rushing in trains of fire like meteors in all directions. Sometimes one came on groups of men who were saturating in water the rough bands of sack-ling in which they were enveloped before going to wrestle with some white-heat forging, sometimes on men nearly naked, with the perspiration pouring from them, who had come to rest for a moment from the puddling furnaces, and to take a long drink of the thick oatmeal and water, which is all that they venture on during their labour, and which long experience has proved to be the most sustaining of all drinks under the tremendous heats to which they are subjected. On every side the glare, the smoke, the din, and steam are alike deafening and blinding. On every side are masses of melted iron running down troughs, or great blocks of it heated to a glow that is almost melting being welded and knocked away in myriads of sparks and jets of refuse under the blows of the hammers. Most uncomfortable of all are the slabs of armour-plate and blocks of steel ingots which, half cooled, and of a dull slate colour, lie about everywhere. From those in a bright, red glow the visitor can guard himself, for he sees them; but from those which are partly cooled, but yet hot enough to scorch the flesh from the bones when closely approached, there is little safeguard, as one hurries out of the way of seething puddle blooms or open furnaces, which diffuse such an intense general heat around that little extra warning is given by the treacherous masses of half-cooled slabs till the danger is almost too near to be avoided. After seeing and suffering under seeing such scenes, the visitors were conducted to the armour rolling-mill, where the monster plate was to be drawn. The process of drawing it is simple, but peculiar. The plate, when laid in the furnace, rests upon little stacks of fire-bricks, so that the flame and heat plays equally round it, till all is glowing white, and the successive layers have settled down into one

dense mass. A great deal of the success depends upon the time at which the plate is drawn and the amount and length of time to which it is to be heated. All this is regulated by the chief roller and chief furnace-man, who are paid wages which many eminent professional men might envy—wages amounting from 1200*l.* to sometimes 2000*l.* a year. On Friday, as the time for "drawing" approached, these officials opened the furnace doors, and, approaching close to them with only the shelter of a lump of wet rag held loosely before their arms and faces, peered into the blinding glare from time to time with as much care and apparently as much indifference as if they were looking into the tube of a telescope. Suddenly, at a signal from the furnace-man, the bands of workmen, to the number of about 60, arranged themselves on each side of the furnace, as near to it as they could bear the heat. Then the doors were opened to their fullest, and what had been a glare before and what had been a heat were quite eclipsed by the intense light and fervency with which the long tongues of flame leapt forth. In the midst of this great light lay a mass even whiter than the rest. To this some half a dozen men drew near. They were all attired in thin steel leggings, aprons of steel, and a thin curtain of steel wirework dropping over their faces like a large long visor. All the rest of their bodies were muffled in thick wet sack-ling. Thus protected they managed, with the aid of a gigantic pair of forceps slung from a crane above, to work as it were amid the flames for a few seconds, and to nip the huge plate with the forceps. The signal was then given, and the whole mass of iron, fizzing, sparkling and shooting out jets of lambent flame, was by the main force of chains attached to the steam rollers drawn forth from the furnace on to a long wrought-iron car. The heat and light which it then diffused were almost unbearable in any part of the huge mill, but the men seemed to vie with each other to approach and detach the colossal pinchers which had drawn the iron forth. More than a dozen attempts were made on Friday before this was effected, and more than a dozen of the best and most skilful workmen were driven back one after another by the tremendous heat and glare. At last all was made clear. The forceps, then red-hot from their grip of the plate, were drawn away; the chains cleared from the rollers, and, with a great hurrah, the other workmen seized the chains attached to the iron truck, and drew it to the incline by main force, where it was left by its own weight to run into the jaws of the rolling-mill. It was then *saute qui peut* among the workmen, who rushed for shelter in all directions as the mass was nipped between the rollers, and wound rapidly in amid quick reports like those of dull musketry, as the melted iron was squeezed by the tremendous pressure out of the mass, and flew out in jets of liquid fire on all sides. In spite of all the care and all the skill which the best workmen can use on these occasions, they cannot always escape the splashes of melted iron, and the burns inflicted are numerous and often severe. The turning of the rollers crushes the plate through to the other side, where it rests for a minute on a wrought-iron truck similar to that on which it was brought from the furnace. The action of the rollers is then reversed after they have been by the action of screw levers brought closer together by about an inch. These again nip the plate and drag it back in an opposite direction, and again and again does the mass go forward and backwards, each time passing between a smaller space between the rollers, till, as on Friday, the whole of the huge thickness was reduced to a compact mass 15 in. thick, in less than a quarter of an hour. During every stage of the process, quantities of fine sand are thrown upon the plate, and this literally takes fire as it touches the flaming surface, and covers it as it melts with a coat of silica, or with a glaze like that of earthenware. After every discharge of sand, and these go on almost incessantly, buckets of water are thrown upon the plate and explode in clouds of scalding steam, and when these are partly dissipated men rush forward, and with wet besoms with handles 20 ft. long sweep off whatever little scraps of oxidation may have taken place. Thus every time the plate passes through the mill the sand is scattered, the water thrown, and the surface swept, and at every roll the chief roller of the establishment runs forward, and, under the shelter of wet cloths, measures with a gauge its thickness from end to end. On Friday the required dimensions were obtained, as we have said, by less than a quarter of an hour's rolling, and a plate 15 in. thick, the product of the labour of nearly 200 men and of the consumption of nearly 250 tons of coal, was shot out by the rolling-mills and left to cool. When this had been effected two large rollers of iron, each weighing 15 tons, were placed upon it by the cranes, and moved slowly backwards and forwards, and, eventually, as the plate cooled, were left upon its ends to keep the whole perfectly level. Nothing further now remained in order to complete it as the finest specimen of armour-plate manufacture ever attempted but to plane off its rough ends and edges. The flat surfaces on either side, which form what is called the skin of the plate are never interfered with, for the action of the steel rollers leaves them literally almost as smooth as plate glass.—*Times*.

UTILIZATION OF TOWN SEWAGE.—At a recent meeting of the Liverpool Town Council, a recommendation of the finance committee to subscribe for 500 shares of 10*l.* each in the Liverpool Sewage Utilization Company (limited), on consideration that satisfactory proof is furnished that the amount of other subscriptions with this sum is sufficient to execute the first portion of the works, was adopted.

MECHANICAL VENTILATION.



THE following paper by Mr. G. Cope Pearce, of Cyfarthfa, was read at a recent meeting of the South Wales Institute of Engineers, and its importance induces us to transfer it to our columns:

We all agree that the health and the safety of the men engaged underground depends in a great measure upon their having a plentiful supply of fresh air; but the best method of effecting this has not yet been determined. Some persons advocate the furnace, while others prefer mechanical ventilation; and it is our duty to ascertain, to the best of our ability, which is the best. You all know the merits of a furnace, its beautiful simplicity, and so forth, much better than the writer can tell you. On the other hand, it can be said that in many cases mechanical ventilation will be found superior in overcoming friction where the drag is very great, and in economy; however, we cannot shut our eyes to the fact, that no matter how well a machine is made, still, after all, it is liable to stop unexpectedly. If this should take place, what will become of the men underground? How long would they live with the ventilation stopped? Could they be withdrawn before the air got too foul to support life? You are better able to answer these questions than the writer is, and he hopes they will provoke a discussion as to whether the men, in the case supposed, would actually be in danger or not.

There can be no doubt that if machinery is used for ventilating, we ought to lessen the chance of stoppage, by making it with as few moving parts as possible, for which reason the writer is decidedly against all kinds of reciprocating machines, composed of pistons, tanks, beams, spur-wheels, cranks, numerous flaps, and so forth. The only machine, in his opinion, likely to have the least chance with the furnace is the fan; but it ought to be made very large, so as not to require the engine to work at too great a velocity.

Shallow upcasts are sometimes found insufficient, and it is a common practice to build stacks on the top to increase the draught; but as the quantity of air passing only increases with the square root of the depth, the ventilation will not be increased to any great extent by adding a stack, without it is built much higher than is the common practice, and thicker also to retain the heat. In a situation of this kind a fan is likely to be useful, and there are cases where a fan can be applied, but where a furnace would be quite out of the question.

It would be useful if we could have a formula by which to calculate beforehand what quantity of air a fan, moving at a given rate, would be likely to draw from a mine; but the drag varies so much from local causes, that if we can calculate near enough to give a rough guess, it is as much as we can reasonably expect. If we take the case of a fan 20 ft. diameter, going 40 revolutions per minute, with an area of orifice of 30 square ft., not applied to a mine, but

simply employed to displace air; then supposing there is no "slip," or that the discharged air moves at the same rate as the extremities of the vanes, the power required, height of water gauge, and so on, can be found in this way: The velocity of the ends of the vanes will be 41.888 ft. per second, or 2513.28 ft. per minute; and this multiplied by 80 ft. area of vent, or orifice, gives 75,898.4 cubic ft. of air per minute, or 6031.872 lb. per minute—taking a cubic foot of air at .08 lb. We must next find how far a heavy body must fall to acquire the velocity of 41.88 ft. per second, which is 41.888² or 27.27 ft. for the height due to the velocity. If 27.27 is multiplied by 6031.872, the weight of air displaced, and divided by 83,000, it will give 4.98 for the horse power expended.

If the height due to the velocity is multiplied by the weight of a cubic foot of air, it gives the pressure per square foot in pounds, or 2.1816 lb., and this divided by 5.2 gives a water-gauge of .419 in.

If the quantity of air in cubic feet per minute is multiplied by the water-gauge, .419 then by 5.2, and the product divided by 83,000, it will give the useful effect or power existing in the air, which in our theoretical case will be 4.98 horse power, the same as before; but in practice this calculation is made from the quantity of air and water gauge, taken experimentally; and by comparing the power so obtained with the indicated horse power of the engine, we can estimate the duty done by the machine.

The writer has given the usual calculations, as above, for a theoretical fan, because it shows the rationale of the matter; but it is rather round about, so he has, by dividing the constant numbers, transposing, and so forth, reduced it so as to give the same results as before, but with fewer figures, thus:

$$\begin{aligned} & (\text{Revolutions per minute} \times \text{diameter in feet})^2 \times .0000426 \\ & = \text{height due to velocity in feet,} \\ & (\text{Revolutions per minute} \times \text{diameter in feet})^2 \times .000008408 \\ & = \text{lb. per square foot.} \\ & (\text{Revolutions per minute} \times \text{diameter in feet})^2 \times .000000655 \\ & = \text{water-gauge in inches, A.} \\ & (\text{Revolutions per minute} \times \text{diameter})^2 \times .00000000324 \times \\ & \text{area of orifice} = \text{horse power for slip, O.} \end{aligned}$$

If the orifice in our theoretical fan was reduced from 30 square feet to 15.36, the rate of the engine would increase from 40 to 50 revolutions per minute, the quantity of air would decrease to 48,255 cubic feet per minute, and the water-gauge would alter from .419 to .655, while the power required would be 4.97, the same as before. This is something like what takes place when the passage of air is obstructed by the friction of a mine; but, in practice, the quantity of air displaced is less than the theoretical quantity, owing to the vanes slipping through the air.

Before we can tell what quantity of air a fan is capable

of drawing in practice, we must know how much to allow for "slip;" but this cannot be done to a nicety, for you will see by the experiments that the per-centage of power utilised varies, even when the velocity of the fan remains the same; and we have a still more uncertain and difficult matter to make out, which is the friction of the air in passing through a mine. The only information the writer has been able to get on this point is from a paper read by Mr. Atkinson, inspector of mines, published in the Transactions of the Manchester Geological Society, March 25th, 1862. It is therein stated, that for every square foot of rubbing surface exposed to the air, and for a velocity of 1000 feet per minute, the friction is equal to a column of air .26881 feet high, of the same density as the flowing air. Calling this the co-efficient of friction, the formula given by Mr. Atkinson for the friction of mines is this:

$$P = \frac{KSV^2}{A}$$

where P = Pressure per square foot.

A = Sectional area in square feet.

S = Rubbing surface in square feet.

V = Velocity of air in thousands of feet per minute.

K = Co-efficient of friction in the same terms as P is taken in.

The density of the air will vary with the temperature and height of barometer; so in the above calculation the weight of a cubic foot of air must be taken by this formula:

$$\text{Cube foot of air in pounds} = \frac{1.3253 \times \text{inches of mercury}}{459 + \text{temperature.}}$$

Atkinson's formula is, no doubt, as correct as practicable, but the writer does not see how we are to measure the rubbing surface of the colliery with anything like certainty; and without we can do this, we must not expect to get an accurate result. If the drag in pounds per square foot could be found with a tolerable degree of exactness, we could then tell nearly what a fan could do; for the theoretical pressure per square foot, calculated from the speed of the fan, agrees very nearly with the pressure taken experimentally by a water-gauge.

Our formula for the pressure per square foot caused by the fan is only calculated for a constant density, and will, therefore, not be strictly correct if used in conjunction with Atkinson's formula, which is corrected for temperature and height of barometer. This error is hardly worth taking into account in a rough calculation, but, if necessary, it can be done by applying the correction to our formula, which will then become this:

$$(\text{Revolutions per min.} \times \text{diam.})^2 \times \frac{.000056457 \times \text{in. merc.}}{459 + \text{temperature.}}$$

pounds per square foot nearly for the force of fans when uncovered. If the efflux of air from a fan with a casing is obstructed, instead of the speed of the engine falling off, the fan has, in fact, less work to do, and the engine increases in speed till the power is balanced by the increased resistance of the air, due to that increased speed. If the orifice or vent is shut altogether, the fan can only whirl the air round in the casing, and will require little or no power to turn it. If the entrance into a fan is partially closed, the engine will in this case likewise increase in speed; but in practice this only takes place to a certain extent when the circumference is left open, for it is found that when the entrance of the air is obstructed by the friction of a mine, the air at the ends of the vanes will form eddies, and some of it will return to supply the partial vacuum at the centre of the fan. In this case, although the quantity of air passing is lessened, still the air brought back by the eddies must be thrown out again continually by the vanes, and considerable power will thus be wasted.

It would seem likely at first sight that a fan left open at the circumference would discharge air to better advantage than when enclosed, but if, by enclosing it, the air is discharged at a higher velocity, its return is prevented, and although the force due to the velocity of the discharged air is lost, yet this is found to be less waste of power than if the vanes are allowed to battle with the eddies.

As there is a loss in discharging the air at a high velocity, the aperture ought only to be contracted just enough to prevent the return of the air, and no more. This can only be done by experiment, and to get the greatest effect it is therefore necessary to have means of altering the area of the orifice.

By discharging the air into a chimney it can be used in some measure as a jet, and this, it is said, will utilise some portion of the force that would otherwise be lost by the velocity of the efflux. Volume XIV. of the Transactions of the North of England Institute of Mining Engineers, contains a description by William Cochrane of an enclosed fan, named from the inventor a Guibal's ventilator. It is working at Elswick Colliery, and from the experiments given you will be able to see what it is capable of performing. The writer has also obtained information from Mr. William Armstrong as to a similar machine in use at Pelton colliery.

A fan of this description is shown at A, where P is the opening communicating with the pit, and the engine is applied to the shaft at E. The masonry of the fan is not connected with the pit exactly as it is drawn, but ought to be placed at the end of a short drift, and the top of the pit covered by boards or light plates, to act as a safety-valve in case the gas should fire up the pit. At S is a shutter sliding in grooves, which can be drawn up or lowered by means of a chain passing over a small sheave, R, in the

chimney, so as to increase or diminish the aperture through which the air is discharged. At B are boards, which can be removed when necessary to give room for repairing, or examining the vanes.

The dimensions of the Elswick fan are as follows: Diameter over the vanes, 23 ft.; width, 6 ft. $\frac{3}{4}$ in.; centre opening, 10 ft.; clearance between the vanes and the walls, 1 in.; and the outer edge of the vanes, 2 in.; length of vane, 8 ft.; vanes made of oak, $\frac{1}{4}$ thick; cylinder of steam engine, 23 $\frac{1}{2}$ in. diameter; stroke of piston, 19 $\frac{1}{2}$ in. The results obtained by this ventilator are shown in Table B. The water-gauges given at the right-hand side show the amount of exhaust at various points inside the casing, where a partial vacuum is formed. The numbers over the water-gauges refer to sketch C, and the different positions where the water-gauge was tried are there pointed out. In the column headed "Position of Shutter," O denotes the lowest position of the shutter; S and I the highest or greatest opening. The column of useful effects is the number of cubic feet of air per minute multiplied by the water-gauge, then by 5.2, and divided by 33,000, as before described; and by comparing this with the indicated horse power of the engine, the two last columns of per centages are obtained. The other columns speak for themselves, and need no explanation.

At D are the tabulated results of experiments tried with the fan at Pelton colliery, the dimensions of which are these: diameter over vanes, 29 ft. 6 in.; breadth, 9 ft. 10 in.; centre opening, 13 ft. $\frac{1}{2}$ in.; height of chimney, 26 ft. 6 in. above the centre of the fan; area at the top of chimney 9 ft. 10 in. by 8 ft. 2 $\frac{1}{2}$ in.; cylinder of steam engine, 23.6 in. diameter by 23.6 in. stroke.

You will, no doubt, notice that the experiments are rather contradictory; this, however, is what we must expect, for the drag of the air is variable, being altered by the opening of doors and various other causes, which will alter the quantity of air drawn, even when the speed of the fan is constant. The water-gauge in the experiments is greater than the theoretical one, and only applies to fans uncovered. This is said to be owing to the chimney utilising a portion of the force existing in the discharged air; but whatever the cause may be, the fact is proved by experiment.

At Tursdale colliery there was an uncovered fan, and a temporary casing with a chimney was added, with this result:

Revolutions per min.	Cub. ft. of air.	W.G.	Stm.	Coal per 24 hrs.
Uncovered ... 50	22170	55	25	5 tons
With a casing and chimney 50	32980	.9	25	4 tons

At Pelton colliery, the boards, B, at the bottom of the chimney were removed, when the rate of the engine fell off from 55 revolutions per minute to 52, the water-gauge decreased from 1.77 to 1.62, and the rate of the anemometer changed from 780 to 745.

The experiments are contradictory, therefore it is useless to take any one of them for a standard, but we have a good many, and we can lay them down in the form of a diagram, such as E, where the horizontal scale represents the number of revolutions multiplied by the diameter of the fan. The dots on the vertical lines represent the cubic feet per minute, and the water-gauge at No. 1 station, as given by the experiments. If we now find the rate of increase of curved lines that shall pass near to the dots, we shall be able to calculate in a rough way the effects of any fan, when applied under similar circumstances, and can form a Table like F.

The easiest way to do this is to use a table of logarithms, and the above quantities were calculated thus:

Log cube ft. = 1.1 (log revolutions per minute + log diameter) + 1.35267, B.

Log water-gauge at No. 1 station = 1.8 (log revolutions per minute + log diameter) - 5.5044, C.

Water-gauge at No. 2 station = (revolutions per minute $\times$ diameter)² $\times$.000006953, S.

Horse power including back pressure = cubic feet per minute $\times$ water-gauge $\times$.0003329, D.

Horse power transmitted to fan = cubic feet per minute $\times$ W.G. $\times$.000291.

The curves were fixed upon after several trials, as being the nearest to suit all the circumstances; and we thus find that, according to the experiments, the quantity of air drawn increases a little faster than as the velocity of the vanes, and the water-gauge at station 1 rather slower than as the square of the velocity; but the experiments indicate that the water-gauge at station 2 increases with the square of the velocity very nearly. The formula for cubic feet per minute is only intended to find the rate of increase in the experiments, and is not applicable to all cases, because the quantity of air drawn is governed in a great measure by the drag, which varies in different collieries, and it is therefore impossible to form a general rule of any value.

It will be seen at Table F that the calculated water-gauges are near enough for practice, and although we cannot find the absolute quantity of air in every case answering to a given speed, yet we can get the rate of increase nearly; and if we know the amount of ventilation in any colliery, with the water-gauge answering to it, we can then give a near guess at the speed of fan necessary to draw that amount of air, or any other amount in that particular colliery.

B										ELSWICK.									
No. of Experiment.	Revolutions per minute.	Position of Shutter.	Indicated Horse-power.	H. P. transmitted to Fan.	Cubic Feet of Air per minute.	Water Gauge at Station 1, in Inches.	Useful effect in H. P.	Calculated useful effect per cent on the whole power applied.	Calculated per cent useful effect of power transmitted to Fan.	Water Gauge at Stations on Sketch C.									
										No. 1.	No. 2.	No. 3.	No. 4.	No. 5.	No. 6.	No. 7.			
1	20	1	2.59	1.99	24,123	.200	.76	29.34	38.2	.2	.125	.100	.05	.025	.0	.03			
2	38	1	9.94	8.37	38,487	.600	3.04	36.63	43.5	.6	.55	.25	.125	.100	.25	.15			
3	38	1	10.02	8.81	39,883	.550	3.45	34.43	39.1	.55	.50	.20	.075	.100	.25	.125			
4	39	9.72	7.80	36,504	.500		2.88	20.63	37.0	.50	.45	.15	.025	.05	.25	.135			
5	39	8.21	6.85	29,641	.250		1.17	14.26	17.1	.25	.100		.375	.5	.2	.250			
6	41	0	7.63	6.00	23,469	.100	.37	4.85	6.2	.10	.0	.400	.47	.15	.02	.065			
7	55	1	29.84	20.94	56,378	1.200	10.66	44.71	59.9	1.2	1.10			.30	.05	.20			
8	55	not given	...	...	56,995	not given	...	...	...	...	...	...	...	...	...	...			
9	57	1	23.33	19.73	60,441	1.400	13.33	52.40	67.56	1.4	1.35	.50	.325	.35	.05	.31			
10	87	1	69.96	58.16	85,544	2.550	34.37	49.13	59.10	2.55	2.5	1.0	.650	.675	.10	1.2			
11	94	1	not given	...	104,943	3.150	52.09	...	...	3.15	3.2	1.15	.900	.80	.125	1.3			

F																			
Revolutions.	Diameter of Fan.	Horse-power including back pressure experiment	Horse-power by formula D.	Cubic Feet of Air per minute. Experiment.	Cubic Feet of Air per minute, by formula B.	Water Gauge at Top of Drift No. 1. Experiment.	Water Gauge at Drift No. 1, by formula C.	Water Gauge at entrance of Fan No. 2. Experiment.	Water Gauge at entrance of Fan No. 2, by formula S.	Theoretical Water Gauge, by formula A.									
20	23	2.59	1.22	24,123	19,129	.2	.194	.125	.147	.1386									
38	23	9.94	7.86	38,487	38,755	.6	.617	.55	.531	.5003									
48	29.5	26.5	31.859	67,582	65,893	1.5	1.47	1.65	1.394	1.313									
49	29.5	28.8	33.82	61,145	67,405	1.55	1.526	1.65	1.453	1.368									
55	23	23.84	22.97	56,378	58,204	1.20	1.204	1.1	1.113	1.048									
57	23	23.53	25.80	60,441	60,829	1.4	1.29	1.35	1.205	1.135									
64	29.5	75.85	73.37	95,385	90,422	2.55	2.468	2.77	2.478	2.334									
66	29.5	69.95	80.22	94,545	93,534	not given	2.608	3.0	2.635	2.482									
70	29.5	103.69	95.15	96,793	90,789	2.75	2.9	3.0	2.965	2.793									
87	23	69.96	86.8	85,544	96,386	2.55	2.74	2.5	2.784	2.622									
94	23	not given	108.6	104,943	104,943	3.15	3.1497	3.2	3.250	3.061									

D PELTON.

Two Seams Ventilated.																			
No. of Experiment.	Revolutions per Minute.	Position of Shutter.	Horse-power, including back pressure.	Horse-power, excluding back pressure.	Cubic feet of Air per minute.	Water Gauge at entrance to Fan.	Water Gauge in Drift.	Water Gauge in Mine.	Power in Air at entrance to Fan in H.P.	Per-centage of Power utilised, including back pressure.	Per-centage of Power utilised, excluding back pressure.	Pressure of Steam on Piston, lb. per square inch.	Back Pressure.						
1	48	1	...	...	72,521	1.70	1.55	1.42	19.427	...	...	...	...						
2	53	1	...	...	91,529	2.70	2.50	...	38.941	...	...	...	...						
3	64	1	...	...	95,346	3.00	...	...	45.073	...	...	...	...						
4	64	...	70.91	61.27	96,488	2.70	...	...	41.051	57.89	67.00	21.190	2.88						
5	64	...	68.10	58.18	106,802	2.80	...	...	47.122	69.20	80.99	20.350	2.965						
6	64	...	68.07	61.29	91,147	...	...	1.70	...	...	...	20.340	2.025						
7	64	...	71.33	61.02	91,147	2.72	2.58	...	39.066	54.77	64.02	21.315	3.080						
8	64	...	82.56	69.81	99,180	2.78	2.55	...	43.438	52.61	62.22	24.670	3.810						
9	64	...	83.06	75.88	96,488	2.75	2.60	...	41.811	50.34	55.10	24.820	2.145						
10	64	...	87.01	78.27	86,576	2.70	2.50	...	36.834	42.33	47.06	26.000	2.610						
11	70	...	107.64	93.72	98,778	3.00	2.75	...	46.695	43.38	49.82	29.410	3.805						
12	70	...	99.74	86.11	94,809	3.00	2.75	2.60	44.819	44.92	52.04	27.250	3.725						

One Seam only Ventilated, Z.																			
1	48	1	26.222	23.864	62,645	1.65	1.50	...	16.241	61.94	68.06	10.34	0.93						
2	49	1	28.849	25.39	62,620	1.65	1.55	...	16.281	56.43	64.12	11.26	1.35						
3	49	1	28.542	25.52	59,671	1.65	1.55	...	15.514	54.36	60.80	11.14	1.18						
4	48	1	26.529	23.442	56,400	1.60	1.50	...	14.664	55.27	62.56	10.57	1.23						
5	48	1	23.643	21.453	55,550	1.50	1.45	...	13.180	54.64	61.19	9.42	0.87						
6	47	0	22.005	19.273	49,578	1.425	1.375	...	11.133	50.59	57.76	8.86	1.10						
7	66	1	67.950	60.151	67,237	3.150	...	...	33.374	49.11	55.48	19.69	2.26						
			Moving anemometer		62,984	...	...	...	31.263	46.01	51.97	...	...						
8	66	1	...	60.151	94,545	3.07	...	...	45.787	52.01	64.56	25.48	4.95						
9	64	1	...	...	...	3.00	...	...	...	...	...	...	...						

The anemometer was fixed in all the experiments except No. 7.

The formula for horse power is only the power in the air as before described, increased by the average amount of all the percentages given in the experiments.

The economy of a fan as compared with a furnace, depends upon the depth of the upcast. Where pits are shallow, a fan requires far less coal, and that of an inferior quality; but there are cases where the quantity of coal saved will not pay for the increased first cost and working expenses.

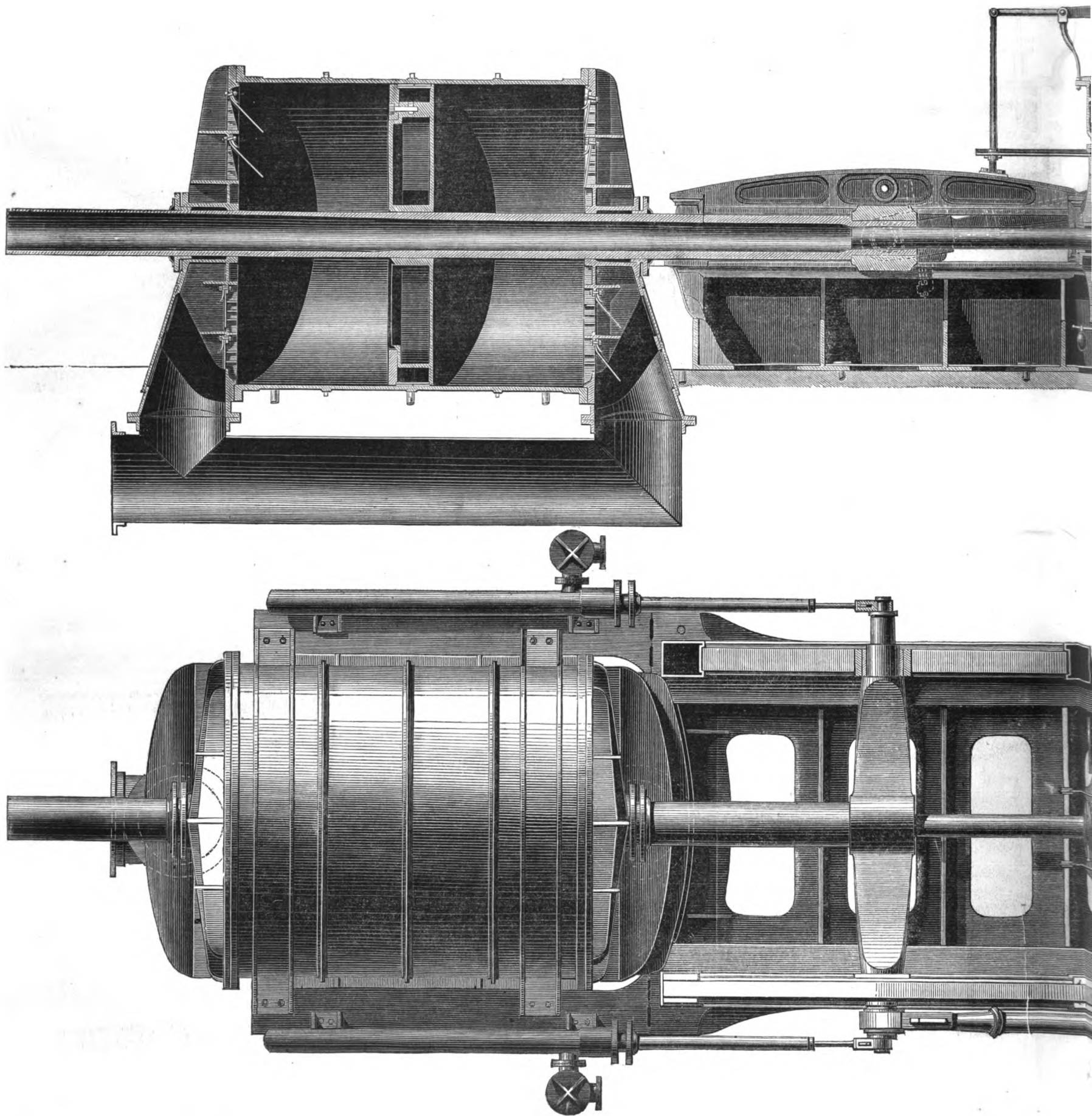
Previously to the erection of a fan at Pelton colliery, the ventilation was effected by furnace. The upcast pit was 112 yards deep by 7 ft. 6 in. diameter. The quantity of air obtained by .9 in. water-gauge was 31,000 cubic feet, and the consumption of coal about seven tons in twenty-four hours.

If this upcast had been larger, the duty of the furnace would perhaps have been higher; however, supposing that it had been as much as 55,000 cubic feet per minute, the experiments show that, to do this with a fan, an engine of only 23.6 horse power would be necessary, which would consume about two tons of coal per day instead of seven; so there can be no doubt as to the superior economy of the fan in this case, as regards the consumption of coal.

In cases where the fan consumes less coal than the furnace, before we can tell which is the most economical, we must determine the cost of coal at the furnace underground and the cost of small coal on the surface.

Furnaces are generally supplied from coal left underground for that purpose, and some viewers think this coal ought only to be charged at what it actually costs to deliver it to the furnace; but others maintain that it is as valuable as other coal, and that by using it you lose what could be got by

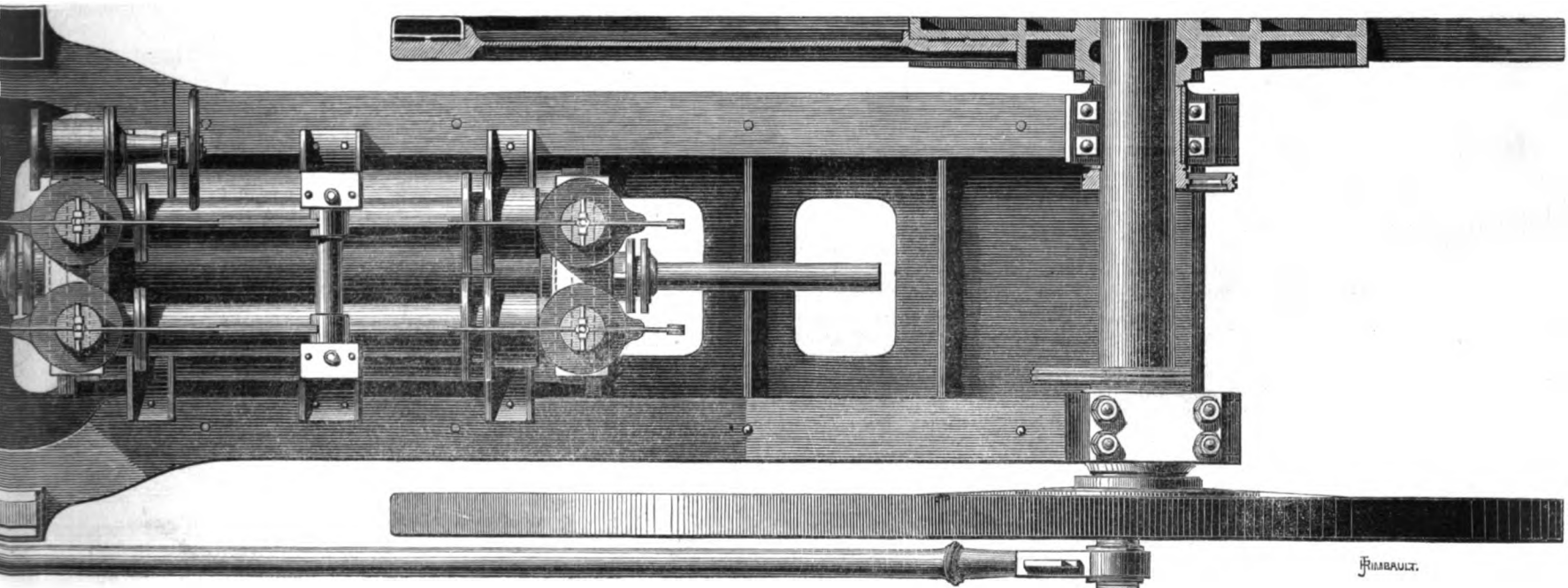
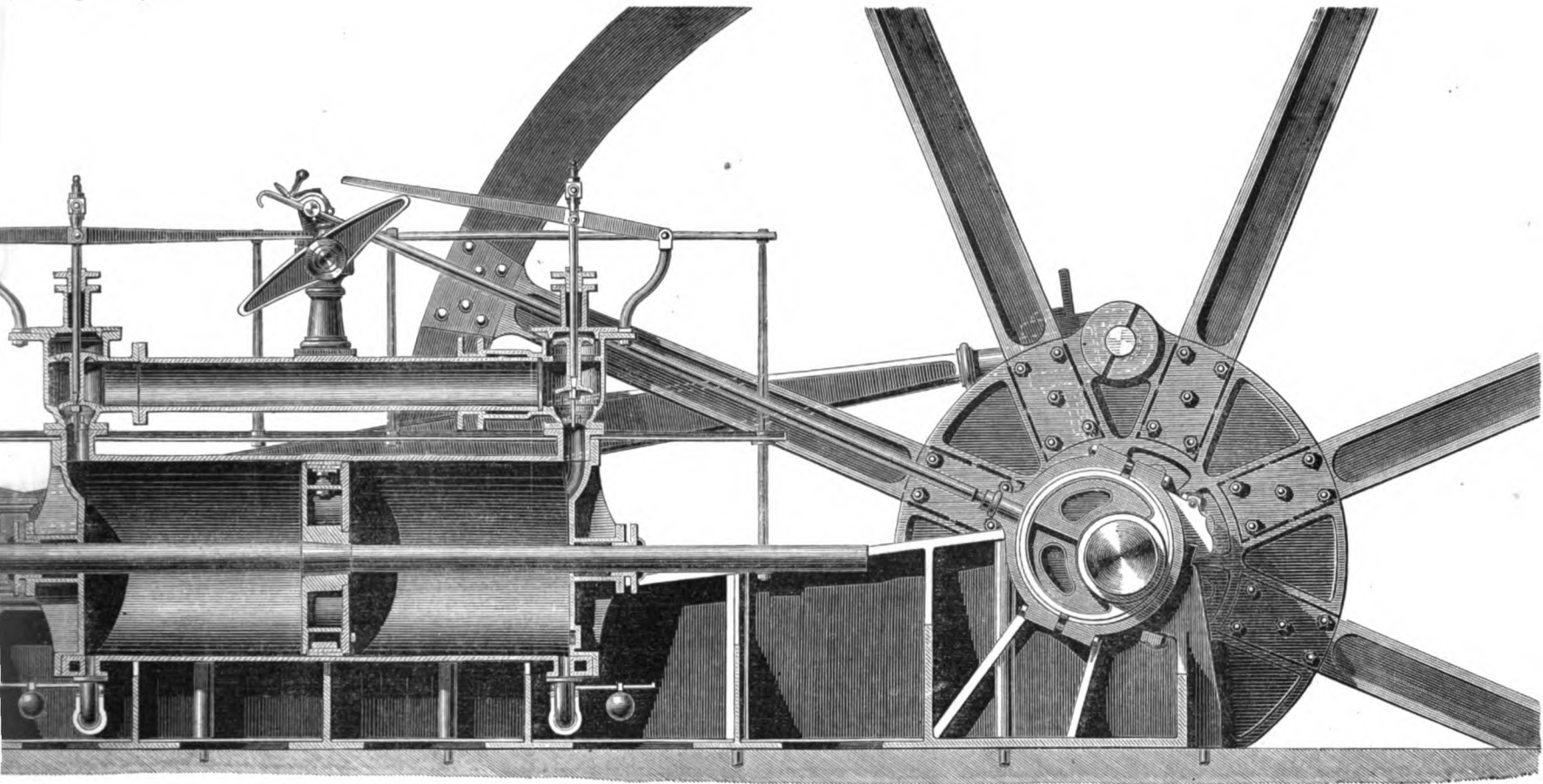
HORIZONTAL BLOW
CONSTRUCTED AT THE WEST-POINT FOUNDRY, U.S.
(For Description, see



OWING-ENGINE.

U.S.; CAPTAIN ROBERT P. PARROTT, ENGINEER.

(See Page 227.)



HORIZONTAL BLOWING-ENGINE.

THE subject of our two-page engraving this week is a horizontal blowing-engine arranged on a plan which has been adopted for numerous sets of blast machines for smelting furnaces constructed, during the last few years, by the West Point Foundry, State of New York—works of which Captain Robert P. Parrott, the inventor of the gun bearing his name, is the manager. Two of the largest engines made on this plan were completed early in the present year, one of them being for the works—well known in America—of Messrs. H. Burden and Sons, of Troy, U.S., and the other being for Mr. C. J. Nourse, of the Chesnut Hill Furnaces, Columbia, Pennsylvania.

The arrangement of the engine will be readily understood by reference to the engravings. The steam and blowing cylinders, which have a stroke of 7 ft. and are 38 in. and 84 in. in diameter respectively, are placed with their axes in line, and are bolted down to a stiff continuous bed-plate, which also carries the pedestals for the fly-wheel shaft. The piston-rods of both the steam and blowing cylinders are attached to a wrought-iron crosshead, furnished with brass blocks working between two pairs of guide bars. The ends of the crosshead projecting through the blocks serve as journals for the pair of connecting-rods, these latter passing back on each side of the steam cylinder, and taking hold of crank-pins fixed in the bosses of the fly-wheels, of which there are two, placed one at each end of a short straight shaft. The connecting-rods are of wrought iron, and have strap ends.

The ends of the crosshead being prolonged beyond the connecting-rod journals serve to work the feed-pump, as shown in the plan. The steam is admitted to, and released from, the steam cylinder by double-beat or equilibrium valves worked by the arrangement of gear shown in the longitudinal section, this section being shown in the longitudinal section, this section being taken through the exhaust-valves and their passages. The eccentrics—of which there are two, one for working the steam and the other the exhaust valves—have 5½ in. throw or 11 in. travel, and they actuate the valves through the medium of the rocking shafts, lifting-fingers, and levers shown in the engraving.

The arrangement of the engine gives ample length to the connecting-rods, and enables the piston-rod of the steam piston to be passed through stuffing-boxes on both cylinder covers, so that the piston, which has cast-iron packing rings, is well carried. The blowing-cylinder piston rod is also carried through both ends of the cylinder, and the piston being in this case much heavier, the rod is made of cast iron, hollow, and of large diameter, so that it is not only amply stiff enough to carry the piston without springing, but also has large bearing surfaces in the stuffing-boxes. This system of construction has been found, in every case in which it has been tried, to secure the cylinders from wear on the lower side, and to cause the piston to remain constantly tight and efficient. The blowing, like the steam piston, is of cast iron, and has cast iron packing rings.

The arrangement of the air valves is shown on the longitudinal section, from which it will be seen that they are fitted to blowing-cylinder covers, the inlet valves being above, and the discharge valves below, the centre line of the cylinder. They are all flap valves, made of leather and canvas, and they are hung so as to close naturally.

Altogether, the engine which we have described is well arranged. The machinery being all fixed to one frame, the parts are constantly kept in their proper relative positions, and all the details are disposed so that they can be readily got at. We are informed by Mr. Parrott that two engines of this construction have now been in use eight years without having the pistons repacked or any of the valves renewed; and that, so little have the pistons worn the cylinders on the lower side, that the slight marks of the boring-tool are still visible.

The following are some of the principal dimensions of the engine shown in our engraving:

	ft.	in.
Diameter of steam cylinder ...	3	2
" blowing " ...	7	0
Length of stroke ...	7	0
Diameter of piston-rod of blowing cylinder	1	0
Length of bearing in stuffing-boxes, about	1	4
Length of connecting-rods between centres	22	7½
Section of " at centre 12 in. × 5 in.		
" " at ends 4½ in. diameter		
Diameter of connecting-rod bearings ...	0	8½
Length " " ...	0	8
Diameter of fly-wheel shaft ...	1	2
Length of fly-wheel shaft bearings ...	1	4½
Diameter of fly-wheels ...	24	0
Width of crosshead guide-bars ...	0	7
Length of crosshead blocks ...	1	3
Diameter of air-delivery pipe ...	2	0
Diameter of feed-pump plungers ...	0	8½

TELEGRAPH EXTENSION.—The new submarine cable proposed to be laid from France to the United States will extend from Brest to St. Pierre-Miquelon, following a plateau which has been sounded very carefully. From St. Pierre-Miquelon the cable, in order to reach New York, will follow the English coast of New Brunswick and the American littoral of the States of Maine, New Hampshire, Massachusetts, and Connecticut. At first sight it might appear desirable to carry a line from Brest to New York direct, but to achieve this object it would be necessary to carry the cable across parts of the bed of the Atlantic which are utterly unsoundable. The operation of submersion is expected to be commenced in May, 1868. The Portuguese Government has granted to Messrs. Darley Rose, Charles Cooper, and Stephenson Clarke the concession of a line which is to be established between Falmouth and Peniche. The concession is granted for 99 years, dating from 1869, by which date the line is to be established. A telegraph station will be formed at Lisbon, and will be in communication with that at Peniche.

INDIAN TOWNS.—The population of Calcutta is returned at 377,924; of Madras, at 427,771; and of Bombay, at 816,562. These figures are based on calculations made in January, 1866 (Calcutta), 1862-3 (Madras), and February, 1864 (Bombay).

THE MESSINA BRIDGE.

(Continued from page 201.)

Description of Metal for the Suspension Systems.

THE tenacity of iron and of plate iron is not sufficient for the construction in those materials of a suspension system of 1000 metres span, with a rise of 20 metres; but the tenacity of steel would allow of its being attained without fear of similar doubt.

If at present steel has not been employed on a scale to be compared to that of most iron structures, it is because construction in that metal is more expensive than in iron, and it is not so readily obtainable.

The tenacity of homogeneous steel is very constant for each construction; but it is very variable in different structures, and according to the thickness of the steel. That constancy of tenacity in individual cases is explained by the homogeneity of the metal; considerable variations in the tenacity of steel in different cases depends much on the nature of the ores used, and on the workmanship employed in their conversion into steel.

The steel to be employed in the spans at Messina would certainly have to be of a great homogeneity of resistance; its employment would be undertaken under such conditions of simplicity as to easily arrive at absolute perfection in its manufacture; that perfection of work could easily be proved. Under such conditions it might be expected that the suspension systems would be capable of supporting, without fracture, the strains calculated after the results of partial tests.

In supporting by a suspension system a constant strain—if, for example, it is employed for a canal bridge—it would not be necessary to adopt any very great difference between the possible resistance of suspension systems and the strain to be supported.

If it is desired to support fluctuating loads by suspension chains, and that such loads might, owing to unforeseen circumstances, cause considerable variation of strain, an allowance must be made proportioned to the additional strain which could be realised in practice.

Suspension chains have to support at the same time two different kinds of strain—the one due to the dead weight of the structure, which is constant, the other due to the effects of varying loads, which might cause unforeseen circumstances. It is customary to calculate suspension systems by taking account of the constancy of the measure of the load equivalent to the dead weight of construction, and to allow a margin for unforeseen strains which moving loads might occasion.

This is how we think it should be worked:—The dead weight of structure being about 19 tons per lineal metre, whilst the greatest possible load is 7½ tons per lineal metre, it follows that the section of the systems should be such that it might be divided into two parts, of which one should sustain the dead weight of 19 tons opposed to ¾ of the coefficient of security, and the other should support the load of 7½ tons opposed to ¼ of that coefficient.

If we take for that coefficient of security 100 kilogrammes, the section of the suspension chains will be such that the less figure of the maximum expected tension would be equal to

$$19 \times \frac{1}{4} \times 100 \times 7 \frac{1}{2} = 50 \times \frac{1}{4} \times 100 = 70 \text{ kilogrammes.}$$

$$19 \times 7 \frac{1}{2} 50$$

The spans then could resist within the limit of the adopted coefficient of security, not only a calculated load covering them completely, and estimated at 7½ tons per lineal metre, but also a possible additional strain equal to 26½ tons × ¾, or 11 tons per lineal metre.

The coefficient of 100 kilogrammes, which we consider as the strain which the suspension systems could sustain with safety in an unforeseen occasion, is well in excess of anything that is possible, so that there is no occasion for fear concerning it.

Steel of 4½ points (French gauge) could easily support that strain without injury. If at that limit its elasticity should become slightly altered, that could not give rise to any serious consequences.

Between 100 kilogrammes and 150 kilogrammes (the point of rupture) there is a considerable difference. That difference cannot diminish in consequence of an unforeseen addition in the strains, since, after allowing for all contingencies, it would be impossible for the load to attain to 100 kilogrammes; neither could it diminish for want of resistance in the suspension chains, since those chains would be composed of elements of one homogeneous character manufactured with great care.

Piers supporting the Spans.

The construction of the piers for supporting the spans of the Messina Bridge will be a colossal undertaking; but we shall not say much on that subject at present. When public opinion is accustomed to projects for large spans, when the possibility of constructing spans of 1000 metres, rigid under the passage of trains, immovable under the action of winds, it will be admitted that we know how to lay with safety the foundations of the piers for the Messina Bridge in 110 metres' depth of water, and how to erect the portion above the level of the sea, which will be about 110 metres in height, without incurring enormous expense either in time or money.

We have reflected much on the difficulties presenting themselves in the erection of piers about 220 metres in height; we have taken into account the enormous efforts that would be necessary, and the destruction to which they would be exposed; and we are convinced that they may be constructed, and that the day will come when the thing will be accomplished.

Raising the Spans.

The raising of the spans of the Bridge of Messina is not a difficulty of the first order; it is easy to understand this when one is accustomed to the constant method employed in the construction of suspension bridges, to set the spans in their places.

A cable of a weight 1 per lineal metre could carry, when once in position, a cable of a weight 3; that, a cable weighing 9; the last, a cable weighing 27 per lineal metre, and so on. The first of a very light weight, in steel wire, being stretched from one pier to the other, it can be employed for getting into position a steel wire cable of three times its weight, in the same way as the constructors of suspension bridges employ ferry boats to erect their cables. The second cable being in place, it will serve to get a cable three times its weight into position, and so on.

The suspension chains being in position, temporary rods are attached, and the raising of the platform would be effected, commencing from the piers, as is done in any ordinary suspension bridge.

Thus it is seen the raising of the spans of the Messina Bridge is possible, and that without any scaffolding or special appliances.

DUNDEE AND ITS FACTORIES.

At the present time seventy-two firms own spinning-mills or power-loom factories, or both, of 5822 horse power, containing 202,466 spindles and 7992 power-looms. In these works 35,310 persons are employed, and the same firms also employ 6240 persons in hand-loom weaving, and in other departments, making a total of 41,550 persons employed by them, and the total number of persons directly engaged in the various branches of the linen manufacture in Dundee cannot be much, if at all, short of 60,000. The buildings which have been erected in Dundee for spinning and weaving are most imposing structures, unsurpassed in extent, in durability, and in their proportions by any others. Internally they are furnished with every modern appliance to render them salubrious and healthy, and as the different floors are lofty and the whole thoroughly ventilated, the workers enjoy a degree of comfort unknown to their predecessors. The machinery in the various mills and factories is as perfect and as well adapted for the work it has to perform as human ingenuity and money can make it, and it is invariably kept in the most complete order. Every real improvement is readily taken advantage of as it is discovered, and so numerous and so great are the changes which have been made on both spinning and weaving machinery, that in many works the whole of it has been renewed within the last few years. This year the consumption of jute will be about 65,000 tons. Including hemp, the consumption of material in Dundee is at present at the rate of about 90,000 tons a year, and the cost of this material is about two and a half million pounds sterling. In the district of which Dundee is the centre, but excluding Dundee, the average annual consumption of flax and tow is at present about 37,000 tons of flax and tow, 2000 of hemp, and 1000 tons of jute, being in all 40,000 tons, the cost of which is about one and three-quarter million pounds sterling. In the entire district, including Dundee, there are now, therefore, about 130,000 tons of flax, hemp, and jute consumed annually, the cost of which is about four and a quarter million pounds sterling. In the district, excluding Dundee, the details of which have already been given, there are 110 firms in the linen trade, employing steam or water power of the aggregate of 6290 horse power, driving 191,452 spindles and 10,151 power-looms, and employing 28,875 persons. The only way of approximating to the quantity of yarn spun is by multiplying the spindles by the average daily spin of each. This gives a total of about 31,000,000 spindles for Dundee and 29,000,000 for the district, making together 60,000,000 spindles of yarn spun annually, which, at the average price of 2s. 3d. per spindle, gives a value of 6,750,000L. No reliable estimate of the number of yards of linen made, either in Dundee or in the district, can be formed. Neither is there any mode by which the correct value of the goods made can be ascertained; but it is estimated that the total value of the yarn and linen made in Dundee and throughout the district cannot be under 8,000,000L. The capital invested in the spinning-mills and power-loom factories in Dundee is about 2,500,000L, and those in the district 2,200,000L—together, 4,700,000L. When the works now in course of erection are completed, which will be within a few months, they will bring up the total cost of the whole to 5,000,000L. The amount invested in bleach-works, calenders, and other auxiliary branches of the trade cannot be less than 1,000,000L. If to these sums be added the average value of the stock-in-trade in the hands of the spinners, manufacturers, and merchants, it will be within the mark to estimate the capital required to carry on the trade of Dundee and the district around at 10,000,000L.

THE WATERWITCH.

TO THE EDITOR OF ENGINEERING.

SIR,—In a short notice, in your last number, of the new trials of this vessel, you have made a great mistake—to the prejudice of the water-propeller—which I hope you will allow me to rectify.

You say "the jet-propelled vessel Waterwitch has had two further trials since that reported by us three weeks ago; but she has only exerted still greater engine power, and attained 'less speed.' The trials at half-boiler power show a large loss of effect, the mean speed being but 6.326." Now, instead of a loss of effect, this speed, at the so-called half-power, shows comparatively a better result than at the full power, as may be easily seen by comparing the proportions. At the trial referred to (3rd of September), the full speed is said to have been 8.879 knots, and say (for the horse power has not yet been published) 800 horse power. At half-power—that is, with one boiler merely—the speed was 6.326, and say, 228 horse power, being the highest power hitherto obtained from one boiler. From this it will be seen that the half-power gave a higher speed in proportion to the power employed, and a better, and not a worse, result, as you have stated.

This half-speed is, moreover, the highest speed ever attained by any vessel afloat, with same power, same length, and same displacement. Can you name a better or an equal?

Let us should feel inclined to doubt the accuracy of the horse powers at the last trial, as I have so far inferred them to have been, I give similar particulars from the more careful trial made on 9th August, which have been obtained from authentic sources, namely, full-boiler power, 777 horse power; speed, 9.233 knots; half-power, 226 horse power; and speed, 6.163, showing also a slightly better result for the half-power.

London, September 10, 1867.

[The first portion of our paragraph, referring to the full-power trials, is strictly correct in any case. The last is correct also, upon the supposition that the term "half-boiler power" means what it expresses. How is it that while the full number of boilers gives 800 indicated horse, half the number of boilers gives but 226?—ED. E.]

KURRACHEE HARBOUR.

At page 164 of last week's number of *ENGINEERING* we gave Messrs. Stevenson's report to the Secretary of State for India on Mr. Walker's project for the improvement of Kurrachee harbour, and which, being unfavourable, led to orders being issued for all further works to be suspended. Having given that report in full, it is but right and fair that we should also give the counter opinions which have been recorded on the subject; and this, not only in justice to those whose professional opinions have been set aside (and, as circumstances have shown, unjustly), but because the improvement of Kurrachee harbour involves questions of the very first importance in harbour engineering, and, by publishing all that has been said on both sides of the question, will, together with the description of the harbour and contemplated works for its improvement, which will be found at pages 454 and 497 of *ENGINEERING*, vol. ii., enable any one interested to form a very good opinion on the entire subject.

On the conclusion arrived at by Messrs. D. and T. Stevenson, understood to be condemnatory of Mr. Walker's design, Mr. Parkes wrote as follows to the Under-Secretary of State for India, under date of 3rd March, 1866:

"I have been advised by Messrs. D. and T. Stevenson that they have forwarded to the India Office their report on Kurrachee harbour, and I understand that their conclusion is condemnatory of Mr. Walker's design.

"In a matter so seriously affecting the public interest, and the professional credit of myself and my late friend Mr. Walker, I feel it my duty to lose no time in bringing to your notice the circumstances under which that conclusion has been arrived at, so that they may be considered at the same time with the conclusion itself.

"From the time that Messrs. Stevenson commenced their investigation of the subject till now, they have never asked me a single question, or expressed a desire for any information beyond that contained in the papers sent them, or any explanation of that information. To my repeated requests for interviews, and expressions of desire for personal unreserved consultation, they have given no response whatever; and though Mr. David Stevenson called on me on one occasion when I was unfortunately absent through illness, no opportunity was given for a subsequent meeting either in London or Edinburgh.

"They forwarded to me a draft report in January, which was the subject of some discussion as to its form. On the 10th February I sent them some comments on this draft, with a clear intimation that I hoped they would appoint a meeting. Messrs. Stevenson, nevertheless, adopted those comments, though qualified by this intimation, as conclusive, and made their report without further communication with me.

"If it be asked why the whole information was not furnished to them in writing, my answer is, that the question is one which can only be efficiently discussed by personal consultation. I gave all I could that I thought pertinent to the immediate questions at issue, but in the full knowledge that collateral questions must arise at a subsequent stage, which I reserved, for the sake of convenience, till our expected interview.

"I submit, therefore, that Messrs. Stevenson have not given me the opportunity to present to them my whole case, and that their conclusion must be considered as premature.

"I am quite at a loss to account for their disinclination to meet me in personal consultation. There must be a misunderstanding somewhere, and we must be acting in some unknown way at cross purposes.

"I the more regret this because I am convinced, looking at the absolute identity of their fundamental principles with my own, that an unreserved discussion upon the whole question would, at an earlier stage of the proceedings, have led us to an agreement. No doubt I should have had to yield something of my present position to their ability, experience, and unbiased view of the case; but they, on the other hand, would surely have derived advantage from my far more intimate acquaintance with its history, details, and special circumstances."

After perusal of Messrs. Stevenson's report, Mr. Parkes again wrote to the Under-Secretary of State for India, on 20th March, 1866, requesting that the conclusion arrived at might be subjected to a suitable review, and forwarding a report on the subject from Mr. Beardmore, C.E. Mr. Parkes wrote as follows:

"Since I had the honour to address you on the 3rd instant, I have been favoured with a copy of Messrs. Stevenson's report on the above subject, and I subse-

quently had an interview with Mr. David Stevenson himself.

"I feel it now to be my duty to urge upon the Government in the strongest manner consistent with due respect, that the conclusion arrived at by Messrs. Stevenson be subjected to a suitable review.

"I am well aware that such a request is unusual, perhaps irregular, and that it rests with me to justify it. I am also aware that the fact of Messrs. Stevenson's conclusion being against my own conviction would be no justification from your point of view, while nothing but the greatest confidence in the truth of my own position would be a justification from my own.

"With a view, therefore, to testing the possibility of my being really in error, I submitted all the papers which had been sent to Messrs. Stevenson, together with their original draft, and my remarks thereon, and their report, to Mr. Beardmore, C.E., a gentleman whose authority on such a question is certainly not inferior to that of Messrs. Stevenson. I have the honour to enclose the written opinion with which he has favoured me, which speaks for itself.

"I would further submit to you, that although my authority on matters of opinion upon this subject is for the present in abeyance, my intimate knowledge of fact remains the same. I am therefore in a position to assure you that Messrs. Stevenson's report is so singularly open to criticism, owing to their mode of treating the evidence on matters of fact laid before them or tendered to them, as to render it unsuitable for a final and authoritative settlement of a question involving so many and varied interests, both national and commercial, as the improvement of Kurrachee harbour.

"I am, of course, prepared to substantiate this statement in detail, if called upon to do so; but the Government will easily understand my wish that a course which would render this unnecessary should be adopted in preference.

"I adhere to the opinion expressed in my letter of the 3rd instant, that if the investigation had been carried on by Messrs. Stevenson in an open and unreserved manner, our final agreement on all essential points would have been inevitable."

The following is the report by Mr. Beardmore, C.E., referred to in the foregoing letter:

"Having perused the voluminous papers relating to the improvement of Kurrachee harbour, and Messrs. Stevenson's recent report thereon, and having examined the numerous maps, charts, soundings, and sections extending from 1854 to October 1865, I will endeavour to answer your question, viz.:

"Do you think that the depth of water outside the harbour, and the general conformation of the bottom, are such as would have discouraged you from applying the ordinary resources of harbour engineering, with the hope of obtaining the conditions necessary for the formation and maintenance of an entrance channel of 20 ft. deep (or thereabouts), with ample width for navigation?"

"I do not think there is anything formidable in the dimensions of the bar or bank of sand projecting from Manora Point, and maintained by the action of successive monsoons, that will preclude a successful application of the admitted principles of harbour engineering suited to this case.

"The soundings from the bar in every direction indicate a by no means unfavourable bottom. A depth of 24 ft. at low water was reached at a distance of 1500 ft. from the centre of the bar, weatherward and seaward, in the year 1858.

"By the last survey, in October, 1865, it appears that the distance between 24 ft. soundings and the centre of the bar is less than 1000 ft.

"With my knowledge of many entrances to harbours in this country of a like character (*i.e.* with sandy bottom), I should say that the natural capabilities of Kurrachee are above the average.

"I have perused Colonel Tremenhare's objections, and am of opinion that they are fallacious in theory, and the alleged facts appear to me unsupported. The vitality of Kurrachee harbour, as proved by all record, is quite inconsistent with the theory of a persistent drift from the delta of the Indus. If such a current were in existence, it must have been so for a sufficient time for Kurrachee harbour to have been entirely destroyed. But even if there had been such a drift, no better prevention for its evil effect on the harbour could be found than the Keamari Groyne, irrespective of its other manifest advantages. The argument, that the water on the flood tide being drawn through the breakers in the neighbourhood of the bar causes more sand to be carried into the harbour than was the case when it passed over the Keamari sand-spit, is not

tenable, for such an action implies a current over the bar, opposite the end of the groyne, that would certainly have the effect of pushing the bar *inwards*; whereas, by all the surveys up to October, 1865, the bar is shown to have travelled bodily *outwards*.

"This fact of the bar having moved outwards is not in itself of great importance; but in connexion with it, I observe that the bar in the middle portion of its length has narrowed considerably, and also that it has extended to the eastward. The action which has produced these results must ultimately cause a new channel to be opened through the bar, in continuation of the line of the main harbour channel.

"To secure the permanent maintenance of such a new channel, the Manora breakwater is absolutely necessary. For present purposes, I think the length of 1500 feet as designed may be sufficient; but having relation to the future increase of scour caused by the diversion of Chinna Creek, I think it might be desirable ultimately to extend Manora breakwater by an arm running in a south-easterly direction, following somewhat the line of the 27 ft. soundings. There would be an additional argument in favour of this, because such a breakwater would offer an outer harbour of refuge for vessels running to Kurrachee for shelter.

"I am of opinion that there is no possible fear for the permanent and successful result of these works. It is very possible that the immediate scouring of the bar by natural causes would not exceed a depth of 16 feet. Below this depth the dredger would be applied with extreme value for bottoming out a channel to 20 feet deep. More would be done in one season by a dredger than in several years by the action of current alone, on a deep bottom, especially as the width of the channel increased by the natural action of the tide. The tendency will be for the channel rather to widen than deepen by tidal action after 16 feet at low water is acquired. In favour of dredging, it appears that a channel 300 yards in width could be dredged through the present bar between 16 and 20 feet depth by the removal of about 150,000 cubic yards, which would cost on the Tyne or the Clyde 4000*l.* Probably at Kurrachee the cost would be three or four times as great, but still a small sum compared with the advantage of getting rid of so much material from the harbour mouth.

"I have looked over all the precedents in my own professional knowledge and experience for any case to support the adverse opinions that have been given against these works, and I am unable to find any case which would lead to a condemnation of them.

"On the contrary, works now in progress on the Tyne and on the Tees are based on the same principles, and good results have already been obtained. Great improvements have been effected at Dunkirk by similar means; and the immense sand-banks and channels forming the entrance to Liverpool have experienced changes from less apparent causes than might be brought to bear at Kurrachee.

"The policy of persevering in these works is rather a national question than one for the judgment of an engineer. That they can be carried out so as to fully warrant Mr. Walker's original anticipations I have no doubt."

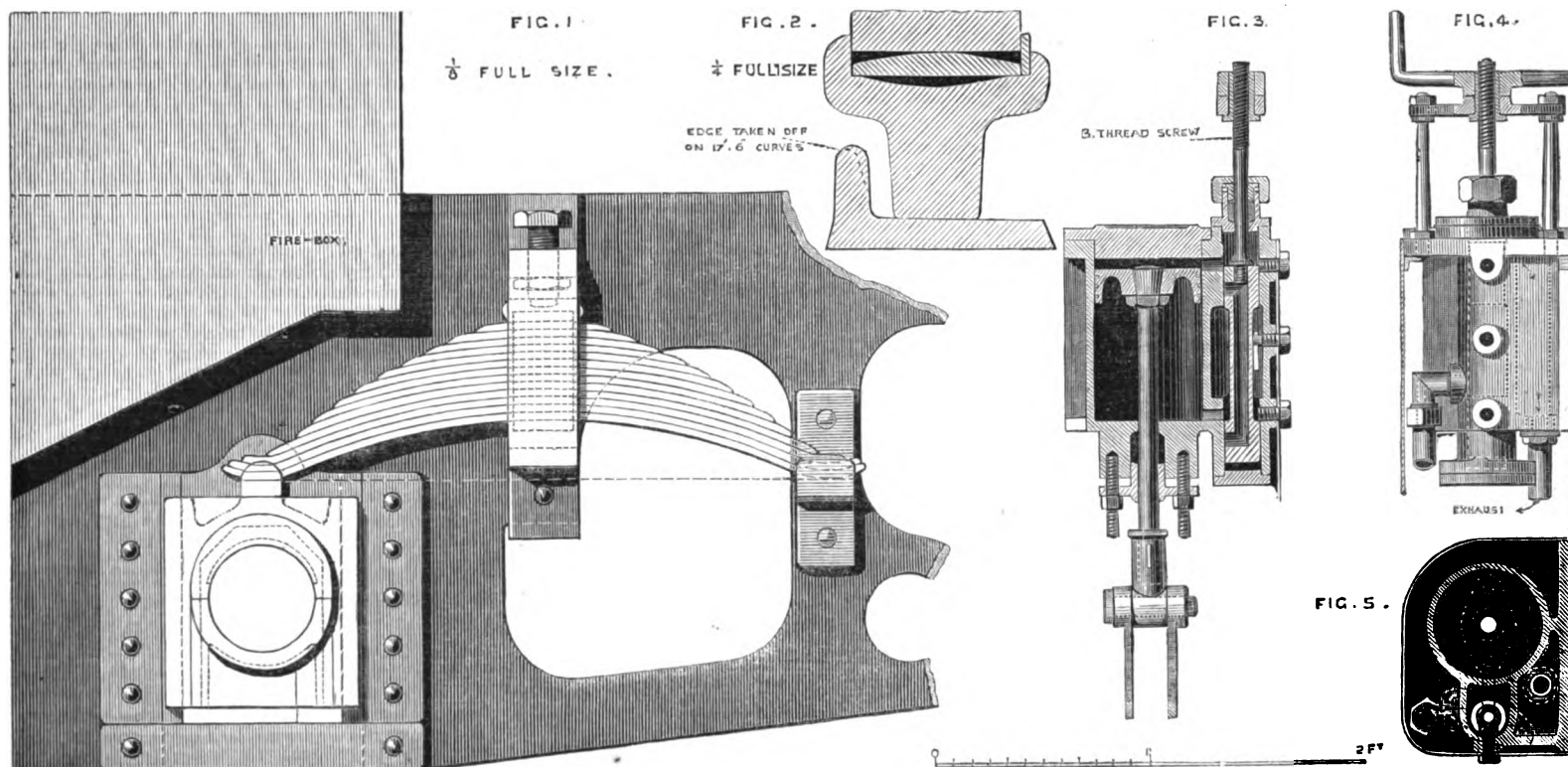
In order to render these papers complete, there only now remains for us to give Mr. Parkes's analysis of the evidence on which Messrs. Stevenson had based their conclusions, but which, for want of space, must be deferred for our next week's issue.

THE LATE PROFESSOR FARADAY.—At the last sitting of the Academy of Sciences, M. Dumas announced the death of Professor Faraday in the following terms: "The labours of that incomparable philosopher are known to the whole world; but the ineffable kindness, frankness, and ingenuousness of his nature could only be appreciated by his intimate friends. It is nearly fifty years ago when I first met Mr. Faraday, and from that time I had frequent intercourse with him. I therefore had an opportunity of watching his glorious upward progress, and saw his natural and simple modesty increase in the same proportion as the strength of his genius and the splendour of his services. If his discoveries have immortalised him, and if he is remembered as one of the most fruitful minds of this century, he also leaves, to the honour and dignity of science be it said, the example of a pure life and a noble heart. England will not be alone in mourning his death."

THE CAPE COLONY.—Works undertaken for the construction of a dock and breakwater at Table Bay are being pursued regularly and actively. It had been originally proposed to construct only a dry dock of a depth which would limit its usefulness to the reception of ships of the mercantile marine. But the directors of the works have deemed it desirable that the basin should be enabled to receive ships of war, and the Admiralty has promised to give the enterprise its moral and material support. The outlay likely to be involved by the supplementary work which has just been decided on, is estimated at 40,000*l.*, which will be sought for partly in the London money market and partly in the Cape Colony.

DETAILS OF LOCOMOTIVE FOR THE 3 FT. GAUGE, RHYMNEY IRONWORKS.

CONSTRUCTED AT THE NEATH ABBEY WORKS, FROM THE DESIGNS OF MR. WILLIAM MOYLE, ENGINEER TO THE RHYMNEY IRON COMPANY.



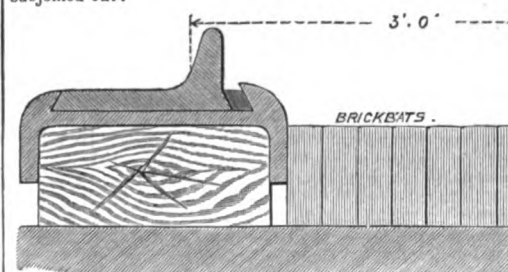
A fortnight ago (*vide* pages 173 and 174 of the present volume of this journal) we gave an illustrated description of a small locomotive engine constructed at the Neath Abbey Works from the designs of Mr. William Moyle, the engineer of the Rhymney Iron Company; and we now give engravings showing more clearly the steam brake and some other details of the engine. The cylinder of the steam brake is fixed at the hind end of the footplate, as shown in the general elevation and plan already published (*vide* page 174), and it is 6 in. in diameter, and of sufficient length to accommodate a stroke of between 6 in. and 7 in. As will be seen by the views given above, the admission of the steam to, and its release from, the brake cylinder is effected by a small piston-valve, 2 in. in diameter, which is moved by a hand lever and nut fitted to a three-threaded screw formed on the valve-spindle. The passages leading to the top and bottom of the cylinder are $\frac{1}{2}$ in. in diameter, and the passage formed through the valve itself for connecting the upper and lower cylinder passages is of the same size. The steam is admitted to the chamber between the two ends of the valve; and when the latter is in the position shown in the vertical section, the steam has a free passage into the lower end of the cylinder, so that it can force up the piston and apply the brake. At the same time the upper cylinder port is uncovered to the exhaust chamber, which latter extends down the side of the cylinder, as shown in the figures, and is fitted with a pipe for conducting away the waste steam. When the valve is raised, by the aid of the screw, the ends of the passage in it are brought fair with the cylinder ports, and the two ends of the cylinder are thus placed in free communication with each other, so that the piston can fall and the brake be taken off. The brake is applied to the hind pair of wheels only.

Another detail, shown in the engravings now given, is the arrangement of the driving springs. The narrow gauge (3 ft.) of the tramway on which the engine has to work rendered it impossible to place the springs directly over the driving axle-boxes in the usual way without raising the firebox inconveniently high, and the difficulty has therefore been got over by adopting the plan shown in Fig. 1. From this it will be seen that each driving spring rests at one end upon the corresponding axle-box, and at the other upon a shoe fixed to the framing, the centre of the spring bearing against the point of an adjusting screw carried by a bracket also fixed to the inside of the frame. Each spring thus acts as an elastic beam, and the arrangement, besides its convenience in other respects, has the advantage of rendering the spring readily accessible for adjustment or renewal, and leaving the top of the driving-axle boxes clear for oiling, &c.

The remaining figure of the above engravings is an enlarged section of one of the tyres and a portion of the wheel-rim, thus section showing the shape of the tyre and of the trainway upon which it runs. The tyres are, as we stated in our previous notice, seated on Mr. William Bridges Adams's springs, and the section now given shows clearly the manner in which those springs are arranged. In the section of the tramway rail, the dotted line shows the manner in which the edge of the flange is taken off on the curves of 17 ft. 6 in. radius.

Since our former notice appeared, the engine has been weighed, and Mr. Moyle has furnished us with the results. The total weight in working order is 9 tons 15 cwt., of which weight 8 tons 10 cwt. rests upon the coupled wheels. The coupled wheels are, we may mention, 3 ft. 6 in. apart from centre to centre, and the total wheel base of the engine is 7 ft. 1 in. At present the locomotive we are describing does not work up to her full power; but others on the same plan, which are to be constructed, will have more to do, as they will have to work up long gradients of 1 in 25. The boiler is, as we have before stated,

usually worked at a pressure of 60 lb., but it is sufficiently stayed to be safely worked at 120 lb., at which pressure an effective average pressure of at least 60 lb. could be readily maintained in the cylinder, although the valves have outside lap equal to the width of the steam ports. An average pressure of 60 lb. in the cylinders would give a tractive force of 1920 lb., less, of course, the engine friction and resistances. A few days ago the engine was tried on an incline of 1 in 180, and was found capable of taking up a load of 85 tons. It was a damp day, and the tramway was in by no means perfect order, although it was better than in some places, as the rails were laid on longitudinal timbers, and the outside ballast was well clear of them. A section of the rail and timbers is given in the subjoined cut.



When the Rhymney Iron Company first applied (without furnishing designs) to the various makers of small locomotives for a six-wheeled four-coupled tramway engine to work round the sharp curves of 17 ft. 6 in. radius (measured to the centre line), all we believe recommended the substitution of the ordinary short centred four-wheeled engine. The tramway at the Rhymney Works, however, runs at top of a very high "tip," and Mr. Moyle objected, and very properly, to working one of the unsteady four-wheeled engines on such a road, in such a situation. The consequence was the designing by Mr. Moyle, of the engine we have described, and which has answered its purpose admirably, the radius bar arrangement applied to the bogie enabling it to traverse the sharp curves with perfect ease. The details of the engine we may mention were worked out at the Neath Abbey Works from Mr. Moyle's directions, by Mr. L. Thomas.

SOUTH LANCASHIRE COAL.—A number of Lancashire and Cheshire coalowners, who have formed themselves into an association called the South Lancashire and Cheshire Coal Association, have for some time past been carrying on, at a considerable expense, a most elaborate series of experiments, the objects being, in the first place, to test the economic efficiency of the coals of this district, and, in the second, to ascertain the most economical form of boiler, the best mode of firing, whether mechanically or by hand, so as to evaporate the greatest amount of water with a given quantity of coal without the production of smoke. The experiments, which are not yet completed, have been conducted on a large scale, under the joint superintendence of Dr. Richardson, of Newcastle, and Mr. Fletcher, chief engineer of the Association for Preventing Steam Boiler Explosions. As far as the trials have progressed they have clearly shown that the formation of smoke may be entirely prevented, without any diminution of the evaporative efficiency of the coal, by careful firing alone; while it has been found, in addition, that the coals raised in this district will realise as high an economy and efficiency as the best North-country and Welsh coals, and that without the production of smoke.

ON A NEW MODE OF CONSTRUCTING THE SURFACE OF STREETS AND THOROUGHFARES.

By JOSEPH MITCHELL, F.R.S.E., F.C.S., C.E.*

THE wear and tear of an ordinary macadamised road, and, consequently, its cost of maintenance, are very great.

The explanation appears from experiments which show that a cubic yard of macadamised stone, when well pressed down in a box with a capacity of 27 cubic feet, contains 11 cubic feet of vacuities; and that a roadway covered with 12 in. of metal, before it is consolidated into a smooth and useful surface, has a large portion of its stones crushed into small particles, and that more than one-third of its dimensions consists of mud and sand. When heavy rains occur, combined with heavy traffic, disintegration of the stones in such a roadway takes place, and quantities of mud are generated in proportion to the amount of traffic.

In the new mode of constructing a roadway which I propose, the vacuities in the metal are filled with cement grout, which, when hardened, forms a concrete, binding together the macadamised stones into a mass impervious to water, and, unlike asphalt, unaffected by heat; while, at the same time, it preserves entire the original size and dimensions of the stone.

Again, every one must have noticed the tear and wear of the causeway stones in an ordinary street pavement, and the irregularities of the surface of the streets, after six or twelve months' traffic. Granite and other stones of the hardest quality appear to give way under the weight of the traffic. The explanation of this waste may be found in the ordinary mode of constructing street pavement. The stones are laid on a bed of loose sand some two or three inches deep above the soil, and are then beaten down into an approximately even, but really irregular, surface. They are laid $\frac{3}{4}$ ths of an inch to $1\frac{1}{4}$ inch apart, and the intervals between them are filled up with sand (which is soon reduced to mud). Thus, each stone is insulated, and made to rest on a yielding surface.

In a street so constructed, the ends of the causeway stones are found, after twelve months' traffic, to be worn down from $\frac{1}{4}$ to $\frac{3}{4}$ of an inch. This arises from the percussion of the wheels of carts and carriages falling from the centre of one stone on to the joint of the two adjoining, which, being on a yielding surface, and the wheels striking on the ends, sink a little from the pressure. When a stone has sunk bodily from $\frac{1}{4}$ inch to an inch, or when a little hollow occurs in the pavement of the street, it will commonly be found that the adjoining stones are much worn, the hollow on the surface increasing the force and effect of the percussion of the wheels. The greater the hollow, the greater is the tear and wear from the strokes of the wheels.

The source of waste is seen to be the yielding surface on which the stones are laid. To prevent their tear and wear, what was wanted seemed to be a rigid and

* Paper read before the British Association at Dundee.

perfectly regular surface, by which also the traction might be greatly improved.

These defects in the construction of causeway have long been noticed, and the only remedy hitherto used, and which has been in very general use (but which has always failed), has been, to lay a body of lime concrete 6 in. deep, below the stones, and to fill with lime grout the joints or intervals between them. The lime, it has been found, has never consolidated, owing to the stones being beaten down when it is half set, and to the tremor subsequently caused by the traffic. Thus, on the best paved streets, after heavy rain or watering, much mud is generated from the wet unconsolidated lime and sand. Where there is much traffic, as in London, this mud on the surface, in drying, proves slippery and dangerous, and many serious accidents occur in consequence.

The irregularities of the surface, and consequent mud, are increased by 2 in. of sand being placed between the bed of lime concrete and the bottom of the paving stones.

In the new mode of constructing street pavement which I have proposed, there is first laid down a bed of cement concrete 3 in. deep (gravel may be used instead of macadamised stone where abundant and cheaper), and to the requisite convexity in the cross section. This concrete quickly consolidates, and entirely excludes moisture or water from below.

On this foundation, the paving stones, 5 in. deep and 3 in. wide (a width of 3 in. gives a better hold to the horses' feet than a width of 4 in. or 4½ in., which are the common sizes), are built, and, when brought to a perfect form, the joints are filled with cement grout. When the whole is consolidated, it forms a surface perfectly immovable by traffic and impervious to moisture. The wear and tear of the stones arise from the attrition of the traffic only. If the causeway be well made, there should be no irregularities on the surface. Where such irregularities exist, they are due to defective workmanship.

Three experiments have been made to test the merits of the new or concrete road, and two to test the merits of the new form of causeway.

The first trial road and pavement were laid down in Inverness early in 1865. They have been under traffic for upwards of two years, being passed over by the whole goods traffic of the Highland Railway. The road is now perfectly sound, and it has required no repairs; whereas the macadamised roadway adjoining it has constantly required repairs, and is now full of irregularities and ruts.

The second trial new road was laid in London. As it was important that this plan of road-making should be subjected to the test of severe traffic on some of the London thoroughfares, I applied to, and obtained permission from, the Right Honourable William Cowper, Chief Commissioner of Works, to lay down 100 yards of it in length by 35 ft. in width, on the Mall in St. James's Park, at the foot of the Green Park. The whole traffic between the district of Regent-street, Piccadilly, Pall Mall, Buckingham Gate, and the Victoria Station, passes along this route, which is, apparently, subjected to as heavy traffic as any thoroughfare in London.

Subsequently, this road proved a failure, the surface breaking up under the traffic. My explanation of the failure (which was very puzzling at first) is as follows: The roadway at each end of the experiment was macadamised at the time the experiment was made, and the contractor's men, who were crushing the macadamised road with a heavy roller of 3 tons to 4 tons weight, were inadvertently permitted by the person in charge to pass their heavy roller from end to end continuously over the experiment before it had properly consolidated. The crystalline structure of the cement was injured by this, and, in consequence, the surface yielded to the incessant cab traffic and the month of continuous rain to which it was immediately thereafter exposed. The surface was repaired by the trustees by a coating of 2 in. of macadamised stone, which was rapidly ground down on the hard concrete by passing vehicles. As the bottom was entire and consolidated, had a coating of 2 in. or 3 in. of new concrete been laid down, with the required time to consolidate, it would have answered all the purposes contemplated; but the surveyor deemed it his duty to remove the concrete surface entirely, which was only done at great trouble, by means of levers and iron crowbars. The experiment was certainly a failure; but, in attempts of realising new conceptions, it is in the nature of things that there must be repeated failures before success is reached.

The third experiment was made in Edinburgh, and has, in my opinion, proved very satisfactory and successful. A length of 150 ft. of concrete road by 45 ft. in breadth, and a similar extent of street pavement, were laid down last summer at Geo. IV. Bridge, where the traffic is heavy and continuous. One-half of the street was laid down with the concrete at a time, and the traffic was rigidly kept off that portion for a month. The other half was then laid down. The whole roadway has since been under traffic for twelve months, and has proved perfectly sound and immovable, not a stone turning up all that time. After the road had consolidated, and had been under traffic during the winter, it was observed that some small hollows had shown them-

selves at the joinings along the centre of the roadway, and arose from our inexperience in laying down the concrete, and will in future be avoided. These hollows were cut out, and made up with new concrete, and opened for traffic in a week. The result has been that the surface is now perfectly smooth and regular.

The street pavement on the south end of the concrete road was then laid down on a bed of cement concrete 3 in. deep.

The cement concrete was permitted to consolidate for about ten days, and thereafter the pavement was built on it with cement mortar; and when the stones were regularly set, the joints were filled up with cement grout.

The pavement has also been perfectly successful, the water running off it as from a foot-pavement, leaving no mud; and the only wearing of the surface is from the attrition of the traffic.

It has been stated that the noise of vehicles on the pavement is greater than on the ordinary pavement. I do not consider it greater. The blows arising from the irregularities on the ordinary pavement are noisy, as well as destructive to the road and to carriages; but the noise on the concrete pavement, though not greater, is different, it having more of a ringing sound, like that on a street bound up with frost.

In point of wear and tear, and freedom from mud and dust, this street pavement has many undoubted advantages over that now in common use, particularly where there is heavy traffic; but I anticipate that a road consisting of a good body of concrete should supersede even this species of street pavement.

The following is an extract from a report made by me to Mr. William Duncan, secretary to the Edinburgh Road Trustees:

"The concrete road cost 6s. 8d., and the paved road 17s., per square yard. A sum of 1s. 8d. per square yard was incurred for excavating and removing the materials of the old road, and for watching; but I calculate that the value of the old materials would go to meet these outlays. The small experiment that has been made, however, is not a good criterion of the cost. In a work on a large scale, the cost ought to be less.

"The advantages offered by this mode of construction on a road under heavy traffic, as far as our experience has gone, are—

"First, diminished wear and tear. The general surface is apparently not worn in twelve months more than one-eighth of an inch.

"Second, superior cleanliness. The road is almost wholly free from mud and dust.

"Third, diminished cost and annoyance from repairs. The road has required little or no repairs for twelve months. It requires no scraping or watering, and its maintenance is almost nominal, while the coatings, scrapings, and waterings of a macadamised road under similar traffic in Edinburgh cannot be done under 1s. to 1s. 6d. per square yard per annum, besides the great inconvenience and discomfort they cause to the public.

"The original cost of a macadamised road 9 in. deep, which, before it is consolidated, is crushed into 6 in. of available material, is about 2s. per square yard, or say somewhat less than one-third of the concrete road. In London, where the metal is 20s. the cubic yard, instead of 6s., as in Edinburgh, and where the cement is cheaper, the cost of a road of 9 in. of metal will nearly amount to the cost of a concrete road.

"It thus appears that the cost of the concrete road will be proportionally less, and its advantages proportionally greater, in London and towns similarly situated than in Edinburgh.

"The cost of the concrete pavement, which is 17s. per square yard, is higher than it should be, as the stone was procured from Aberdeen instead of the neighbourhood of Edinburgh, and gravel would have served for the concrete bottom quite as well as the more expensive macadamised stone.

"In conclusion, I consider that the experiment which, through the liberality and public spirit of the road trustees, I have been permitted to make on this most important subject has been successful,—the road having sustained the traffic on Geo. IV. Bridge without a stone being moved for twelve months; and that it only requires further experience in the manipulation and laying down of the concrete to accomplish all that I anticipated from this new mode of road-making."

Since the date of this report, Messrs. Wylie and Slight, engineers in Edinburgh, have been good enough to make experiments which show that the new road possesses another advantage over the old. It was natural to anticipate that, from the superior evenness and solidity of the new road, the traction would be less upon it than on common roads; and these gentlemen have found that the traction on the concrete road of a wagon 2 tons weight, against a gradient of 1 in 80, was 70 lb., while on a common macadamised road of the same grade, wet and muddy, was 140 lb., or double that on the concrete road. On a road with wheel-tracks through new metal it was 340 lb.; and on a road newly covered with metal 500 lb. The gradients of these several roads were 1 in 80.

The experiments are to be further prosecuted, as the dynamometer got injured; and I have every confidence

that they will establish the very great superiority of the new road as regards traction—a circumstance affecting the preservation of horses and carriages, and the comfort of travelling. Many experiments will yet have to be made before the merits of the new road and pavement can be held to have been conclusively tested. In particular, it will be necessary to have an experiment on a large scale before the cost of construction and maintenance of the new road can fairly be put in comparison with the cost of construction and maintenance of the roads now in use; but in the mean time, so far as my experience has gone, I feel entitled to sum up the advantages of the new roadway over the old, in the four following propositions, viz.:

1st. The wear and tear are less on the new road than on the old.

2nd. The cost and annoyance of repairs are less.

3rd. The mud and dust are a minimum quantity, and there is superior cleanliness.

4th. The traction is less, as has already been proved.

It must be observed, however, that the entire efficiency of this mode of road-making depends on the quality of the cement, which should be the best Portland cement, tested to bear a tensile strain of 500 to 600 lb. on a bar 1½ in. square. Time, after the road is made, is a great element of efficiency, as the hardness of the concrete gradually doubles in the course of twelve months; but further experiments are necessary to determine the precise time the road should be left for consolidation before it is opened for traffic—a month I found quite sufficient in Edinburgh.

THE DECAY OF STONE—ITS CAUSE AND PREVENTION.*

By MR. JOHN SPILLER, F.C.S., of Woolwich.

For several years past I have been occupied at intervals in studying the causes of the decay of stone, and in experimenting with such chemical re-agents as appeared to offer any promise of being usefully applied as means of prevention. At an early stage of the investigation I arrived at the conclusion that the corrosive action of sulphurous and sulphuric acids in the atmosphere, resulting from the combustion of coal fuel, operate in large towns especially in a destructive manner upon dolomite and the numerous class of limestones commonly employed in public buildings. This chemical action, aided no doubt by the simultaneous attack of carbonic acid and moisture, and in the winter season further supplemented by the disintegrating effects of frost, must, I conceive, furnish a sufficient explanation of all the facts observed. I would here remark that Dr. Argus Smith, Mr. Spence, and others have already directed attention to the immense scale of production of these sulphur-acids, and have even quoted statistical data showing the extent or degree of pollution of the air from this cause in the manufacturing districts of Lancashire. When it is known that the best class of coal and coke contains usually one per cent. of sulphur, and that this proportion reaches a treble equivalent when stated in the form of the final oxidised product—hydrated sulphuric acid—it follows that a ton of coal of this high quality necessarily evolves during its combustion nearly 70 lb. of oil of vitriol. Here, then, is the origin of the sulphates which we find invariably present in the loosened crust of decayed stones, whether of calcareous or magnesian character. I have tested numerous samples of dolomite, Caen, Bath, and Portland stones fresh from the quarry, and in no instance found more than a trace of ready-formed sulphate, whereas scrapings taken from the decayed portions of the stone of the new Palace at Westminster are bitter to the taste in consequence of the comparatively large amount of sulphate of magnesia formed during a few years' exposure to the sulphurous gases occurring in a metropolitan atmosphere. Caen stone from several buildings and localities, Portland stone, and even old faces of chalk cliff in the neighbourhood of Woolwich, were in like manner found to contain appreciable quantities of the sulphate of lime, having undoubtedly a similar origin. A close examination into the circumstances attending the decay of stone at the Houses of Parliament invariably shows an increased liability to corrosion under the projecting eaves and mouldings, and at such sheltered parts of the stone surfaces as are usually covered with soot and dust, and are in a position to retain for the longest period the moistures absorbed during a season of rain. The plain ashlar is throughout very much less affected than the buttresses, gables, and other elaborately carved and highly ornamental portions of the work, which appear to be more assailable by reason of their relatively greater superficies. In many places the disintegrated stone exhibits white crystals of the sulphate of magnesia, which alternately dissolving and recrystallising in the pores of the stone may be conceived to exert a disruptive action sufficient to account for the scaling and fracture of the dolomite, which has been so often made the subject of complaint and regret. With the view of overcoming some of these difficulties, I submitted a plan to the Royal Commissioners charged with inquiring

* Paper read before the British Association at Dundee.

into the decay of stone at Westminster, in May, 1861, which consisted in the application to the cleaned surfaces of the stone of an aqueous solution of superphosphate of lime—a salt remarkable for its action in hardening the surfaces of chalk, Caen stone, or other calcareous building stone to which it may be applied either by brushing or immersion, and which acts upon the carbonate of lime in the stone, giving rise to the formation of Büdker's salt (crystallised diphosphate of lime— 2CaO , HO , $\text{PO}_5 + 4\text{Aq.}$). My suggestion received a practical trial in a competition, to which other five candidates were admitted by the Right Hon. the First Commissioner of Her Majesty's Works in April, 1864; and, in regard to the work executed on that occasion upon three faces of the Westminster Palace, I fearlessly await the Government report. In the mean while, another promising scheme for the treatment of the decayed stone, especially applicable to dolomite, has been submitted by me to the notice of the First Commissioner; but this new proposal has not yet been selected for trial. It consists in the employment of baryta conjointly with the hardening salt, so that a base may be presented which is endowed with the power of destroying the soluble sulphate of magnesia in the pores of the stone, forming with it the remarkably insoluble sulphate of baryta, and at the same time engaging the magnesia in one of its most difficultly soluble combinations. On a recent occasion I have applied this process on a small scale to some Caen stone facings at St. John's Church, Woolwich, which were badly decayed. With reference to the application of the superphosphate to decayed Caen stone, I am able to refer to several successful examples of its use. In the year 1862 I applied the process upon some almshouses forming part of Northfleet College, where the decay has been completely stopped. In 1864 I operated upon a window and buttress of St. John's Church, Woolwich; and in the following year the facade of the Grand Hotel, Brighton, was treated by my process. With respect to Portland stone, the earliest experiments were made at the Army Clothing Establishment, Woolwich, where in 1861 some decayed window-sills were treated, and with perfect success. I have some interesting results to record in connexion with the treatment of Portland stone, which serve to illustrate the increased hardness and strength, and the diminished rate and capacity of water absorption attending the employment of the superphosphate. Small cubes of Portland stone, each of 1.5 in. dimension, were treated with the phosphate solution, and left to dry in the air; these were then subjected to gradually increasing pressure, until crushed between plates of lead in the American testing-machine at the Royal Gun Factory; and the breaking weights of two precisely similar cubes of the native stone were at the same time carefully determined. The results were as follows:

	Crushing weight.
I. Stone, in original condition	3650 lb.
II. Do. do.	3800 „
Mean	3725
III. Stone treated with superphosphate	5375 lb.
IV. Do. do.	5500 „
Mean	5437 „

Thus acquiring an increased strength amounting almost to 50 per cent. The relative hardness of the stone before and after treatment could be readily ascertained by mutual friction of their surfaces, and also by scratching with a pointed instrument of copper, which metal proved to possess a degree of hardness intermediate between the original and treated Portland stones.

The porosity of the stone, as indicated by the amount of water absorbed in equal intervals of time, proved to be greatly diminished in the case of the treated cubes. On this point several experiments were made, the stone being first weighed in the air-dried condition, and then immersed in distilled water at the temperature of sixty degrees Fahrenheit for the several periods named, and the increase of weight in each case noted:

"Whit Bed" Portland.

	Original Stone. Grs.	Treated Stone. Grs.
Weight of Cube (dry)	1421	1420
Water absorbed in 5 min.	70	7
Do. do. 15 min.	91	8
Do. do. 30 min.	91	12
Do. do. 1 hour 30 min.	92	25

"Base Bed" Portland.

	Original Stone. Grs.	Treated Stone. Grs.
Weight of Cube (dry)	1291	1335
Water absorbed in 5 min.	120	20
Do. do. 15 min.	122	33
Do. do. 30 min.	124	50
Do. do. 1 hour 30 min.	126	78

These results have been further controlled by other experiments, in which the same block was used in the original condition, and again after treatment with the superphosphate. It will be noticed that the advantage

of the process is most clearly apparent in the case of the denser and more compact variety of Portland known as the "Whit Bed," which alone is employed for external building purposes; the other, the "Base Bed," is softer, and only fit for internal decoration, and its texture is so porous that in becoming saturated it absorbs nearly ten per cent. of water. Samples of Mansfield dolomite absorbed amounts of water varying in different specimens from six to eight per cent. After treatment by my process the degree of absorption was reduced one-half, and the results were even more favourable in the case of Caen stone. The cost of materials employed in the treatment of stone according to this plan is very trifling, and bears but a small proportion to the cost of labour necessarily expended upon the cleaning and preliminary preparation of the stone before the solution can be applied. One gallon of solution will cover about 300 feet superficial, when two coatings are applied upon Caen or Portland stone. The superphosphate employed must not contain any appreciable amount of sulphuric acid, and the specific gravity of the solution, when diluted for use, should be about 1.100.

In the discussion upon this paper, the president said that the destruction of the Houses of Parliament had been naturally looked upon as a most serious question, and they had looked forward with the greatest possible interest to the result of these experiments, so as to prevent further delay. Mr. Spiller's account of the results of his process were therefore peculiarly interesting to us, and the observations he had made were of considerable value, inasmuch as they afforded some explanation of the cause of the decay. They could see what was peculiar in the decay, and it showed them how important it was to bear that in mind, when they were making arrangements such as those in connexion with the Houses of Parliament. At the time when the erection of these buildings was commenced, immense care was bestowed in the selection of the stone, and the peculiar magnesian limestone was selected because it was found that all the buildings erected of it in the middle ages were in an entire state of preservation. However, it had been seen that these were not exposed to the atmosphere of large towns and other influences peculiar to such populous places, so that when the same stone was built in London it was found not to serve the same end. He was satisfied that the crystallisation of the soluble salt on the pores of the stone subjected to wet and dry weather was a great cause of the disintegration of the stone; but the results obtained by the application of Mr. Spiller's preparation, as illustrated by the several instances shown them that day, were of great importance, and he thought there was little doubt but that the process would meet with general approbation.

Mr. Spence said, as Mr. Spiller had done him the honour of mentioning his name, he would take the opportunity of saying that he thought it was the presence of sulphur amongst smoke that had the influence on the stones. In London they used a larger quantity of coal than in other cities, but then it was of a better quality than in other towns. In Manchester they used coal with 2 per cent. of sulphur; and as they consumed in that city 2,000,000 of tons per year, they put daily 120 tons of sulphuric acid into the atmosphere. This was rather a fearful thing, did they see it fully. Then the first shower that came brought down the acid—it lay under the cornices of the buildings, and he had no doubt the acid then commenced to seize on the stone, especially if there were any iron in it; and so began the disintegration. This was done, and the influence spread abroad. In speaking of the emission of sulphuric acid from smoke, he had, it was known, some peculiar opinions, and these he had published; he did not think the acid came mostly from the black smoke, which was the subject of the prosecutions. He thought that when the black smoke was cleared away they would have the acid stronger than at present—that the invisible smoke was by far most mischievous, as there was still as much sulphuric acid, and that, too, in a more concentrated form, for the carbon was all consumed. He hoped they would yet be able—but the time was perhaps distant—to carry off the acid in the towns' atmosphere, and he thought they would never be right till they got it carried away so far that it would never come near them.

REPORT ON INTERNATIONAL COINAGE BY THE COMMITTEE OF THE BRITISH ASSOCIATION.*

By PROFESSOR LEONE LEVI.

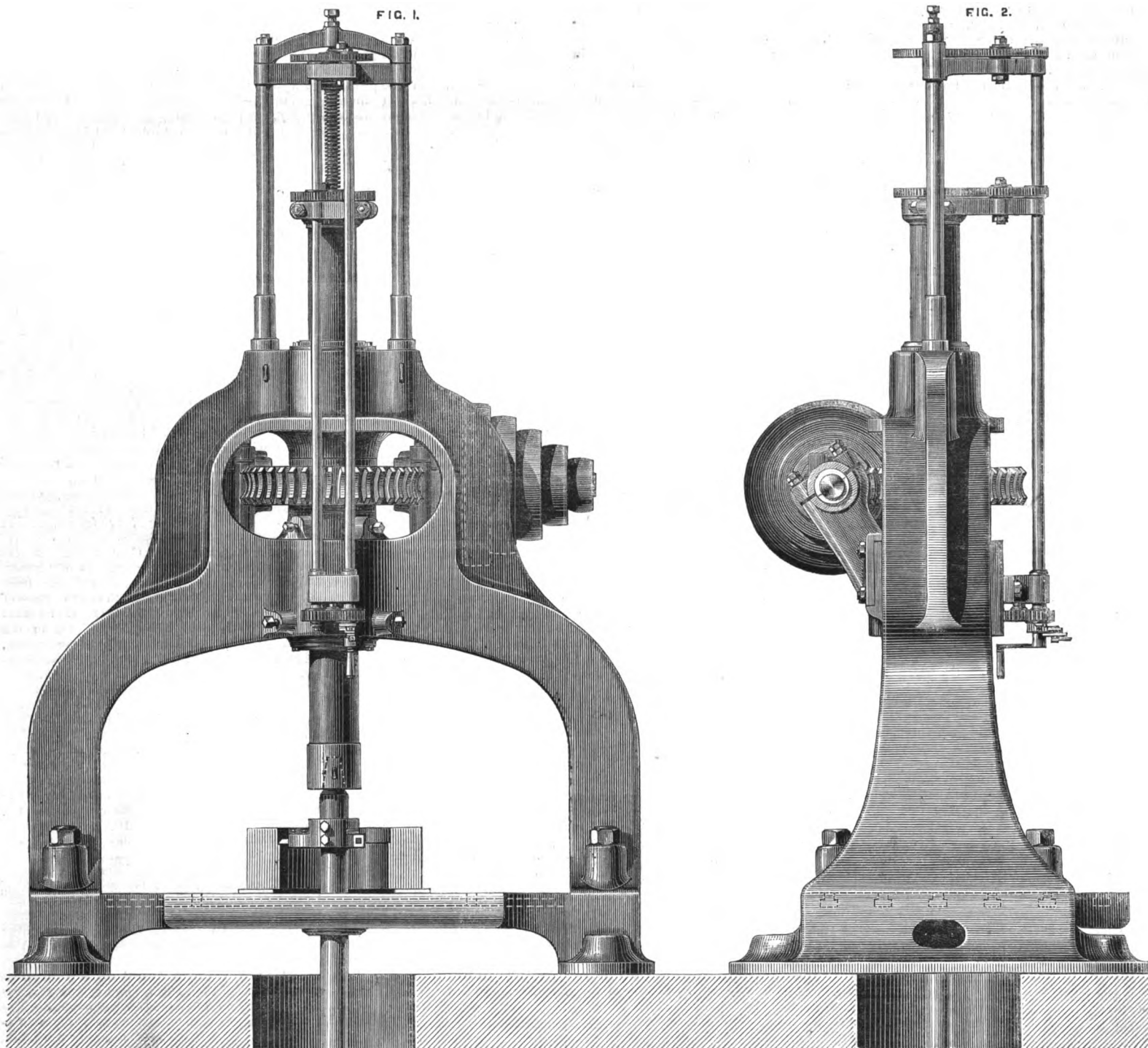
In this report the committee contented themselves by reporting the resolutions of important conferences between representatives of the various nations in Paris during June last, under the presidency of his Imperial Highness Prince Napoleon. We believe these resolutions have not before been published. The United Kingdom are bound to return an answer to the French Government regarding them before February next. At the official international Monetary Conference, it was

* Paper read before the British Association at Dundee.

unanimously agreed:—1. That the monetary unification may more easily be realised by the mutual co-ordination of the existing systems, taking into account the scientific advantages of certain types, and the number of people who have already adopted them, than by the creation of a new system altogether independent of the existing ones. 2. That for this purpose the system agreed upon by the Monetary Convention of 1865 should be taken principally into consideration, subject to any improvement of which it may be capable. It was agreed by all except the representatives from the Netherlands,—3. That it is not possible to attain such identity, or even a partial coincidence, in such monetary types on an extended area, on the basis and on condition of the exclusive adoption of a silver standard, but that it is possible to attain it on the basis of a gold standard, allowing each State to preserve the silver standard in a transitory manner. It was agreed by all except the representatives of Prussia and the United States,—4. That the advantage of internationality which the coinage taken for common standard would possess is not itself a sufficient guarantee for its being maintained in circulation in all the States, but that it is necessary to stipulate that in the countries which continue to use the silver standard only, and in those which have a double standard, the relation between gold and silver should not be established on too low a footing, in order to give due facility for the practical introduction of the gold coinage. It was unanimously agreed—5. That for the success of the monetary unification, it is necessary to fix types having a common denominator for the weight of the gold coin, with an identical fineness of 9-10 fine. It was agreed by a majority of 13 votes against 2—the representative of England and Sweden having voted against, and those of Russia, Bavaria, Baden, Wurtemberg, and Belgium abstaining from voting,—6. That the common denominator should be the piece of five francs. It was unanimously agreed—7. That the gold coin, or the common denominator of five francs, should have legal course in all the States which are mutually bound by the Monetary Convention. It was agreed by all, except the representatives of Prussia, Baden, and Wurtemberg, who abstained from voting,—8. That it would be useful that the types of coinage determined by the Monetary Convention of the 23rd of December, 1865, should be, in the interest of unification, and consequently of reciprocity, completed by new types, as, for example, one of twenty-five francs. But for the proposal that a piece of fifteen francs be also added, the representatives of seven countries voted in favour, those of seven countries voted against, and those of six, including Great Britain, abstained. It was unanimously agreed—9. The Conference expresses the wish that the measures which may be adopted by the Governments of the different States, in order to modify their respective monetary systems in accordance with the basis indicated by the Conference should be made as much as possible the subjects of diplomatic conventions. 10. That soon after the reception of the answers, which may be given by the different States to the official communication which will be made to them of the labours of the Conference by the French Government, that Government may, if necessary, call another Conference. But as to the time by which such answers should be given, the representatives of ten countries voted that it be given before the 15th February proximo; those of five voted that it be given before the 1st October, 1867; those of the United States voted for the 15th May, 1868; and those of Great Britain for the 1st June, 1868. The representatives of France and Spain abstained from voting. The resolutions of the semi-official conference are as follows: "Whereas the adoption of a uniform system of coinage would present evident advantages as regards convenience and economy in the settlement of international exchange, and recommends itself to the attention of all enlightened Governments; whereas, on the other hand, such a desideratum cannot be realised unless several nations are prepared to sacrifice their old and habitual instruments of traffic, whilst it is important that the change may be effected in a gradual and continuous manner, and that the mode of effecting this change should be as simple as possible, and free from all incidental complication. The committee proposes as follows: 1. It is necessary, in the first instance, that the different Governments interested in this question should agree as to the same unit in the issue of their gold coin. 2. It is desirable that this coin be everywhere coined of the same fineness of nine-tenths fine. 3. It is desirable that each Government should introduce, among its gold coins, one piece at least of a value equal to that of one of the pieces in use among the other Governments interested, so that there may be among all the systems a point of common contact, from which each nation may afterwards advance in gradually assimilating its system of coinage to that which may be chosen as a uniform basis. 4. The series of gold coins now in use in France, being adopted by a great part of the population of Europe, is recommended as a basis of the uniform system. 5. Whereas, in consequence of accidental and happy circumstances, the most important monetary units may be adapted to the piece of five francs in gold by means of very small changes, this

VERTICAL BORING-MACHINE AT THE PARIS EXHIBITION.

CONSTRUCTED BY THE SOCIÉTÉ DES CHANTIERS ET ATELIERS DE L'OCEAN, HAVRE; M. F. MAZELINE, ENGINEER.



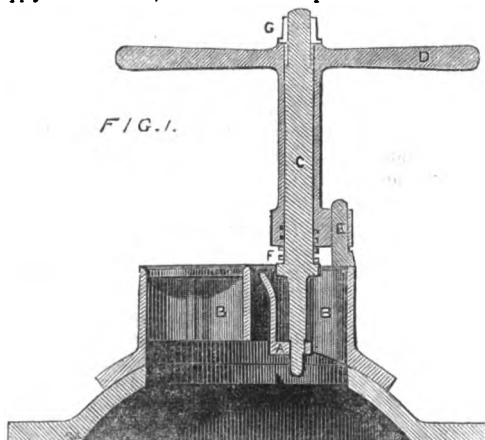
piece seems the most convenient to serve as a basis of a monetary system; and the coins issued upon such a basis may become, as soon as the convenience of the nations interested permit, multiples of this unit. 6. It is desirable that the different Governments should decide that the coins issued by each nation in conformity with the uniform system proposed and agreed should have legal currency in all other countries. 7. It is desirable that the system of double standards be abandoned wherever it yet exists, that the system of decimal numeration be universally adopted, and that the money of all nations be of the same fineness and the same form. 8. It is desirable that the Governments should come to an understanding for adopting common measures of control, so as to guarantee the integrity of the coinage both when issued and whilst in circulation."

KNIFEING MACHINE.

TO THE EDITOR OF ENGINEERING.

SIR,—I have taken the liberty of sending you the enclosed tracings of a tool for facing safety-valve seats, which has been in use for some time in this department. The design, so far as I am aware, is entirely new, and possesses great advantages over the mode generally in use (viz., chucking on the lathe), one man being able to set the tool and face two valve-seats in one hour, and without breaking the dome-cover joint. Fig. 1 is a cross section of a dome cover, with tool in position for working. (See annexed engraving.) The action is easily explained. Thus, in Fig. 1, place the nut, A, inside the valve-seat, B; screw the pillar, C, into the nut, A; then place the box-handle, D, which carries the cutter, E, and is

bored out to receive the spring, F, on to C. Screw the nut, G, to supply the feed to E, and the tool is in perfect order for work-



ing. This tool is exceedingly valuable in railway establishments, where safety-valve seats frequently require facing. The work done is excellent.

I am, Sir, yours truly,

J. W. MANN.

York Locomotive Department,
North-Eastern Railway, September 7, 1867.

BORING-MACHINE.

We have repeatedly noticed in our articles on the Paris Exhibition, the well-designed and neatly constructed engineers' tools exhibited at Paris by the Société des Chantiers et Ateliers de l'Océan, the successors of the well-known firm of Messrs. Mazeline and Co., of Havre; and we now give an engraving of a large boring-machine constructed by them, this machine being specially intended for boring railway wheels, or large spur wheels and pulleys. It will take in articles up to 5 ft. 6 in. in diameter, and of a maximum depth of 2 ft. 6 in. The boring bar is carried by two very strong and deep bearings, and it derives its motion from a worm-wheel, which is driven by a worm fixed to the end of the driving-shaft carrying the cone pulleys. The feed motion is self-acting, and is derived from the boring bar by gearing which works the central feed screw of this bar in the usual way. The general design of the machine is neat, and the frame, which is hollow, is cast in one piece with the base-plate.

THE CUBA AND FLORIDA CABLE.—The Cuban telegraph cable, although the ocean portion is complete, is not yet opened to the public, for the reason that the section of cable which was to have been laid between Punta Rosa and Key West, Florida, was nearly all used between Punta Rosa and Cuba. The officers, before laying the remainder, are awaiting authority to do so from the Cuba Cable Company, as it will probably not reach all the way to Key West, and may have to be buoyed. This causes delay in opening the line to the public, but it is reported that the portion already laid is in perfect order.

THE PARIS EXHIBITION.—It is now stated that the iron-work of the Paris Exhibition has been sold for exportation to America. What an elephant for an American purchase!

PUBLISHER'S ANNOUNCEMENT.

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ENGINEERING.

FRIDAY, SEPTEMBER 13, 1867.

THE MONT CENIS RAILWAY.

THE complicated combination of locomotive machinery employed for working the Mont Cenis Railway cannot, in the nature of things, long continue to work satisfactorily. Our readers will find it clearly depicted and described in pages 284 and 285 of our last volume; and while they will, at first, possibly have some little difficulty in following out the motions of the various parts, they will, when the engine is once understood, perceive that it embodies much that is objectionable. Not but that it is, perhaps, as good a design as could be proposed for working the centre rail; but the whole system is necessarily faulty, and tolerable only in view of its working upon inclines of exceptional steepness. All complication is objectionable, and this engine is conspicuously complicated, even to the least practised eye. In an ordinary six-coupled engine the motion of the pistons is communicated to the wheels by and through, in all, sixteen crosshead pins, crank pins, and journals. In the Mont Cenis engine the number of pins and journals is forty-six, and some of these journals are anything but readily accessible for oiling. On extensive portions of the line, where the gradient is flatter than 1 in 40, the mid rail is not laid, and the gripping-wheels, although always going when the engine is at work, take no bearing. The driving-wheels, however, are always working under the full weight of the engine, and therefore wearing away their little 2 ft. 4 in. tyres considerably faster than those of the gripping-wheels. It is, indeed, one of the faults of the system that it compels the use of excessively small driving-wheels, since, as long as the gripping-wheels are worked from the same pistons, they must be of the same diameter, and anything like 5 ft. gripping-wheels, the pair extending 10 ft. 6 in. horizontally across the line, and in the range of stray stones, &c., would be obviously out of the question. When the driving-tyres are worn $\frac{1}{2}$ in. smaller in diameter than the gripping-wheels—corresponding to a difference of 1 in. with 4 ft. 8 in. wheels, or to $1\frac{1}{2}$ in. with 7 ft. wheels—the reader may imagine the grinding and slipping that will be always going on.

Curiously, the greatest complication attaches to the motion for working the ordinary driving-wheels, which are always going on all parts of the line, whereas that for working the gripping-wheels used only on the steeper portions is much more direct. For working the ordinary driving-wheels there is first a pair of links from each crosshead, working the lower end of a vibrating arm, the shaft of which is supported in bearings above. This shaft has a corresponding vibrating arm on its outer end, and from this a link extends to and works another crosshead moving between a pair of guide-bars outside the wheels, and from this crosshead a connecting-rod works the driving-wheel. What could be more sweetly simple than this? Seven opportunities for lost motion, instead of two, between each piston and driving-wheel! All this is to take place at every 3 ft. 8 in. as measured along the rail,

or 1440 times a mile, or 240 times a minute at 10 miles an hour. The driver, we fear, will find his post no sinecure, and even a North-Eastern man, sacked by his directors, and most anxious for a job, need not wish to stand in his shoes.

The gripping-wheels, as shown in the drawings to which we have referred, are supported in a framing which is not nearly stiff enough for the strains to which, when the wheels are set up with a pressure of 24 tons, the whole structure will be exposed. When, too, the gripping-wheels are working under the full pressure of their springs, they must greatly interfere with the easy rise and fall of the engine on its own bearing springs, inasmuch as only a very considerable force would allow of the corresponding vertical traverse of the gripping-wheels on the mid-rail. Taking their adhesion as five tons (as it may be, under 24 tons pressure from their springs), it would require this force to move the engine up or down, even through an inch or half an inch, in obedience to the action of the bearing springs, when passing over any irregularity on the line. To a great extent, the gripping-wheels, when at work, must neutralise the action of the bearing springs, and if indeed the parallelism of the former with the mid-rail is not strictly preserved, and the mid-rail and side-rails are not maintained at exactly the same level, it is easy to see that the effect of the gripping-wheels might be either to tend to lift the engine off the outer rails, or to increase its pressure upon them, and that in either case great strains and undue wear would be thrown upon the permanent way.

Sand cannot well be applied to the gripping-wheels to increase their bite, and, indeed, with such a microcosm of machinery under the boiler, it would be better if sand were not used at all, and if all the dusty showers attending the summer winds of the lower Alps could be suspended or diverted in favour of this pretty engine.

We have said nothing of the possible difficulty of keeping three rails in exactly the same gauge and level. This would of course be essential to the success of the whole scheme.

Under the most favourable circumstances an engine with all its wheels coupled, and having a steam power corresponding to its full adhesion, could ascend an incline of 1 in 4, and it could therefore draw nearly, or quite, twice its own weight behind it up a slope of 1 in 12. We have expressed our belief, in another column, that the Mont Cenis engines will generally be worked up 1 in 12 by the simple adhesion of their own driving-wheels, and we cannot foresee more than a short and critical childhood for the whole scheme of the centre rail, which has been engrafted upon the working of Alpine railways. We have shown, on another page, what other and less complicated systems of working might have been adopted—the one of locomotive carriages in which the whole weight of passengers and goods is utilised for adhesion, the other a plan of pneumatic working, which, although original with ourselves, possesses advantages which will be recognised at first sight. With so many and more promising alternative modes of climbing steep mountain slopes, we are convinced that a few months' experience of the mid-rail system will suffice to show its inexpediency.

THE CORLISS ENGINE.

THE almost interminable dialectics of mechanical controversy with which our pages have been overflowed by the respective assailants and partisans of the Corliss engine will have edified some and wearied many of our readers. Victory is claimed on each side, boldly so by "Observer," who led the attack; and it would be a nice yet thankless task for one who derived his knowledge of the engine from this discussion alone to determine which side really has the best of it. As to the merits or otherwise of the engine, two courses of inquiry were open. In one direction inquiry would proceed upon the well-settled principles which determine the conditions of steam economy—principles whereby the relative excellence of all engines may be investigated. The other line of inquiry was that addressed to the history of, and accumulated experience with, this engine.

The peculiarity of the Corliss engine is wholly in the mechanism which regulates the distribution of the steam, and it contains no special excellence or defect, distinguishing it by the name of its inventor, apart from the structure, working, and results of the apparatus of distribution—in other words, the valve gear. The question is not one of boilers, nor of high-pressure or low-pressure steam, of condensation or non-condensation, of superheating, of piston speed, of

steam-jacketing, of excellence of mechanical construction, nor even a question of expansion, although touching very closely upon it. Mr. Corliss, indeed, to the writer's knowledge, has seldom or never worked his engines with steam of very high pressure, seldom more than 50 lb. or 60 lb., he has built but few condensing engines, and, speaking generally, or without regard to a few exceptional cases, has never superheated his steam nor employed steam-jackets. The consideration of the value of his valve gear must be kept distinct, therefore, from all consideration of the economy of fuel of the engine as a whole. We must suppose, that to any given engine, working with an ascertained consumption of fuel, his gear is applied. It will be found, at once, that, as compared with the ordinary valves, his open and close quicker and with less friction, that they waste less steam (indeed, an exceedingly small quantity) in the steam-ports, that they waste no steam by wire-drawing, and that they give a minimum back pressure and practically no compression. Further than this, they measure out, upon each stroke, exactly the amount of steam required on that stroke to keep the speed of the engine at its prescribed rate, no matter (within certain very wide limits) what may be the load upon the driving-pulley. If a great resistance comes upon the engine, the steam is admitted for the full stroke of the piston; if the ordinary amount of work is being done, the admission is but from one-tenth to one-third stroke, according as the engine has been proportioned to its average work; and if little or no work, beyond overcoming its own friction, is to be done, the piston gets just a sip of steam on each stroke, just enough to keep it moving, and that always at the prescribed speed. There can be no dispute, among those who are properly acquainted with the Corliss valve-gear, that it actually *does* what we have stated, and there can be no dispute, among those who have a proper knowledge of the principles of the steam-engine, that all that is thus done by the Corliss valve-gear is conducive to economy. That the same cannot be done by other arrangements we will not say, but *it is not* done in any other engines except by much the same means. In so far as we have explained the Corliss engine, it is more economical than the common slide-valve engine, but the proof does not lay in any random comparison of the consumption of fuel by Corliss and other engines taken promiscuously, and working under different conditions as regards boilers, quality of coal, pressure, and dryness of steam, condensation, &c. It would be mechanically possible to construct and to work an ordinary slide-valve engine with less than 2 lb. of coal per indicated horse power per hour, and to immediately effect a further saving by substituting the Corliss valve-gear, or other gear upon the same general principle, and merely because, to all other conditions of economy, the Corliss valve-gear superadds further and unquestionable conditions effecting a saving of steam. There is nothing here to warrant the dogmatic condemnation of one party or the inconsiderate partisanship of the other. It requires but a moderate and ordinary knowledge of the steam-engine to understand the merits of this question.

Beyond this line of inquiry there is that as to the history and results of the Corliss engine. It is eighteen years old, and has sustained abroad the closest competition with the "ordinary" or "common" slide-valve engine, and has displaced many in close competitive trials, and it has been made and introduced to the number of many more than a thousand. There is no patent upon the engine in England, except upon certain details, in no way affecting its general principle, added by Mr. Spencer and Inglis. Any maker is otherwise free to make the Corliss engine, and we find a number of respectable firms already engaged in their manufacture, having satisfied themselves that these engines possess certain advantages over other engines. This kind of commercial experience is not to be altogether ignored, even in a scientific discussion; for it is a necessary qualification of the engineer to be a man of the world, and a man of business, as well as a man of science.

That the Corliss valve-gear has more parts than the ordinary slide-valve gear admits of no dispute, and it is thus, to a certain extent, complicated. Yet the moving parts are subjected to but a very small amount of strain, and we can say, of our knowledge, which must go for something in this discussion, that the Corliss valve-gear is durable and efficient in action. It is now successfully driving many hundreds of factories where a break-down or interruption would be attended with great and especial inconvenience, and we can testify that, in such positions, it enjoys the full confidence of those who have long relied upon its certainty of working.