

THE RODMAN GUN.

THE "big chunk of iron with a hole in it," as the American *Army and Navy Journal* admirably designates the 15-inch, or, as the American ordnance engineers have it, the XV-inch Rodman gun, was again tried, last week, at Shoeburyness, not against a target, however, but with 100 lb. of American powder, and at 32 deg. elevation, as a test, we suppose, of its strength. When last tried with 60 lb. of American powder, an initial velocity of 1170 ft. was obtained. Had the 100 lb. charge produced the same amount of work for each pound of powder, the velocity would have been 1510 ft.; but it was actually somewhat greater, being 1538 ft., this being a very high rate of velocity, and about the same as that from the 68-pounder gun fired with 16 lb. charges. A cast-iron 450 lb. shot at this velocity would possess 7405 foot-tons of work, whereas the 250 lb. shot of the 9 in. rifled gun, fired with 43 lb. of powder, has but 3100 foot-tons of work. Why was not this terrific amount of work thrown upon a target? The strength of the gun would not, it is true, have been so severely tested, inasmuch as on the trial the gun was elevated 32 deg., whereas in firing at a target it would be laid point blank. Are the officials at Shoeburyness afraid of their targets? If they are, let them wait a month, till the Yankee newspapers have reached us with their spicy comments, and, as in the great Herring-Chatwood competition, proclaimed another great American victory over the Britishers! Let us take the strength of the gun as proved, and blaze away at the old representative target—the Warrior's. It is clear that the "XV-in. gun" does not burst so easily as was supposed. It is not much more than a year since an American ordnance engineer, of some note, said to us, concerning these guns, "Bust! why, d—n 'em, they bust laying on the ground; they bust in the lathes. Yes! fire 'em! I guess so. Why, they bust every three shots!" A gun, however, that will bear 100 lb. even of American powder, with a 450 lb. shot over it, and laid at 32 deg. elevation, is not to be despised. It sent its huge shot, the other day, 7680 yards, or nearly 4 miles 3 furlongs, by far the greatest range to which a round shot was ever thrown in this kingdom. As a matter of fact, we believe no one of these big guns was ever burst in service; but, of course, like everything else, they have their limits of endurance; and when they do go, in action, God help the gunners!—everybody, indeed, within the turret. For they will go all at once, like a boiler explosion.

The cast-iron shot, even when driven by 100 lb. of powder, would, it is reasonable to suppose, break up on striking the target. But there is no need of speculation when the trial can be so readily made; and, again, we ask why has it not been made? Why are we still in our third month of ignorance as to what the American gun will really do, and really stand? True, it is a costly subject for experiment, but we bought it for the double purpose of testing its destructive power and its own resistance to powder. If cast-iron shot break up, steel can, of course, be used; and it is not even certain that their cost would prevent their adoption. Let us see what the 100 lb. of powder can do, both against the 453 lb. cast-iron shot and the 498 lb. steel shot.

THE 15-INCH ARMOUR PLATE.

SIR JOHN BROWN has signalled his new knight-hood by rolling an armour plate 15 in. thick, and weighing 21 tons, a plate over 20 ft. long and 4 ft. wide. The plate is pronounced sound, although this can only be fully ascertained by cutting it up, and it is not impossible that a portion of it may be brought under the fire of the 9 in. gun, firing Palliser shot. The plate, it is to be remembered, was produced with the same furnaces and rolls as those put up for making 4½ in. to 9 in. plates, and it cannot therefore be said to represent any new attainment in the means of producing heavy plates. Such plates have not been heretofore rolled, only because they have not been asked for. No ship yet built could carry them; but it is now possible that they may be adopted for casing forts. Messrs. Cammell and Co. have already made sample plates 14 in. thick, and, with the same plant, it is of course as easy to roll a 15 in. plate at the Cyclops Works, or at Barrow, as at the Atlas Works. The one rolled on Friday consisted of five 3 in. and one 6 in. plates laid up in a pile 21 in. thick and welded together by rolling down with a reduction of hardly more than one-fourth the original total thickness. The absolute reduction in thickness is indeed hardly greater than that in rolling 4½ in. plates, which are rolled down from four 2½ in. plates piled together, and having therefore a total thickness of 10 in. To bear this distinctly in mind is in no way to really disparage the feat of rolling a

15 in. plate; but we are not to forget that there are uninformed persons who imagine that the difficulty in making tough rolled plates increases at least in proportion to their thickness; if not, like their resistance to shot, as the square of their thickness. Only let the War Office or the Admiralty order 15 in. plates, and a number of firms would be found ready, with long-existing plant, to supply them.

The *Times* has a really clever article describing the rolling on Friday last—an article after the manner of Victor Hugo, and likely to produce a sensation, and a desirable and genuine sensation, among the multitude, who know so little of iron-making. It hardly needs correction where it says the plates are rolled between steel rollers, as our readers know they are of chilled iron. The *Times* gives the credit of the victory of rolled r. hammered plates to the Atlas Works, not undeservedly, we think. But we are reminded of the effusion of a certain poetic wag, in Sheffield, in 1861, who sang, to the air of "The King of the Cannibal Islands:"

"Now hammer'd iron's brittle stuff;
When roll'd, it's fibrous, strong, and tough—
At least they say so—that's enough—
At the Atlas Steel and Spring Works."

The article to which we have referred thus describes the provisions for obtaining a good heat among the slabs of which the single plate is formed:

"One of the great difficulties in making these thick armour-plates was found to be that of securing a uniform heat—that is to say, a heat which should penetrate to the centre of the mass, so as to secure a perfect weld without being so great and long-sustained as to melt the upper layers. This difficulty is overcome most ingeniously at the Atlas Works. Between each layer of slabs a number of cubes of highly carbonised iron about an inch square are placed, so as to keep each slab apart from the others. This allows the whole mass of flame and heat to circulate freely between them, so that all attain the same degree of heat at almost the same time. As the intense ardency of the furnace increases these cubes are gradually melted. In the act of melting they restore to a certain degree the carbon which has been burnt out of the slabs by previous processes, and as they melt allow each slab to settle down, when, like a cement, their melted metal forms a perfect weld. It is not till this has been effected, and the now perfect plate is heated to an almost blinding whiteness, that the mass is withdrawn from the furnace and has to be rolled."

ALPINE CLIMBING.

NAPOLEON THE FIRST had no railway engineers to help his troops, either over or through Mont Cenis, into Italy. The present emperor, with the grander resources of modern science at his command, has promoted the great tunnel line, under that mountain, from the first year of his reign—as far back as the days of the Chevalier Maus, who was to have bored through at the rate of a mile and a half a year. Nowhere else was a railway ever attempted in the face of a greater single obstacle. The mountain rises 6700 ft., or say a mile and a quarter, above the sea, 2700 ft. of this elevation being attained within four miles of either side of the summit. M. Sommeiller (by no means a sleeper in his works) is boring straight through on a line of rather more than 7½ miles. The work is carried on at a great expenditure of time and money, and when finished it will have a gradient of 1 in 45 for half its length, and although there is a difference of level of 439 ft. between its two ends, the ventilation can hardly be all that is desired, especially as there will be no shafts, and as there is a summit at the mid-length of the tunnel, although this is but 12 ft. higher than the Italian or Bardonnèche end. Mr. Brunlees and Mr. Fell, in the mean time, have already opened a line over the mountain, 43 miles in length, and of which no less than 9 miles are in covered way. This line is of but 3 ft. 7½ in. gauge. While Sommeiller was boring through, they resolved to climb up, following the zigzag diligence road already made—like that which runs to and fro up St. Boniface Down, at the back of Ventnor. Much of the ascent is at the rate of 1 in 12, and the ends of the zigzags, instead of being connected by switches, are bent to two-chain curves. In one place, we believe, 1700 ft. rise is gained in this way, with a line of nearly four miles, although the straight distance up the slope of the hill is hardly more than a mile.

But when it comes to climbing mountains, there are many ways, and we have much reason for doubting whether Mr. Fell's is altogether the best. That it is mechanically practicable there is of course no doubt; indeed this was proved long before Mr. Fell adopted it, for the well-known centre-rail and gripping-rollers is an old plan, first patented by Mr. Vignoles, and first practically worked out, in 1850, by George Escol Sellers, of Cincinnati, U.S., who built several locomotives, with five cylinders and gripping rollers, for the mid-rail. Some of these engines we personally and carefully examined in 1853, and others in 1856.

It is to be remembered that locomotives having all their wheels (eight in number) coupled together have worked by their own adhesion up inclines of 1 in 10, drawing their tender and a railway wagon behind them. A series of temporary inclines of 1 in 10, connected by zigzags, were thus worked, in the winter of 1852-53, on the line of the Baltimore and Ohio Railway, U.S., during the construction of one of the tunnels of that line, in the Alleghany mountains. This mode of working continued for several weeks, and without accident. But our present purpose is to consider special modes of working railway carriages up very steep inclines.

First of all, there is rope traction. We have colliery engines winding 1000 tons of coal daily, or say 2000 tons of total weight, from a depth of even 1700 ft., the same as Mr. Fell's principal rise; and the engines at the Dukinfield pit wind from a depth of 2060 ft. Here are more than 4,000,000 foot-tons of work done daily, and with comparative safety, although the ropes do break sometimes, as was the case, indeed, the other day, at Dukinfield, the deepest pit in the whole world. Going from coal-pits to railways, Mr. Brunlees himself, the engineer to the Mont Cenis Railway, has a connected series of passenger railway inclines at work up the Serra do Cubatão, in Brazil, nearly five miles in total length, and rising 2550 ft., the average inclination being 1 in 9½. The objections to the rope are its liability to wear and crystallisation, and the fatal consequences of its breakage. The steeper the incline, however, and supposing the same given strain on the rope in all cases, the less the mechanical wear; indeed, ropes winding vertically, on large drums, wear very slowly, although they fail nevertheless after a certain time, and it is always, perhaps, with some little misgiving that the engineer trusts passenger trains to a rope at all.

There is another mode of using the rope, that proposed and patented by Mr. David Greig, of the Steam Plough Works, Leeds. It is to have a fixed rope, and to climb up it by means of a travelling engine with a clip drum. Mr. Greig, indeed, hit off this ingenious application of the invention of his former partner, the late Mr. John Fowler, while himself crossing Mont Cenis. But it is an object, in using a rope, to get rid of the travelling engine altogether, with its weight and resistance from gravity. Mr. Fell's 17 ton engines throw away 23,900 foot-tons of work in overcoming their own gravity on the 1700 ft. rise to which we have referred, and of their whole weight, 2½ tons is special gear for working on the mid-rail, and which is literally dead weight on all other portions of the line. It is not improbable, however, that Mr. Greig's expedient was intended as a substitute for the mid-rail. In this case, we fear it could not well be worked around the curves, as unless the rope were divided into separate lengths for the straight portions only, it would require special and probably complicated and unsatisfactory arrangements for working it around 2-chain curves. In this case, too, the engines would work, not only by their bite upon the rope, but by the adhesion also of their driving wheels upon the outer or ordinary rails. And here a fresh difficulty would arise, for the rope would stretch, to a certain extent, when the clip drum first grasped it, and by its own inherent elasticity the rope would alternately extend and contract, to a certain extent, while the engine was working up its length; a result due to the combined effects of varying strains and to a considerable compensation always going on in the rope itself. But as the rails would neither stretch nor contract, and as the driving wheels ought never to slip (and if they did, and the clip drum was worked from the same motion, that would slip too), it is clear that a strife would often be going on between the rail and the rope, sometimes one and sometimes the other doing the whole work. The rope, too, would be found to crystallise, or, at least, to undergo the molecular change commonly designated by that term, with nearly the same readiness as if worked over winding drums.

Another mode of climbing steep gradients is that of making the whole weight of the train available for adhesion, instead of relying only on that of the locomotive. M. Flachet proposed, in 1859, to work over the Alps with rolling stock, of which each carriage had steam cylinders and driving gear, the steam being taken through jointed pipes from a single large boiler, mounted upon a carriage also fitted with cylinders and driving gear of a strength to work up its own adhesion. Another plan is to make each carriage a complete locomotive, supporting it upon two steam-worked bogies, which would readily work around short curves (½ chains radius on the 3 ft. 7½ in. gauge) even if placed at a considerable distance apart.

The bogies might have either four or six wheels each, according to the distribution of weight required, the present 17 ton engines at Mont Cenis resting upon four wheels only. The objections to M. Flachet's plan are the greater complication as compared with ordinary engines, and the loss for the purposes of draught of the steam worked in the carriages, as well as the certainty of a considerable loss in winter by condensation in a long series of jointed pipes, and probably a constant considerable loss by leakage. The objections to the other plan are fewer, and, unless it be an objection on the part of passengers to ride in such near neighbourhood of the boiler, this would probably be found the very best system of working inclines of from 1 in 10 to 1 in 20, the limit of inclination up which such a steam-carriage could work on a good dry rail being perhaps 1 in 5. Passengers make no objection to their proximity to the boiler on board steamboats, and they would doubtless soon reconcile themselves to the locomotive boiler, separated from them by the water-tank and coal-bunker and by a luggage compartment. But one boiler would be required for working both bogies of the carriage. In favourable weather such a carriage could draw an ordinary railway carriage, or possibly two, behind it, and that up a gradient of even 1 in 10 or 1 in 12.

Other plans for steep climbing are those for increasing the adhesion of the wheels of ordinary locomotives. One is that of one or more V grooves in either the tyre or the rail. This plan would no doubt secure a powerful "bite;" indeed, Mr. Robertson, of Glasgow, has his V-groove frictional gearing in use for driving rolling-mills. But for railways the plan is open to many objections. First, it requires the maintenance of an absolute uniformity of gauge, to a nicety unattainable, we fear, upon a railway. One inventor, we are aware, proposes to allow one tyre of each pair of driving or coupled wheels to slide laterally on the wheel, so as to adjust itself to any slight inequality in the gauge; but this sliding of a tyre, fitting its wheel with even tolerable closeness, and having its full load of four or five tons upon it, would be clearly impossible, especially as the force from which sliding is expected would be applied at but one point in the circumference. We are saying nothing of the safety or otherwise of tyres fitting so loosely as to admit of even the idea of lateral sliding. A further obvious objection is that of the grinding of V's and V-grooves due to the difference of diameters, and that in some cases one wheel of a pair would be found bearing on the larger and the other on the smaller diameter of the groove, making one wheel, in effect, 2, 3, or more inches larger than the other, and probably rolling the engine out of the grooves and off the line. The grooves, if made in the rails, would fill up, and also probably cause the rails to split. If the tyres were grooved, they would inevitably split. The whole scheme, indeed, although frequently proposed, is one which cannot bear consideration. Another mode of increasing the adhesion of the driving wheels is that proposed by Mr. Page, who has worked a loaded model locomotive up an incline of 1 in 2½, in our presence. While he would reserve ordinary rails for the carriages he proposes to run the engine up broad tramways of timber, the surface of the driving wheels being somewhat roughened to secure a better bite. It is clear, however, that the timber would be rapidly destroyed, the joints giving especial trouble, and it is not certain even that the full adhesion could be depended upon with snow and ice on the wood.

It has been proposed to run the carriages on ordinary rails, and to draw them by traction engines working on the ballast between or outside the rails. As the speeds on the Mont Cenis Railway are slow, not more than ten miles an hour on the steep inclines, this plan would be feasible, no doubt, although it would involve changes of engines on a journey, as traction engines would be too slow and wasteful upon the flatter portions of the line.

The plan of magnetising the tyres of the driving wheels has been tried with but indifferent success.

Finally, there is another mode of climbing in favour of which much may be said, a mode which answers best on the very steepest inclines, or rather on vertical lifts. This is by the pneumatic hoist. In a 10 ft. tube, with a pressure of but 1 lb. per square inch, we have a propelling force of 11,310 lb., which would carry a gross load of 20 tons up an incline of 1 in 4, supposing the mountain to be as steep. To drive this load at ten miles an hour would require about 300 horse power, irrespective of losses by friction of engines, leakage of air, &c.; but the effort would be but for a few minutes, as, at this rate, 6800 ft. of tube, rising 1700 ft., would be traversed in less than eight minutes. A blowing-engine having a 15 ft. air-piston, and a 40 in. steam-

piston, working with 50 lb. of steam, would follow up a train at ten miles an hour, or 880 ft. per minute, the blowing-piston moving at about 400 ft. per minute. And only a blowing-engine would answer, a fan upon Mr. Rammell's plan being wholly out of the question for such a pressure. It might be preferred to store the compressed air in an air-holder, rising and falling in a tank like a gas-holder, and to send up trains from this. A 10 ft. tube, 6800 ft. long, would require 534,072 cubic feet of blast, equal to the capacity of an air-holder 120 ft. in diameter and 47 ft. 6 in. deep, the holder weighing 725 tons, to balance the pressure within it. It would be only by the use of an air-holder at the foot of each incline that the system would be rendered entirely independent of accidents to the blowing-engines, the only danger then remaining being that of the explosion of the air-holder, which, if 120 ft. in diameter, and made of ½ in. iron, would have a diametrical strain of 1440 lb. only per square inch of the solid plates, or, say, 1 ton per square inch of net section between the rivet holes. The upper portion would be made hemispherical. Even if made of ½ in. iron throughout, the holder would require about 450 tons of additional weighting, or to weigh 725 tons in all, in order to keep down against the pressure, and to force out the blast at 1 lb. per square inch.

When a train of the regulation weight, for the weight would require to be regulated nicely, was run up to the mouth of the tube, a suitable piston with a slight amount of windage would be affixed to each end carriage, and the doors of the tube would then be shut. Except for the train lights, the passengers would be in darkness; but the windage of the pistons would secure plenty of ventilation, and no doubt the escape of blast past the pistons, even at 1 lb. pressure per square inch, would make a good deal of noise. When the train reached the short level at the summit, a communication would be opened between the ascending and descending tubes, giving a mean pressure of nearly ½ lb. per inch in both, thus preventing over-running; the communication would then be closed, and the carriages would then be let down by their own gravity, checked at first by their brakes, and immediately afterwards by the compressed air, which when the train had moved through about ¾th the length of the tube, or 230 ft. in a tube of 6800 ft. length, would have a pressure of 1 lb. on the lower side of the train. This compressed air would then be let into the air-holder at the foot of the tube, and at a rate which would exactly regulate the speed of the descending train. The amount of air-pumping thus required would never be considerable after the first train had gone over. The skilful engineer will perceive for himself much of the detail required for working out such a plan, and, just as safety gear is provided in many mine-cages, he will see the applicability of much the same contrivances in the tubes to act in case of the failure of the air-holders, or in any other improbable emergency. The objection to the whole system is the first cost of the tubes, air-holders, and blowing-engines; but considering that the length of the tubes would be but one-third that of a railway overcoming the same elevation by inclines of 1 in 12, and but one-seventh that of a railway line inclined at the rate of 1 in 28, and that in the present Mont Cenis line nine miles are in covered way, it is not certain that the cost would be much greater, while it is certain that the working expenses, as well as the time of transit, would be much less.

The mid-rail system is avowedly a temporary expedient for working an exceptional line, which will be superseded in a few years by the great tunnel, and we believe its success must be as temporary as its expediency. It will be found, no doubt, that the adhesion is sufficient, in most cases, without working the gripping wheels at all, the engine taking up a load equal at least to its own weight. When, however, the gripping wheels are used, it will be found that the eight tyres are of unequal diameter, the ordinary driving-wheel tyres always wearing much faster than those of the gripping wheels. The lost motion, too, in all the wonderful gear we illustrated at page 254 of our last volume, and the innumerable and almost inaccessible parts requiring oiling, lead us to look with much doubt upon the whole system of the mid-rail and gripping wheels. As we have already said, the line, even with its present gradients of 1 in 12, may be, and probably will be, worked without it; and it will be used, if at all, only as a "brake," for which, even where no brake is wanted, the whole system appears admirably well designed.

IRON IN FRANCE.—The make of iron in France declined in the first six months of this year to the extent of about 4 per cent. as compared with the corresponding period of 1866.

BESSEMER STEEL-WORKS.

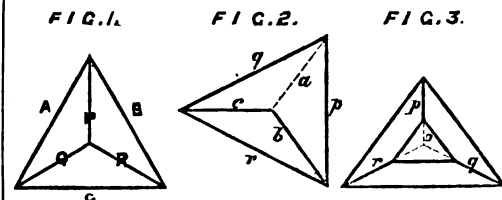
THERE are now upwards of a dozen makers of Bessemer steel in the kingdom, employing very nearly fifty converters of from 3 tons to 10 tons each. The largest works are at Barrow, where, by the way, there are to be great doings on the 19th inst., on the occasion of opening the Barrow and Furness Railway. There are at Barrow ten converters, six of these of 7 tons each, and four of 5 tons. The next largest plant is to be found at Dowlais, where there are six converters of 5 tons, and at the Atlas Works (Sir John Brown and Co.), Sheffield, where there are two 10-ton and two 5-ton converters. Messrs. Cammell and Co. may be said, however, to have a still larger plant, although not at a single establishment; for they have four 7-ton converters at Penistone, and two 4-ton converters at their Cyclops Works, in Sheffield. The Lancashire Steel Works, at Manchester, were laid out for eight converters of 5 tons; but we believe only two have been set to work. The two next largest establishments are the Crewe steel-works of the London and North-Western Railway, at Crewe, and the works of the Manchester Railway Plant Company, at Manchester, each of which has four 5-ton converters. Next are the Bolton Steel and Iron Company's Works, at Bolton, and the Ebbw Vale Company's, at Ebbw Vale, with a pair each of 5-ton converters. Messrs. Henry Bessemer and Co., of Sheffield, have a pair of converters, but we cannot at this moment say of what size. Messrs. Samuel Fox and Co., of Deepcar, near Sheffield, have a pair of 3-ton converters, and there is a pair of the same size at the Old Park Ironworks, Wednesbury. Mr. John M. Rowan, of Glasgow, has a single 3-ton converter. Bessemer plant was fitted up some years ago at Tow Law, in Durham; but we believe it has never been set to work.

Besides the above-named works, a new establishment, with a pair of converters, and possessing the most improved plant, will shortly commence working at East Greenwich. These are the works of Messrs. Bessemer Brothers (the sons of Mr. Henry Bessemer), and have been erected under the constant superintendence of the last-named gentleman himself.

THEORY OF DIAGRAMS OF FORCES AS APPLIED TO ROOFS AND BRIDGES.*

By PROFESSOR J. CLERK MAXWELL, F.R.S.

IN the construction of roofs and bridges, the general practice of ascertaining the strains upon the different elements of these structures by calculation involves a great deal of inconvenience and loss of time on account of the necessity of carrying the arithmetical operations far beyond the limits of accuracy which are actually wanted in practice. It has therefore been proposed by several writers to solve the problem graphically, and various modes of constructing diagrams of forces may be found in books on suspension bridges, &c. A further extension of the principle of the diagram of forces to polygonal frames has been made by Professor Rankine in his "Applied Mechanics;" but the author has succeeded in generalising this theory, and making it applicable to all kinds of frames. The abstract mathematical theory of these diagrams has been first published in the *Philosophical Magazine* in April, 1864. The diagrams in question are reciprocal figures. They are arrived at by reducing the frame to be constructed to a skeleton of straight lines, and supposing all the weights applied at the joints, a supposition which is perfectly admissible, since the stiffness or strength of each single part has nothing to do with the problem under consideration. To explain the nature of reciprocal diagrams, the Figs. 1 and 2 give an illustration of the simplest form. In Fig. 1 a triangular frame, ABC, is supposed to be acted upon by three forces—say a stiff triangle pulled by three strings

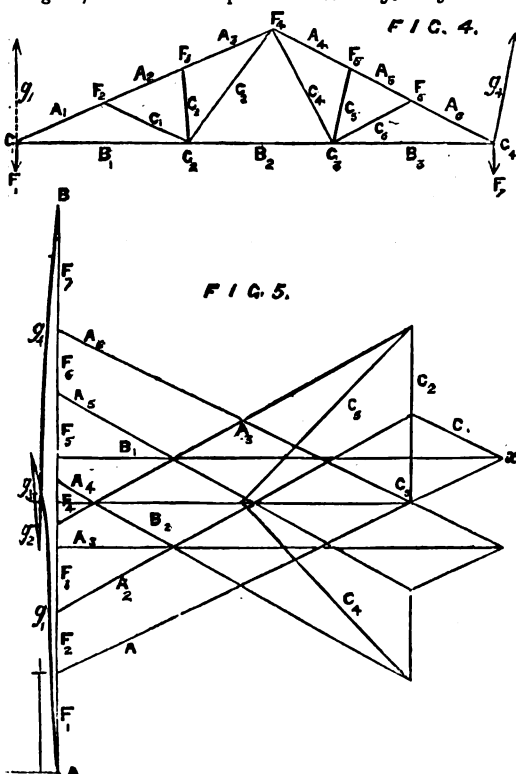


joining in one point. If we draw Fig. 2, the line, q , parallel to Q , p parallel to P , and r parallel to R , we have the outlines of a reciprocal figure which can be completed by drawing the lines, b and c parallel to B and C respectively, and meeting at one point. It can be proved by geometry that the third line, a , which connects this point with the corresponding corner of the triangle must be parallel to A , in Fig. 1. These reciprocal diagrams have therefore all lines parallel to each other, but all lines that form the outline of the polygon in one figure meet in one point in the reciprocal; and all lines which meet in one point in the first figure become the outlines of the second or reciprocal polygon.

Not every figure admits of the construction of a reciprocal figure, and these cases in which no reciprocal diagram of forces can be drawn are precisely those in which the forces are incapable of remaining in equilibrium amongst themselves, so that the method of constructing diagrams of forces contains in itself a control of its correct application. Suppose Fig. 3 to

* Paper read before the British Association at Dundee.

represent a triangular frame, having another triangular frame within it, and the corners of both to be connected by strings in tension. There can be no equilibrium in this, except on the condition that the three lines, p, q, r , representing the forces, meet in one point, if continued to o . In general it can be proved that only such figures admit of a reciprocal diagram, which are perspective representations of solid figures with plane sides. Fig. 3, for instance, represents a truncated pyramid, having its point at o . In supplying the above principles for constructing a diagram of strains for any given structure, say, for instance, for a roof such as that represented in Fig. 4, the first will be to ascertain the total weight resting upon the two side walls. The resistance of the side walls is represented in the diagrams as an equivalent force drawing the whole upwards, while all the other joints of the figure are supposed to be pulled parallel downward with forces F_1, F_2, F_3, F_4 , and g_1, g_2, g_3, g_4 . The forces g_1, g_2, g_3, g_4 , representing the resistance of the walls, are shown slightly out of parallel, in order to prevent the lines of the diagram of forces covering each other, but in practice such covering of lines is perfectly admissible. To construct the diagram of forces, Fig. 5, draw the vertical line representing the actions of gravity, which are marked off upon it in proportionate lengths, F_1, F_2, F_3, F_4 . From the two ends of this vertical line, A, B , the lines g_1 and g_2 parallel to those forces, and of corresponding lengths, are drawn, and the vertical line, g_3 and g_4 , connecting the two ends, and closing this part of the diagram, must then correspond to the strains g_3 and g_4 .



Now, to find the strain in A_1 , drawn the line A_1 (Fig. 5) parallel to A_1 (Fig. 4), through the point F_1 , and the line B_1 parallel to B_1 through the point g_1 . These two lines meet at x , and in this point the line C_1 parallel to C_1 is drawn. In a similar manner draw A_2 parallel to A_2 , and at the intersection with C_1 , draw C_2 parallel to C_2 . This process continued until all lines of Fig. 4 have their parallels in Fig. 5, the diagram will be completed, and if all lines are correct, it will close in one point. The length of each line will then represent the strain in the corresponding element of the roof, and the direction of the strain can be found at any moment by commencing with any vertical downward action of gravity, and then following the continuous figure until the line in question is reached. This mode of graphical representation of strains admits of a very easy and convenient application in practice, as it involves no other work except the application of a parallel ruler and a slight amount of attention in drawing the lines. It has moreover the advantage of controlling itself, since, in case of an error, the diagram will not close, and in this way mistakes are prevented.

THE NICOLAI RAILWAY.—Mr. William L. Winans, of London and St. Petersburg, has presented us with an original drawing, magnificently coloured, of the imperial railway carriage, constructed in 1850, and still in service for the use of the Czar when journeying between St. Petersburg and Moscow. The carriage is 84 ft. long and 9 ft. 6 in. wide. It is supported upon sixteen wheels—two eight-wheel bogies, one under each end. The interior, shown in longitudinal section and in plan, is furnished in superb style, and is divided into a grand saloon, 24 ft. in length, special cabinets for the emperor and empress, waiting-rooms, &c. We shall, in due time, present this splendid drawing to our readers, either in line engraving or in chromo-lithography.

THE MIDLAND RAILWAY.—The great extension of the Midland Railway into London has been opened for goods traffic, passengers still arriving at King's-Cross from Bedford and other stations on the Midland line.

THE MONT CENIS RAILWAY.—The *Official Gazette* of Florence publishes the usual monthly statistics relative to the works for tunnelling Mont Cenis. On the 31st of July, 7263 metres had been pierced, and during August 189 more were completed, making a total of 7402 for the 1st September. The whole length being 12,220 metres, there only remains about one-third, or 4828, to be accomplished. Hopes are entertained of being able to complete the work in three years more.

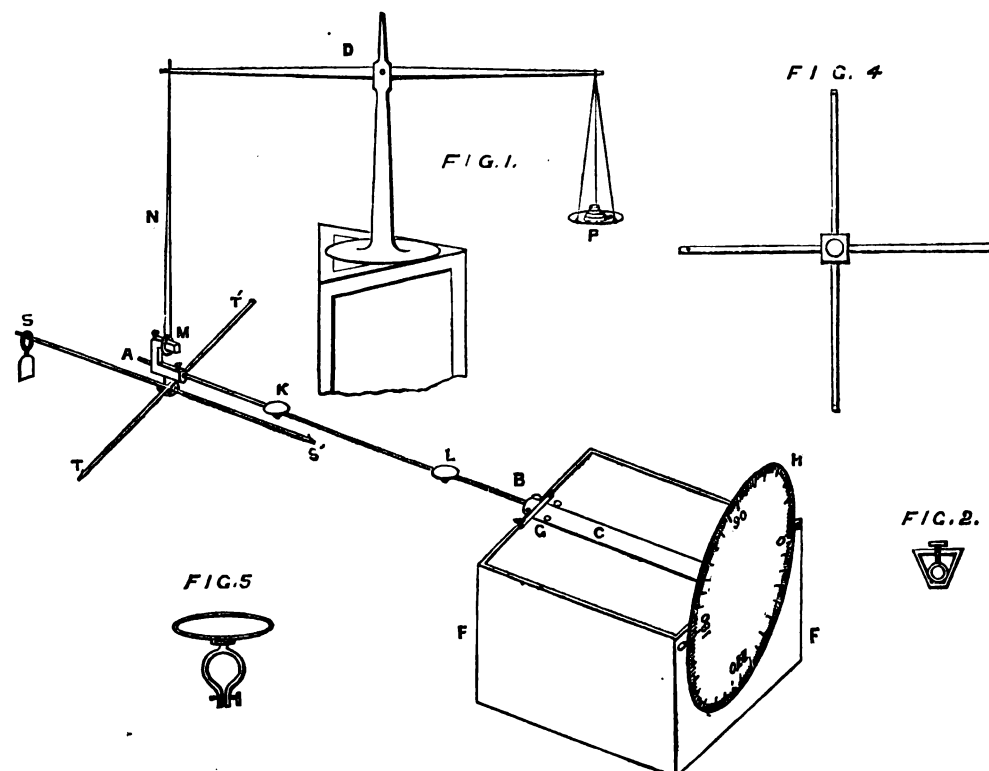
RESULTS OF EXPERIMENTS ON THE RIGIDITY OF GLASS, BRASS, AND STEEL.*

By DR. J. D. EVERETT.

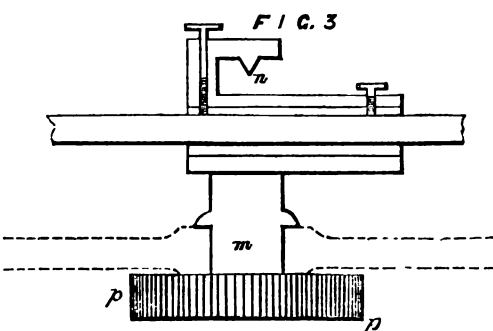
THESE experiments were conducted in the Physical Laboratory of the Glasgow University, upon a plan devised by Sir W. Thomson, and subsequently improved by the author.

Cylindrical rods, about one-third of an inch in diameter, of flint glass, drawn brass and steel, were alternately bent and twisted by known couples, so applied that the couple (whether of flexure or tension) was always uniform through the whole length of the rod. The amounts of bending and twisting thus produced in a given portion of the rod were measured by the aid of two mirrors clamped to the rod. In the earlier experiments,

centre of the crosspiece (Fig. 4) fits the cylinder, m , and the crosspiece can either be rotated about it or slipped off on loosening or removing the nut. The four arms of the crosspiece are all of equal length, and each of them has on the upper side near the end a cone or point for supporting a weight by means of a ring. FF is a cast-iron box, on the top of which the cylinder, C , rests in two notches one at each end, in which it turns freely when not secured by the clamp, G . H is a graduated circle for turning the cylinder (and with it the rod, AB) through any required angle. K, L are two mirrors clamped to the rod, and adjustable by footscrews into any position nearly parallel with the rod. One of them is shown on a larger scale at Fig. 5. By partially releasing the clamps, it was easy to rotate the mirrors about the rod without longitudinal sliding.



these mirrors were made to reflect a dark line placed in front of a lamp flame, and the displacements of the images were measured on a screen. In the later experiments two telescopes were placed almost vertically over the two mirrors, so as to look down into them, and a sheet of paper (cross-ruled) was fixed in a horizontal position overhead. The displacements of the lines on this sheet, as seen in the telescopes, were then observed. From the measurements of flexure and tension thus obtained, the coefficients of elasticity and rigidity for the substances operated on were calculated. The values of Young's modulus and of rigidity, in kilogrammes per square millimetre, were thus found to be respectively 6143 and 2442 for one specimen of glass, and 5851 and 2890 for another. For the specimen of brass operated on, the values were 10,948 and 3729, and for steel 21,793 and 8341. Rods of wrought iron, cast iron, and copper had more recently been operated on, but the experiments were not yet reduced. The experiments had, for the first time, established the ratio of lateral contraction to longitudinal extension for a bar stretched longitudinally, this ratio being deducible from the foregoing numbers by dividing Young's modulus by twice the rigidity, and then subtracting unity.



Similar apparatus to that employed might be used for testing the quality of metal rods, especially as it does not involve breaking or injuring the rods.

The improved apparatus is represented in Fig. 1. AB is the rod operated on, entering a socket in the cylindrical iron bar, C , in which it is firmly secured by screws (three in each set) which clamp it at two places about 2 in. asunder. The other end, A , passes through a brass socket (shown in cross section at Fig. 2), to which it is also secured by screws in two places. This socket forms part of a piece of brass, which is shown on a larger scale in longitudinal section in Fig. 3, where n is a point or cone to be supported by a ring (M , Fig. 1) hanging from one arm of a balance, while the lower part consists of a short cylinder, m (for receiving the crosspiece shown in Fig. 4, and indicated by dotted lines in Fig. 3), terminated by a screw which receives the nut, p, p . The circular hollow shown in the

The point, n , Fig. 3, is supported by the flat brass ring, M , which hangs by the wire, N , from one arm of the balance, D , and a counterpoise is placed in the pan, P , just sufficient to keep the rod, AB , free from strain.

(To be continued.)

RAILWAYS IN BADEN.—The Baden Government have brought out a loan of 12,000,000 thalers, or nearly 2,000,000*l.*, for railway purposes.

ROLLED v. HAMMERED PLATES.—The Secretary of State for War, Sir John Pakington, has caused a letter to be written to the Thames Iron Company, stating that there is no important difference in the quality of good rolled and good hammered armour plates as regards resistance to shot, and intimating that future tenders for armour plates may specify hammered iron as well as rolled.

CLEVELAND BLAST FURNACES.—The number of furnaces in blast in the Cleveland district is 89, and there are 45 out of blast. There are nine furnaces building, seven of which are nearly ready.

SODA WASTE.—At the meeting of the British Association at Dundee, Mr. J. Lowthian Bell read a paper on "A Method of Recovering Sulphur and Oxide of Manganese, used at Dieuze, near Nancy, France," which was illustrated and supplemented by Mons. Burton, who exhibited the products recovered by the process. Mr. Bell having spoken of the great loss which annually occurred through the inability to turn to good account the immense amount of soda-waste and the liquid refuse which were obtained as unprofitable residues in soda-works, entered into practical details of this French process by which these inconvenient and disagreeable products might, to a certain extent, be got rid of, and, at the same time, return a handsome profit, from which only the expense of labour was to be deducted.

THE POLLUTION OF RIVERS.—The third report of the Rivers Commission has been printed. It is devoted to the hearings and conclusions upon the cases of the rivers Aire and Calder. Its recommendations are simple and only what could have been expected, viz., that the water-shed of each river valley should be placed under some authority, independent of artificial boundaries, and that all pollution of the rivers should be prevented by intercepting sewers and by sewage irrigation.

"REFRIGERATING CARS."—Railway wagons carrying dead meat packed between layers of ice have long been common on the American railways. A ton of ice is packed among a "car" load of dressed carcasses, and when once renewed on a four-days' summer journey, it maintains the temperature at about 45 deg.

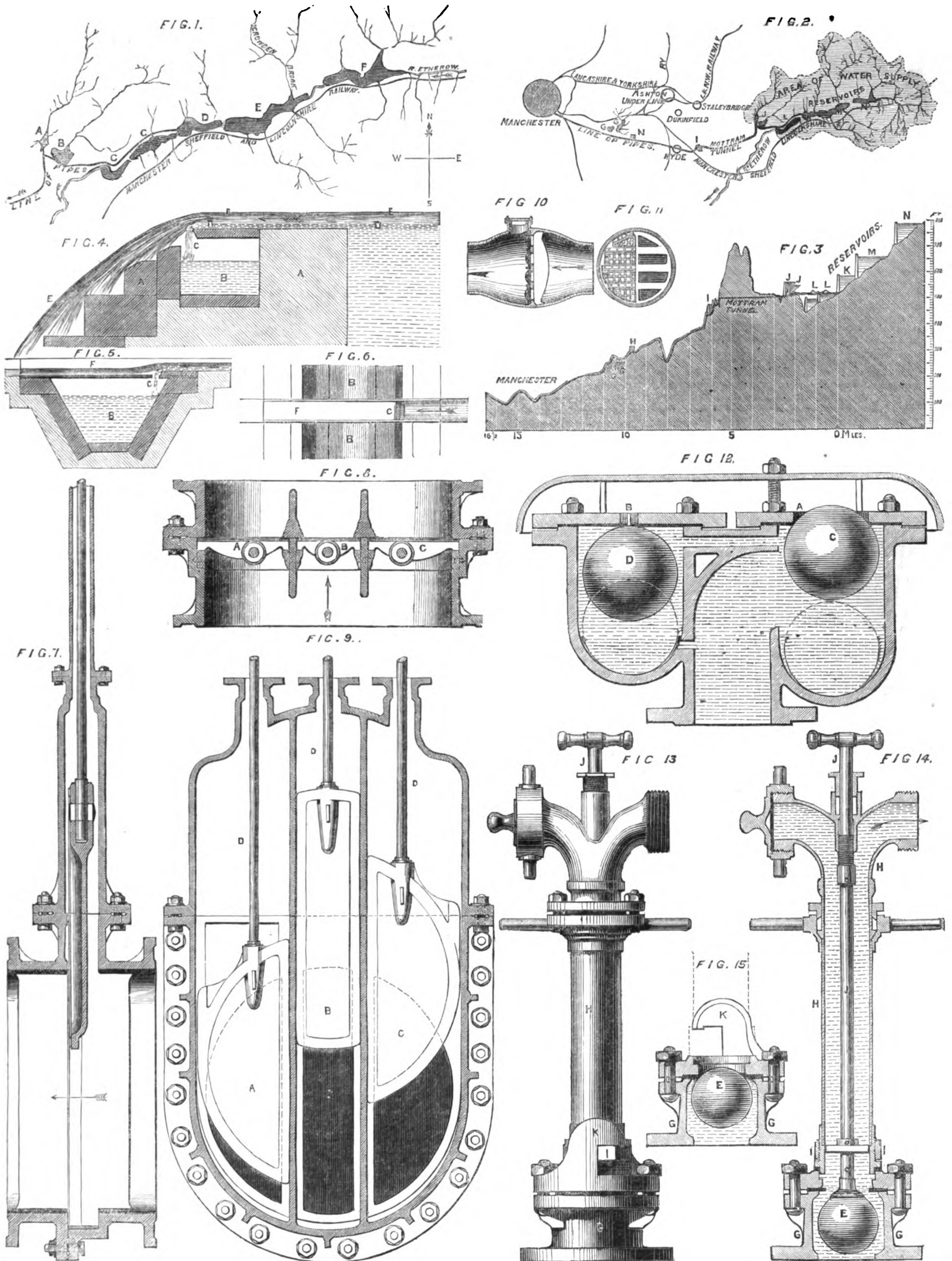
THE EAST LONDON RAILWAY.—This line from Liverpool-street, and including the junction on the south side of the Thames, is to be seven and a half miles long, and is to cost 1,866,000*l.*, a sum sufficient, it is believed, to cover all the works originally planned. The line is to be made through the Thames Tunnel, which has been purchased for less than one-fourth its original cost. It appears that one "financial company" originally demanded 250,000*l.* for "bringing out" this company, but that a more accommodating firm of go-betweens finally managed the matter for 27,060*l.*

* Paper read before the British Association at Dundee.

THE MANCHESTER WATERWORKS.

MR. JOHN FREDERICK BATEMAN, C.E., ENGINEER.

(For Description, see Page 241.)



EXPERIMENTAL RESEARCHES*

On the Mechanical Properties of Steel in its present improved state of Manufacture.

By WILLIAM FAIRBAIRN, LL.D., F.R.S.

THERE is probably no description of material that has undergone greater changes in its manufacture than iron; and, judging from the attempts that are now making, and have been made, to improve its quality and to enlarge its sphere of application, we may reasonably conclude that it is destined to attain still greater advances in its chemical and mechanical properties. The earliest improvements in the process of the manufacture of steel and iron may be attributed to Cort, who introduced the process of boiling and puddling in the reverberatory furnace, and the more recent improvements to Bessemer, who first used a separate vessel for the reduction of the metal. To the latter system we owe most of the important changes that have taken place; for by the comparatively new and interesting process of burning out the carbon in a separate vessel, almost every description of steel and refined iron may be produced. The same results may be obtained by the puddling furnace, but not to the same extent, since the artificial blast, of the Bessemer principle, acts in much greater force in depriving the metal of its carbon, and in reducing it to the state of refined iron. By this new process increased facilities are afforded for attaining new combinations by the introduction of measured quantities of carbon into the converting vessel, and this may be so regulated as to form steel, or iron in the homogeneous state, of any known quality.

By the boiling and puddling processes steel of similar combinations may be produced, but with less certainty as regards quality, as everything depends on the skill of the operator in closing the furnace at the precise moment of time. This precaution is necessary in order to retain the exact quantity of carbon in the mass in order to produce by combination the requisite quality of steel. It will be observed that in the Bessemer process this uncertainty does not exist, as the whole of the carbon is volatilized or burnt out in the first instance, and by pouring into the vessel a certain quantity of crude metal containing carbon, any percentage of that element may be obtained in combination with the iron, possessing qualities best adapted to the varied forms of construction to which the metal may be applied. Thus the Bessemer system is not only more perfect in itself, but admits of a greater degree of certainty in the results than could possibly be attained from the mere employment of the eyes and hands of the most experienced puddler. Thus it appears that the Bessemer process enables us to manufacture steel with any given proportion of carbon or any other eligible element, and thus to describe the compound metal in terms of its chemical constituents.

Important changes have been made since Mr. Bessemer first announced his new principle of conversion, and the results obtained from various quarters bid fair to establish a new epoch in metallurgical manipulation, by the production of a material of much greater general value than that which was produced by the old process, and of, in most cases, double the strength of iron.

These improvements are not exclusively confined to the Bessemer process, for a great variety of processes are now in operation, producing the same results, and hence we have now in the market homogeneous and every other description of iron, inclusive of steel, of such density, ductility, &c., as to meet all the requirements of the varied forms of construction.

The chemical properties of these different kinds of steel have been satisfactorily established; but we have no reliable knowledge of the mechanical properties of the different kinds of homogeneous iron and steel that are now being produced. To supply this desideratum, I have endeavoured, by a series of laborious experiments, to determine the comparative merits of the different kinds of steel, as regards their powers of resistance to transverse, tensile, and compressive strain.

These experiments have been instituted, not only for those engaged in the constructive arts, but also to enable the engineer to make such selections of the material as will best suit his purpose. In order to arrive at correct results, I have applied to the first houses for the specimens experimented upon; and, judging from the results of these experiments, I venture to hope that new and important data have been obtained, which may safely be relied upon in the selection of the material for the different forms of construction.

For several years past attempts have been made to substitute steel for iron, on account of its superior tenacity and increased security in the construction of boilers, bridges, &c. There can be no doubt as to the desirability of employing a material of the same weight and of double the strength, provided it can at all times be relied upon. Some difficulties, however, exist, and until they are removed it would not be safe to make the transfer from iron to steel. These difficulties may be summed up in a few words; viz., the want of uniformity in the manufacture, in cases of rolled plates and other articles, which require perfect resemblance in character, and the uncertainty which pervades its production, require careful attention. Time, and close observation to facts in connexion with the different processes, will, however, surmount these difficulties, and will enable the manufacturer to produce steel, in all its varieties, with the same

certainly as he formerly attained in the manufacture of iron.

In the selection of the different specimens of steel, I have endeavoured to obtain such information about the ores, fuel, and process of manufacture as the parties supplying the specimens were disposed to furnish. To a series of questions answers were, in most cases, cheerfully given, the particulars of which will be found in the Tables.

I have intimated that the specimens have been submitted to transverse, tensile, and compressive strain, and the summaries of results will indicate the uses to which the different specimens may be applied. Table I. gives for each specimen the modulus of elasticity and the modulus of resistance to impact, together with the deflection for unity of pressure. From these experimental data, the engineer and architect may select the steel possessing the actual quality required for any particular structure. This will be found especially requisite in the construction of boilers, ships, bridges, and other structures subjected to severe strains, where safety, strength, and economy should be kept in view.

In the case of transverse strain some difficulties presented themselves, in the course of the experiments, arising from the ductile nature of some part of the material, and from its tendency to bend or deflect to a considerable depth without fracture.

This is always the case with tough bars whether of iron or steel, and hence the necessity of fixing upon some unit of measure of the deflections, in order to compare the flexibility of the bars with one another, and from the mean value of this unit of deflection to obtain a mean value of the modulus of elasticity, E , for the different bars. This unit, or measure of flexibility, given in the Table, is the mean value of all the deflections corresponding to unity of pressure and section. The modulus of elasticity has also been calculated from the deflection produced by 112 pounds in order that it may be compared with the results of experiments on cast iron, given at pages 73 and 74 in my work "On the Application of Iron to Building Purposes." In order to determine the resistance of the bars to a force analogous to that of impact, the work in deflecting each bar, up to its limit of elasticity, has been calculated. These results differ considerably from each other, showing the different degrees of hardness, ductility, &c., of the material of which the bars are composed. The transverse strength of the different bars, up to their limit of elasticity, is shown by the amount of the modulus of strength, or the unit of strength calculated for each bar.

Table II., on tensile strain, gives the breaking strain of each bar per square inch of section, and the corresponding elongation of the bar per unit of length, together with the ultimate resistance of each bar to a force analogous to that of impact.

Table III., on compression, gives the force per square inch of section requisite to crush short columns of the different specimens, with the corresponding compression of the column per unit of length, together with the work expended in producing this compression.

Having selected the requisite number of specimens from the different works, the experiments commenced with the transverse strains, which were conducted, as on former occasions, by suspending dead weights from the middle of the bar, which was supported at its extremities, the supports being 4 ft. 6 in. apart. The apparatus for this class of experiments consisted of the wooden frame, A, to which was bolted two iron brackets, B B, on which the bars were laid. Immediately over the centre of the bar, at a point equidistant between the supports, the wheel and screw, C, was attached to the scale, D, on which the weights were placed, 56 lb. at a time; after each weight laid on, the deflections were taken, and the experiment was continued until a large permanent set was obtained. The permanent set was observed at intervals in the following manner: After the deflection produced by the load had been ascertained, the screw, C, was turned so as to raise the scale and relieve the bar of the load, thus enabling the experimenter to ascertain the effects of the load upon the bar and register the permanent set. This operation was conducted with great precision, as may be seen on consulting the Tables in the following experiments.

The mathematical formula of reduction on the transverse, tensile, and compressive strains has been deduced from the experiments by my friend, Mr. Tate, as follows:

FORMULÆ OF REDUCTION.

For the Reduction of the Experiments on Transverse Strain.

When a bar is supported at the extremities, and loaded in the middle,

$$E = \frac{wl^3}{4\delta Kd^4} \quad (1),$$

where l is the distance between the supports, K the area of the section of the bar, d its depth, w the weight laid on added to five-eighths of the weight of the bar, δ the corresponding deflection, and E the modulus of elasticity.

When the section of a bar is a square,

$$E = \frac{wl^3}{4\delta d^4} \quad (2).$$

These formulæ show that the deflection, taken within the elastic limit, for unity of pressure, is a constant, that is, $\frac{\delta}{w} = D$, a constant.

Let $\frac{\delta_1}{w_1}, \frac{\delta_2}{w_2}, \dots, \frac{\delta_n}{w_n}$ be a series of values of D ,

determine by experiment in a given bar; then,

$$D = \frac{1}{n} \left(\frac{\delta_1}{w_1} + \frac{\delta_2}{w_2} + \dots + \frac{\delta_n}{w_n} \right) \quad (3),$$

which gives the main value of this constant for a given bar.

Now, for the same material and length,

$$\frac{\delta}{w}, \text{ or } D \propto \frac{1}{Kd^4} \quad (4),$$

and when the section of the bar is square,

$$\frac{\delta}{w}, \text{ or } D \propto \frac{1}{d^4} \quad (5).$$

If D_1 be put for the value of D , when $d=1$, then,

$$D_1 = Dd^4, \\ = \frac{1}{n} \left(\frac{\delta_1}{w_1} + \frac{\delta_2}{w_2} + \dots + \frac{\delta_n}{w_n} \right) d^4 \quad (6),$$

which expresses the mean value of the deflection for unity of pressure and section. This mean value, therefore, may be taken as the measure of the flexibility of the bar, or as the modulus of flexure, since it measures the amount of deflection produced by a unit of pressure for a unit of section.

Substituting this value in eq (2), we get,

$$E = \frac{h}{4D_1} \quad (7),$$

which gives the mean value of the modulus of elasticity where D is determined from eq (6).

The work, U , of deflexion is expressed by the formula,

$$U = \frac{1}{2} \times w \times \frac{\delta}{12} = \frac{w\delta}{24} \quad (8),$$

where δ is the deflexion in inches corresponding to the pressure, w , in lb. If w and δ be taken at or near to the elastic limit, then this formula gives the work, or resistance analogous to impact, which the bar may undergo without suffering any injury in its material. This formula reduced to unity of section becomes

$$U = \frac{w\delta}{24K} \quad (9).$$

If C be a constant determined by experiment for the weight, W , straining the bar up to the limit of elasticity, so that the bar may be able to sustain the load without injury, then

$$\frac{Wl}{4} = CKd \quad (10),$$

where $C = \frac{1}{2}S$, or $\frac{1}{2}$ of the corresponding resistance of the material per square inch at the upper and lower edges of the section.

$$\therefore C = \frac{Wl}{4Kd} \quad (11).$$

When the section of the bar is a square,

$$C = \frac{Wl}{4d^3} \quad (12),$$

which gives the value of C , the modulus of strength or the unit of working strength, W , being the load determined by experiment, which strains the bar up to its elastic limit; this value of C gives the comparative permanent or working strength of the bar.

Tensile Strain, &c.

The work, u , expended in the elongation of a uniform bar, one foot in length and one inch in section, is expressed by

$$U = \frac{1}{2} \cdot K \cdot \frac{l}{L} = \frac{1}{2} P_1 l_1 \quad (13),$$

where $P_1 = \frac{P}{K}$ = the strain in lb. reduced to unity of section,

and $l_1 = \frac{l}{L}$ = the corresponding elongation reduced to unity of length.

This value of u , determined for the different bars subjected to experiment, gives a comparative measure of their powers of resistance to a strain analogous to that of impact.

By taking P_1 to represent the crushing pressure per unit of section, and l_1 the corresponding compression per unit of length, the foregoing formula will express the work expended in crushing the bar.

ABSTRACT OF THE RESULTS OF TABLES I., II., AND III.*

Transverse Strain.—Table I.

THE results of these experiments show that, within the elastic limits, the deflections are in proportion to the pressures. For example, in Experiment 1, the deflections are almost exactly expressed by the formula, $\delta = .001361 w$, where the constant .001361 is the mean, D_1 , of all the deflections for a unity of weight, derived from formula (3). By aid of this principle the value of the weight, w , with its equivalent deflection, corresponding to the elastic limit, was determined.

The mean value of the deflection corresponding to unity of pressure and section may be taken as the measure of the flexibility of the different bars. In general, the least flexible bars give the highest values of E and C , and, other things being the same, or nearly the same, the most flexible bars

* Read at the meeting of the British Association.

* We shall publish these Tables in their complete form next week.

give the highest values of u , the work of deflection corresponding to unity of section.

The bars of some of the experiments, with more than an average flexibility, gave very high values for C , the working unit of resistance to transverse strain, showing their great value when applied to the springs of carriages and other constructions, where flexibility and strength should be combined. Such bars as those of other experiments, with less than an average flexibility, gave at least an average value for C , showing their applicability to all constructions where rigidity and strength are required. And so on to other cases.

The mean value of E , the modulus of elasticity, given in col. 5, taken for thirty of the best specimens, is 31,000,000 nearly, whilst the mean taken for a like number, in col. 4, is about 32,000,000. This modulus exceeds that of wrought iron by more than the thirtieth part. Steel, having a much greater flexibility than wrought iron, accounts for the approximation of their values for the modulus of elasticity. The bars that have the greatest flexibility, or the greatest value of D_1 , other things being the same, have the least value for the modulus of elasticity.

The values of u , or the work of deflection for unity of section up to the elastic limit, may be taken as measures of the qualities of bars where flexibility and strength are required.

The bars generally exhibit very high powers of resistance to transverse strain. The mean value of the unit of working strength, C , given in col. 9, taken for one half the number of experiments, is 6.83 tons, and for the remaining half (omitting the last two experiments) this constant is 5.23 tons, giving a general mean of 6 tons. In the model tube of the Britannia and Conway bridges, the value of this constant for breaking weight is 6.7 tons.

It was next shown that, taking 11 tons per square inch as the mean value of the compressive and tensile resistances of wrought iron at the elastic limit, the value of C , in this case, will be less than 2 tons, and thence it followed that the transverse strength of these steel bars will be about $3\frac{1}{2}$ times the strength of wrought-iron bars of the same dimensions.

In order to determine the relative value of the two kinds of material undergoing transverse strain, he then supposed two bars of the same length, one steel and the other iron, having the same strength, to be similar in their transverse sections, the strengths of bars of similar section are as the cubes of their depths,

$$d_1 = \sqrt[3]{\frac{C}{C_1}} \times d = 3.5\frac{1}{2} \times d,$$

where d is the depth of the steel bar, d_1 that of the iron bar, and $\frac{C}{C_1} = 3.5$, the ratio of their units of working strength.

But as the areas of similar section are as the squares of their like dimensions,

$$\frac{\text{Section iron bar}}{\text{Section steel bar}} = \frac{3.5\frac{1}{2} d^2}{d^2} = 3.5\frac{1}{2} = 2.3052.$$

Now taking the cost of iron at 7*l.* per ton, and that of steel at 12*l.*, we have, for the relative cost of the two materials of the same strength,

$$\frac{\text{Cast iron } 7 \times 2.3052}{\text{Cast steel } 12} = \frac{16.1364}{12} = 1.3447,$$

that is, the cost of the iron would be about $1\frac{1}{3}$ times that of the steel.

In the case of railway bars and such constructions, besides this saving in the cost of material, it must be borne in mind that the steel rail would last four times as long as the iron rail.

Tensile Strain.—Table II.

Taking the mean of the results of the experiments on thirty of the best specimens, we find the mean tenacity per square inch = 47.7 tons.

Now if we take 25 tons per square inch as the tenacity of the best English hammered iron in bars, it follows that the tenacity of these steel bars will be about twice (1.91 times) that of the iron bars.

Economic Use of the Material.

For bars of equal strength, undergoing tensile strain, the iron bar should be about twice the section of the steel bar; now if the cost of steel be 12*l.* per ton, and that of iron 7*l.*, then the cost of the iron would be more than $1\frac{1}{3}$ times that of the steel; in this case, therefore, the steel would be the more economical metal. The saving per ton of material would be 1.37*l.*, or 1*l.* 7*s.* 4*d.* The work producing rupture in the different specimens is very variable, owing probably, to some extent, to the errors arising from the determination of such exceedingly small elongations. This irregularity would have been avoided, if the specimens had been of greater length, so that the elongations might have been ascertained with greater accuracy.

The greatest value (6400) of this work of elongation is given in Experiment 14, where the breaking strain of the specimen is below the average, being only about 40 tons per square inch.

The specimen which had the greatest tenacity, viz., about 60 tons per square inch, required only 670 units of work to produce rupture; this arises from the very small elongation, viz., .01, which the bar sustained at the point of rupture.

The ultimate elongations are unaccountably variable, and seem much below what might have been expected; even the greatest elongation, .1437, given in the Table, is below the average for iron bars, whilst the least elongation, .0037,

Produced by a strain of $38\frac{1}{2}$ tons per square inch, is only about the fiftieth part of this average.

Compression.—Table III.

Thirty-two of the bars supported each a pressure of 100.7 tons per square inch of section, without undergoing any sensible fracture, whilst twenty-three bars were more or less fractured with this pressure. The mean value of the compression per unit of length, taken for twenty-four of the best specimens, is .372, whilst the mean, taken for the remaining specimens, is .232, giving a general mean deflection of .302. The work expended in crushing the material in short columns is remarkably large. The mean value of u , taken for twenty-six of the best specimens, is 41,300, whilst the mean, taken for the remaining specimens, is 25,400, giving a general mean value of 33,400.

If 6000 be taken as the value of u , in the case of tensile strain, then the work expended in rupturing the material by compression will be $5\frac{1}{2}$ times the work expended in rupturing the material by extension.

Tensile and Compressive Resistances Compared.

Taking the mean tensile resistance to rupture at 47.7 tons per square inch, it follows that their resistance to compression is more than double (2.1 times) their resistance to extension: thus, $\frac{100.7}{47.7} = 2.1$. Hence it follows, that the

most economic form of a steel bar undergoing transverse strain would be a bar with double flanges, having the area of the bottom flange about double that of the top flange.

This conclusion is borne out by the results of experiments on transverse strain, where the strain per square inch of the material at the elastic limit is equal to 40.98, or 41 tons nearly, but the mean breaking strain per square inch by extension = 47.7 tons, clearly indicating that the compressive resistance in the former case was considerably in excess of the tensile resistance.

ON MOVABLE SEATS FOR SLIDE-VALVES.*

By JAMES R. NAPIER, F.R.S., Marine Engineer, and W. J. MACQUORN RANKINE, C.E., LL.D., F.R.S.

[Abstract.]

THE great practical convenience of the slide-valve and link-motion, as means of varying the rate of expansion in steam-engines is well known. An objection to their use, however, arises from the fact that the points of admission, cut-off, release, and compression are related to each other in such a manner that in designing a slide-valve motion, the fixing of any three of those points for a given position of the link fixes the fourth point also. For example, suppose that, in a certain position of the link, the positions of the eccentrics, and the lap or cover at the induction edge of the cylinder port are so adjusted as to give a certain rate of expansion, then the only element remaining capable of adjustment is the cover at the induction edge of the port, and that element, when it is fixed, fixes at once the release and the compression; and it often happens that the best positions of the points of release and of compression are inconsistent with each other, so that a compromise has to be made. That objection, in some examples of slide-valve motions, has been overcome by the use of double slides; but in all the double slide-valve motions hitherto introduced there exists the defect of complexity in construction and working; for, in addition to the ordinary handle of the link-motion, a second handle has to be used in varying the rate of expansion. The authors of this paper propose to accomplish the same result in a very simple way, by giving a small sliding motion to that part of the valve-seat which contains the induction edges of the cylinder ports, so as alternately to contract and enlarge those ports at each stroke of the engine. The only mechanism required, in addition to the ordinary slide-valve gear, consists in the movable seat, with a rod and a third eccentric to give it motion. The rate of expansion is varied when required by shifting the link in the ordinary way by the use of the ordinary handle alone; yet the effect is the same as if the admission and the exhaust of the steam were regulated by two different slide-valves, each with its own link-motion and pair of eccentrics. Hence, in designing the valve-motion, the points of release and compression can be adjusted to the best positions, independently of the points of admission and cut-off. The authors consider that the movable seat which they propose ought to be used, together with a kind of slide-valve, on which the pressure of the steam is balanced, such as that introduced by Mr. Thomas Adams, in order that the different rates of travel of the slide-valve over the fixed and movable parts of the valve-seat may not produce unequal wear.

THE GLASGOW TOWN COUNCIL AND THE GAS COMPANIES.

—At their meeting last Thursday the town council unanimously resolved to take measures for bringing the gas supply under their own control, and named a committee of their number to negotiate with the two gas companies for that purpose. In the course of the discussion it was stated, by way of illustration, that the gas supply of Manchester yielded the corporation of that city last year the sum of 52,523*l.*, and in dividing that revenue they had paid 13,252*l.* of interest upon money borrowed, and had reduced their debt by 19,784*l.* In Manchester the gas costs 3*s.* 2*d.* per 1000 ft., whereas the price in Glasgow is 4*s.* 7*d.* per 1000 ft. It was also stated that for the year 1866-67 the amount paid, or to be paid, by the town authorities to the gas companies is upwards of 23,000*l.*, and that the illuminating power of the Glasgow gas is 28 candles, while in Aberdeen it is 35 candles; Edinburgh and Greenock, 28; Paisley, 30; Manchester and Liverpool, 22; London, fully 12; Vienna, 9; Paris, 12; Berlin, 15. It is thought by some persons that when the authorities have made the supply of gas as well as the supply of water a duty of the corporation, the expense of the public lighting will be well-nigh, if not altogether, saved.

* Paper read before the British Association at Dundee.

THE SOCIETY OF ENGINEERS.

TO THE EDITOR OF ENGINEERING.

SIR,—It is with much regret that I have to advert to the misapprehension apparently entertained by the president of the Institution of Civil Engineers as to a supposed rivalry existing between the Society of Engineers and the Institution of Civil Engineers. Mr. Fowler remarks that the Institution has long been recognised as the single representative of the profession. I, in common with nearly all the members of the engineering profession, am fully sensible of the high estimation in which the Institution of Civil Engineers is justly held, and quite agree with the president that it is most desirable in the interests of the profession that it should be maintained. I am, therefore, more at a loss to discover in what way the recent application of the Society of Engineers to become incorporated should have led to the conclusion that it is in contemplation to establish a rival society.

The Society of Engineers was established some few years after the Institution of Civil Engineers had become incorporated, following the Institution of Mechanical Engineers, and I cannot but observe with pleasure the cordial praise bestowed by the president of the Institution of Civil Engineers upon the valuable institutions and associations connected with the engineering profession, which have taken their origin since the Society of Engineers itself was founded. The wish, moreover, expressed by Mr. Fowler, that these societies might become extended in number and importance, renders it still more difficult to account for the exhibition of any spirit of hostility towards one of its oldest contemporaries.

As one of the earliest members of the Society of Engineers, and acting president for the current year, I feel called upon to state that the proceedings of its council and body with regard to its recent application for a charter of incorporation were entirely free from any feeling of rivalry towards the Institution of Civil Engineers.

It was greatly to my surprise that I discovered that the Institution was in opposition to the incorporation of the Society of Engineers, instead of extending that support and co-operation which, from the enlightened views expressed by Mr. Fowler on behalf of other surrounding societies, might have been expected. I trust that with reference to the views expressed by the president as to the encouragement accorded to other bodies, that the council of the Institution of Civil Engineers may be instigated towards rescinding their opposition to the claims of a society having as much influence as many of those institutions to which Mr. Fowler has made such happy allusion. The Society of Engineers has laboured, and with great success, towards the advancement of engineering science and practice, and has been the means of distributing valuable professional aid to its members both at home and abroad.

The Society of Engineers has succeeded in bringing into contact those elements which seemed to call for some special opportunities of association.

As stated by the president of the Institute of Civil Engineers of France, its Transactions are held in much estimation by engineers abroad, and are considered to be of value and importance by foreign members of the profession.

It is to be hoped that instead of fostering professional hostility or disagreement, the controversy which seems to have arisen between the Institution of Civil Engineers and the Society of Engineers may rather induce Mr. Fowler, as president of the Institution, to take the initiative in bringing together the representatives of the various engineering societies of England, Ireland, Scotland, and Wales with a view towards discussing the present and future position of engineers, in order that they may be placed on an equality with other learned professions.

I am, Sir, your obedient servant,

WM. H. LE FEUVRE,
President, Society of Engineers.

18, Great George-street, Westminster.

THE IRON MANUFACTURE.—On the occasion of the meeting of the British Association at Dundee, Mr. I. Lowthian Bell read a paper on "The Present State of the Manufacture of Iron in Britain, and its position, as compared with that of some other countries." The paper was suggested by the opportunity afforded in the Paris Exhibition of comparing the position held by English and foreign manufacturers, which had led many to believe that our country was not advancing so rapidly as many Continental nations. Mr. Bell referred to the past history of the art as showing which nation had contributed most to its present advanced state. Beginning with the introduction of mineral fuel by Dudley, he spoke of Cort's rolling-mill, and Neilson's application of heated air to aid in reducing ores as being really revolutions in the manufacture of iron. He further noticed the improvement of furnaces introduced by the Durham and Yorkshire ironmasters, which at once raised the temperature and effected a saving in fuel; the introduction of the steam hammer for the manufacture of armour plates, and the discovery by Sanderson that rolled plates would be more suitable. We hope to give Mr. Bell's paper *in extenso* in our next number.

THE PATENT LAWS.—On Monday last the Mechanical Section of the British Association received the report of the Committee on the Patent Laws, in reference to which the president said that a letter had been received from Mr. Thomas Webster, Q.C., the chairman, which was to the effect that the absence of the members in London and Paris during July and August had prevented the completion of the report in time for the Dundee meeting of the Association. Considerable progress, however, had been made, and it was recommended that the committee be re-appointed. The committee was accordingly re-appointed.

JARROW.—Messrs. Palmer and Co. (Limited) are about to proceed with an armour-plated monitor for the English Government. The vessel will be fitted with engines of 250 horse power, to be also supplied by Messrs. Palmer.

GAS AT MANCHESTER.—Although the quantity of gas sold in 1866-67 from the Manchester Corporation Gas Works increased to the extent of about 4 per cent. as compared with 1865-6, the net profits realised in 1866-7 declined to 47,000*l.*, as compared with 52,000*l.* in 1865-6. The decline in the profits is attributed to the increased sums paid for coal.

THE MANCHESTER WATERWORKS.

MR. JOHN FREDERICK BATEMAN, C.E., ENGINEER.

(For Description, see opposite page.)

FIG. 19.

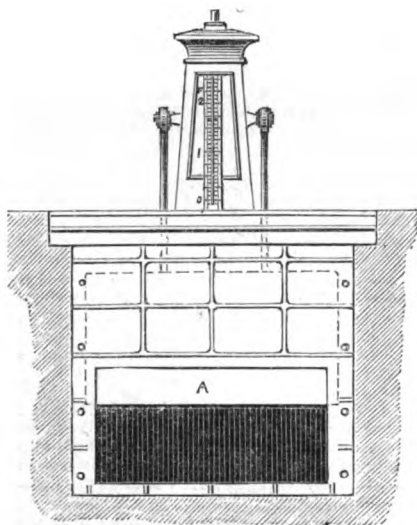


FIG. 20.

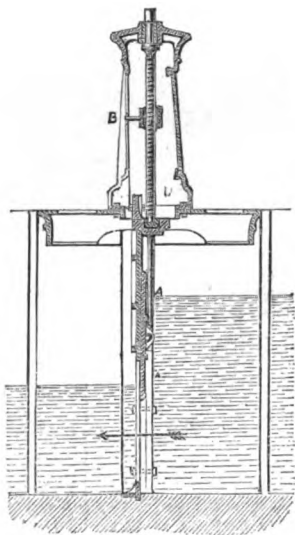


FIG. 21.

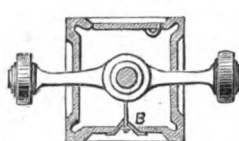


FIG. 22.



FIG. 23.

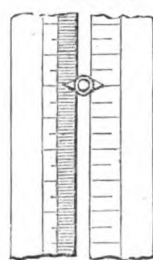


FIG. 30.

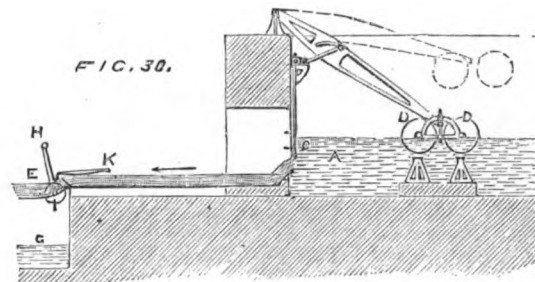


FIG. 31.

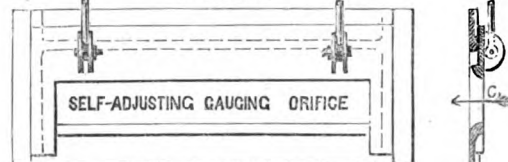


FIG. 33.

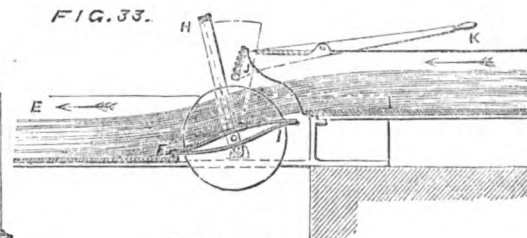


FIG. 34.

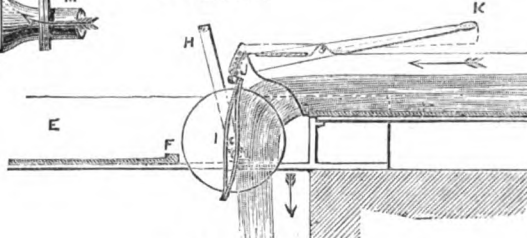


FIG. 16.

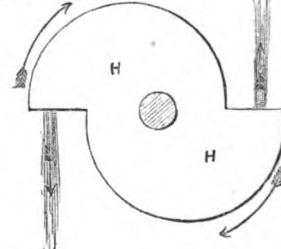


FIG. 27.

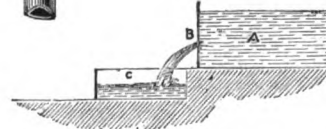


FIG. 24.

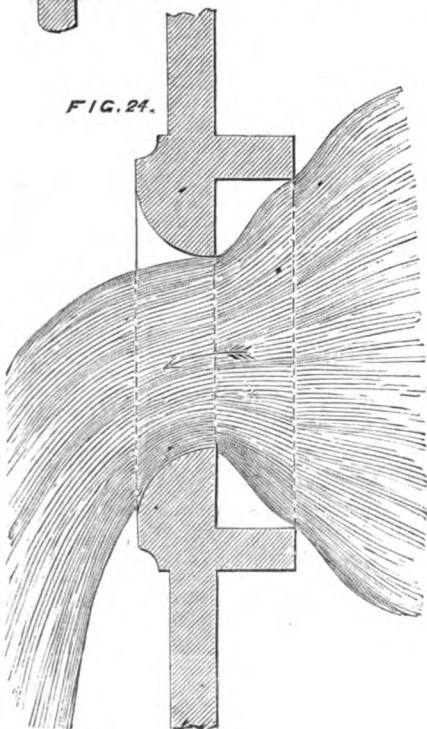


FIG. 25.

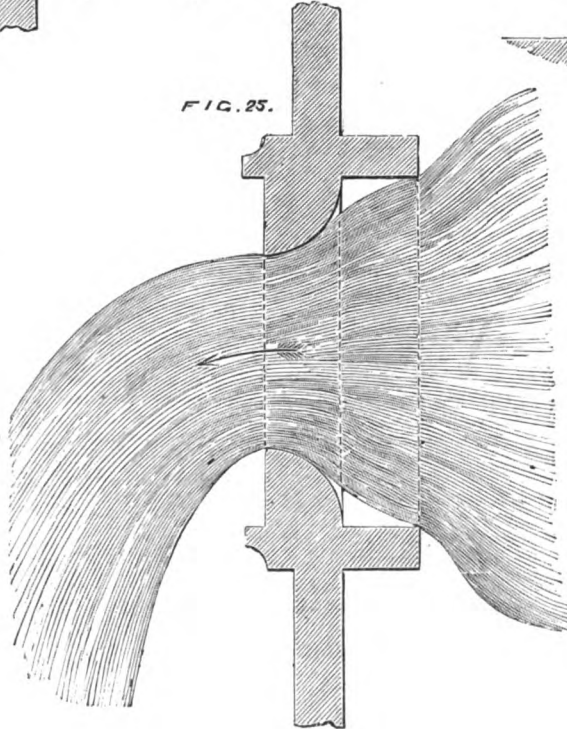
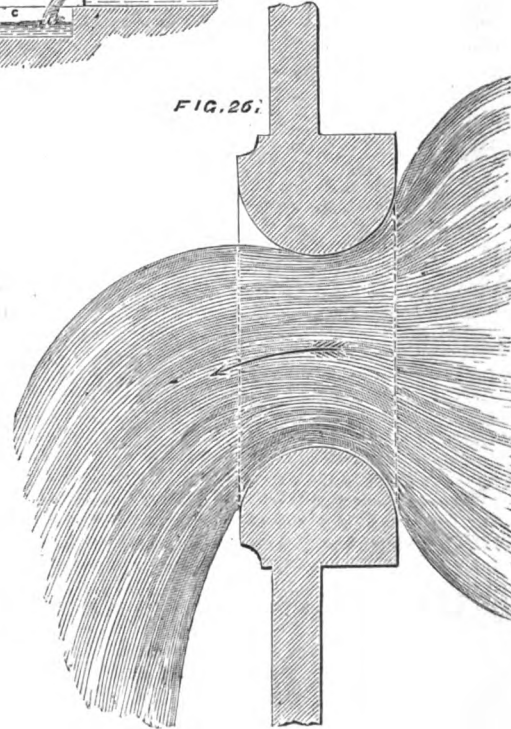


FIG. 26.



DESCRIPTION OF THE MANCHESTER WATERWORKS*.

By Mr. JOHN FREDERIC BATEMAN, of London.

THE works by which the city of Manchester and its suburbs are now supplied with water were originally designed in 1846, and were commenced in the autumn of 1848; and the water was first introduced into the city at the end of 1850. Previously to this date the water supply had been gathered from various sources: for some twenty years the greater portion had been obtained from a limited tract of gathering ground within a few miles of Manchester; a small additional quantity had recently been procured from a well sunk into the new red sandstone at Gorton; and urgent deficiencies were made up by occasional supplies from the Ashton and Peak Forest Canals. The supply, however, was very inadequate and very impure. The present water supply is brought from the river Etherow, which divides the counties of Derby and Chester, deriving its supplies from the western slopes of the great chain of hills commonly called the backbone of England.

A general plan showing the drainage area and the entire course of the works to Manchester is given in Fig. 2, and Fig. 3, page 237, is a longitudinal section along the line of the works. The drainage lies nearly midway between Manchester and Sheffield, and extends over about 19,000 acres. It rises in parts to an elevation of about 1800 feet above the level of the sea, and about 1200 or 1300 feet above the deep and romantic valley of Longdendale, in which the main collecting reservoirs are situated, as shown to a larger scale in the plan, Fig. 1, page 237. The district consists of the shales and sandstones which constitutes the lower portion of the coal series, the upper millstone grit forming the cap of the steep escarpments on each side, while the lower millstone grit, which may be said to separate the coal measure shales from the limestone shales, is found in the bottom of the valley. The water yielded by this geological formation is some of the purest in the world, being equal in general character to the water of Loch Katrine which supplies Glasgow. The spring water is especially brilliant, highly aerated, containing little or no foreign matter, and varying from about $1\frac{1}{2}^{\circ}$ to $2\frac{1}{2}^{\circ}$ of hardness according to Dr. Clark's scale, in which 1° of hardness is that corresponding to 1 grain of lime dissolved in 1 gallon of distilled water. The spring water is at all times most abundant, the district yielding much more than the usual quantity in proportion to the area from which the springs issue.

The average rainfall is about 50 in. per annum, and the average amount of water which may be collected about 40 in., the net produce of three or four consecutive dry years being about 33 in. in each year. This quantity if wholly stored would afford a gross supply of about 39 million gallons per day; from which a certain stipulated guaranteed quantity has to be given as compensation to the mills on the streams interfered with, amounting to nearly 13 million gallons per day on the average of every day in the year; this leaves as the supply available for the city and its suburbs 26 million gallons per day. The quantity at present supplied is about 13 million gallons, so that there is water for double the population at the same rate of consumption.

Pure and beautiful as all the water is in dry weather, and when unaffected by recent rain, the river and most of the principal streams are coloured by peat in floods and wet weather, especially in the summer and autumn months of the year. These circumstances determined several of the more important arrangements of the works. The average quantity of pure uncoloured water was more than sufficient for the wants of the city, but the actual amount was sometimes less than required, and at other times too much. A system of separation was therefore adopted, by which the pure spring water, and the stream water when uncoloured, should either be taken direct to Manchester; or, when there was more than was wanted for the daily supply of the city, should be stored in reservoirs set apart for the storage of pure water. The turbid or coloured water, being the water of floods, was to be stored in reservoirs specially allotted for the purpose; and after becoming comparatively pure by settlement and exposure to the atmosphere, it was either to be discharged into the river as compensation to the mills, or decanted off into the pure water reservoirs for the supply of the city. The means adopted for carrying this object into effect were very simple and certain, and have proved perfectly successful. Each stream, whether large or small, separates itself by a simple arrangement, so that the pure water flows on direct to Manchester, or into the pure water reservoirs, to be there stored for future use; and the turbid water flows into the turbid-water reservoirs, or runs to waste down the river.

In Fig. 4, page 237, is shown the manner in which the separation of the water is effected in a large stream, the Crowden Brook. A weir, A A, is erected across the stream, with a passage, B, for water within the masonry beneath the top. In front or on the down-stream edge of the weir, a narrow transverse slot, C, opens into the passage beneath. When the stream is small, as indicated by the lower water-line, D D, or rather when not swollen by rain, and the water consequently perfectly pure, it drops through the slot into the passage, B, beneath, which communicates with a conduit to convey the water to Manchester or to the pure water

reservoirs. The slot, C, is constructed of such a width as to admit the whole stream, when it consists only of the pure water; but when the stream is swollen, as indicated by the upper water-line, E E, the velocity with which it passes over the weir is sufficient to carry it clear over the slot and down the face of the weir, into the ordinary river course or to the reservoirs for turbid water. Figs. 5 and 6 show the separating arrangement adapted to the case of a small stream, where the object is effected by a transverse slot, C, in a trough, F, crossing the pure-water conduit, B. The water, when small in quantity, and consequently pure, falling from an elevated ledge at the back of the slot, drops through the slot into the pure-water conduit, B; but overshoots the slot when the quantity is large, and is then carried by the trough, F, in another direction.

The main impounding reservoirs, shown in Fig. 1, page 237, are constructed in that beautiful part of the valley known as Longdendale, and are five in number. Three of them, namely, the Woodhead, Torside, and Rhodeswood reservoirs, are constructed along the course of the river Etherow in the main valley, which they occupy for about five miles in length. The other two, the Arnfield and Hollingworth reservoirs, are placed on tributary brooks. The highest, the Woodhead reservoir, is at a level of 790 ft. above the sea. The point at which the water leaves the lowest or Rhodeswood reservoir to be conducted to Manchester is about 13 miles distant from the city. To this point also is conducted all the spring water and pure water collected by the various conduits constructed for the purpose; and the joint volume of water is conveyed away by a common aqueduct for the use of the city, as shown in Figs. 2 and 3.

This aqueduct is principally a covered conduit. It has a fall of 5 ft. per mile, and passes under the Mottram ridge by a tunnel of about 8000 yards length, Fig. 3, and terminates in a reservoir at Godley, near Hyde, about 8 miles distant from Manchester, and 314 ft. above the centre of the city. From this reservoir the water is conducted by a single line of cast-iron pipes, of 40 in. diameter, to two service reservoirs at Denton, about 4 miles from Manchester, and 163 ft. above the centre of the city; the average fall of the pipes from Godley to Denton is 43 ft. per mile. The Denton reservoirs are used for the service of the higher parts of the city, while the old Gorton reservoirs, the lowest of which is 77 ft. lower in level, are employed for the supply of the lower parts; and a pipe of 30 in. diameter is now being laid direct from the Godley reservoir to supply distant localities and various elevated suburbs, such as Pendleton, Broughton, Cheetham Hill, and Newton. From the Denton reservoirs to Manchester there is a line of pipes of 36 in. diameter; and a culvert of 4 ft. diameter conveys a portion of the water to the old Gorton reservoirs, from which the lower parts of the city are supplied. From these latter reservoirs two pipes, of 24 and 18 in. diameter, convey the water to the city.

The total capacity of the five reservoirs in Longdendale is about 550 million cubic feet when full to the level of the overflow weirs, and their area about 400 acres. The heights of the embankments and the capacities of the several reservoirs are given in the following Table:

Name of Reservoir.	Height of Bank.	Depth of Water.	Area of Reservoir.	Capacity of Reservoir.	
				cubic feet.	gallons.
Woodhead	90	72	185	198,000,000	1,235,000,000
Torside	100	84	160	236,000,000	1,474,000,000
Rhodeswood	80	68	54	80,000,000	500,000,000
Arnfield	67	52	39	33,600,000	209,000,000
Hollingworth	70	62	13	11,660,000	78,000,000
Godley	...	21	15	9,800,000	61,000,000
Denton No. 1	...	20	7	4,800,000	30,000,000
" No. 2	...	20	6	3,700,000	23,000,000
Gorton Upper	...	26	84	19,500,000	123,000,000
" Lower	...	29	23	16,000,000	100,000,000

The Manchester Waterworks were at the time of their execution the largest works of the kind which had been constructed in this country, and in some respects the largest which had ever been constructed in any part of the world. Much, therefore, had to be specially considered, and nothing more so than the best form of the large valves, and the easiest mode of opening them under great pressure. There was little which then existed that could be advantageously imitated; everything had to be designed anew, with special reference to the work to be performed. In order to arrive at the best mechanical contrivance, public competition was invited upon a clear description of what was required, and a short specification of certain conditions that were to be met. This resulted in many valuable suggestions, which were either adopted exactly as they were proposed, or modified and improved by subsequent consideration; and altogether a mass of information was in this way collected which could not perhaps have been obtained otherwise. It is but justice to say that, amongst the designs for the larger apparatus, by far the best proposals and the best designs for the objects to be attained, taking all circumstances into consideration, were those received from Sir William Arm-

strong, who was accordingly the maker of all the large valves required for the works.

It was laid down as a principle that, whatever the size of the valve or the pressure under which it had to be worked, it should be so contrived as to be easily opened and shut by one man. No large valve then existing met this condition; and it frequently happened that a valve of no greater diameter than 24 in., if it had to be worked under any considerable pressure, needed the combined power of half-a-dozen men. This requirement was met in all the large valves by dividing the valve into two and in some cases into three compartments, one of these being reduced to such a size as would be equivalent to a small valve, which could be easily opened by one man. This smaller division is first opened, and when it is open, the pressure behind the larger is to a great extent destroyed by the friction of the water flowing through the pipe beyond the valve; and the pressure is reduced to an amount equal to the extra head (never more than a few feet) required to pass the whole quantity through an aperture of the size of the small opening; or if the pipe beyond the valve merely requires filling, as soon as it is filled the pressure will be the same on both sides of the large valve. In either case the large valve can then be opened by one man. In Figs. 7, 8, and 9, page 237, is shown the construction of the 48 in. sluice valves employed for taking off the water from the large reservoirs, the whole valve being divided into the three compartments, A, B, and C, which can be opened one at a time by the power of one man.

Another point of much importance was the adoption of means by which the water could be immediately shut off in case of the bursting of a large main; and this object was effected by the self-acting closing valve invented by Sir William Armstrong. Several of these valves were constructed and were brought into action on several occasions, when they proved most efficacious in arresting the escape of water and preventing serious damage. These valves were afterwards introduced in the Liverpool Waterworks, and a description of them is given in the paper on those works by Mr. Duncan, at a former meeting of the Institution (see Proceedings Inst. M. E., 1863, page 174); they were also introduced in the Glasgow Waterworks, as mentioned again in the paper by Mr. Gale on the subject (see Proceedings Inst. M. E., 1864, page 134). The great value of these valves is in the early stage of the works, when the pipes are first filled and subjected to the pressure they will ultimately have to sustain; but the valves should always be kept in working order, as pipes occasionally burst after years of work, without anything to account for the occurrence. In the Manchester Waterworks some of these valves are discontinued; but others in suitable situations are kept in constant adjustment, and are made to communicate with an alarm in the waterman's house, so that in the event of a pipe bursting and the valve closing, he is instantly apprised of the accident.

In order to provide against the shock caused by stopping a large column of water many miles in length and flowing at a speed of several feet per second, a momentum valve opening outwards is placed upon the main behind each of the large stop valves and self-acting closing valves; and a description of this valve is also given in the former paper already referred to (see Proceedings Inst. M. E., 1863, page 175). These valves were also first used in the Manchester Waterworks.

Self-acting valves, called reflux valves, are placed in the large pipes at the foot of all hills rising in the direction in which the water flows, for the purpose of preventing the water from flowing back again in the event of a pipe being emptied behind the valve by an accidental burst or otherwise. One of these valves in the 40 in. main is shown in Figs. 10 and 11, page 237, the flaps being made of leather, backed with cast-iron plates. The valves open with the current of water in the direction in which it ordinarily flows, as indicated by the arrow in Fig. 10, and close if the current is changed into the contrary direction.

A very important point in arranging water pipes on a large scale is the provision of ample means both for the rapid escape of air from the pipes during the time they are being filled with water, and also for the subsequent discharge of the air which escapes from the water in its passage through the pipes and accumulates in the upper part of the bends formed by inequalities of the ground. Both of these operations, in order to be effectual, should be spontaneous or self-acting; and they are accomplished by means of the self-acting air valve, shown in Fig. 12, page 237, which is mainly the invention of one of the writer's early assistants, Mr. Alfred Moore, to whom also is due the system of separating clear and turbid water, as previously described. The construction shown in the drawing combines two air valves in a single casting, the large aperture, A, of 3½ in. diameter being intended for the escape of the large quantity of air while the pipes are being filled with water, and the small hole, B, of ½ in. diameter for the escape of the air accumulating in the pipes when full of water. The gutta-percha balls, C and D, forming the valves are each 5 in. in diameter, and when the pipes are empty they drop into the positions shown by the dotted circles; but as soon as the water reaches them they are floated upwards, and close the apertures A and B, preventing the escape of the water. The ball, D, closing the small hole, B, is made of such specific gravity that its own flotation, together with the small pressure corresponding to the area of the minute orifice, B, is only just sufficient to hold it up against the

* Paper read before the Institution of Mechanical Engineers, at Manchester, August, 1866.

* In Fig. 1, for "Line of Pipes" read "Line of Aqueduct."

orifice; and, consequently, whenever the flotation is diminished by the slightest accumulation of air at the valve, the ball falls away from the orifice and allows the air to escape, after which the orifice is again closed by the ball rising with the water.

A simple form of hydrant or fire-cock has been constructed, as shown in Figs. 18 to 15, in which a gutter-percha ball, E, is employed as the valve, being closed by the pressure of the water, as shown in Fig. 14, against a leather and vulcanised india-rubber seating. The cast-iron box, G, containing the valve is bolted to a vertical branch attached to the water main, and when not in use the outlet of the valve is closed by a loose stopper, and the whole is protected from injury by a cast-iron cover similar to the ordinary cover for protecting street cocks. For opening the fire-cock, the top cover is removed, and a standpipe, H, is attached, through which the water is drawn off. The screwed collar, I, on the bottom of the standpipe fits under two lugs, K, on the top of the valve-box, and the standpipe being then screwed down forms a water-tight joint by means of a leather washer on the bottom. A spindle, J, passes down the centre of the standpipe, working through a stuffing-box and screwed bearing at the top and through a guide below, and terminating at the bottom in a cup which fits the ball-valve, E, so that by turning the spindle by the handle at the top, the ball is depressed, and the water flows out through the standpipe, H. This standpipe is attached in a few seconds, and as the opening and closing of the valve is effected gradually by the employment of the screwed spindle, J, all concussion is avoided.

The sluice-valves shown on page 287, for discharging the water of the large reservoirs in Longendale, are fixed at the outer end of the outlet pipes, which are 48 in. diameter. They consist of three slides or compartments, A, B, and C, Fig. 9, forming together a complete circular area, which may be opened either separately or together. Each slide is opened by means of a gun-metal spindle, D, passing through a stuffing-box, the upper portion being cut into a square-threaded screw working in a gun-metal bush fixed in head-stocks. They are opened and shut by worm-wheel gearing, as shown at G in Fig. 16, page 400. One man can with some difficulty open one compartment at a time when the valve is under 70 or 80 ft. of pressure. Two men can do the work easily; but at the two deepest reservoirs, the Woodhead and Torside, the operation of closing and opening is performed by the agency of a small turbine-wheel, supplied with water for power from watercourses above the level of the reservoir. This is shown in Fig. 13, and to a larger scale in Fig. 17. The turbine, H, of which a plan is given in Fig. 18, is geared by the spur-wheel and pinion, J, to the worm-wheel gearing, G, working the valve-spindles, D D D; and the water for driving the turbine is admitted to it through the pipe, K, by a hand stop-valve at L, in the supply pipe, M. A self-acting slide-valve is placed at I, connected to levers worked by tappets upon the valve-spindles, D, whereby the water is shut off from the supply-pipe, K, of the turbine, and turned into the waste-pipe, N, as soon as the main sluice-valve is either fully opened or fully closed; this arrangement prevents the possibility of accident, should the attendant neglect to stop the turbine in time by the hand stop-valve, L.

On each separate conduit for collecting spring water, or for conducting water from the large impounding reservoirs to the city are placed gauge sluices, shown in Figs. 19 to 21, page 240, which act not only as stop-gates, but also as gauges for determining the quantity of water passing along each conduit. This is effected by gauging-rods placed before and behind the sluice, A, which is of definite dimensions; and by an index, B, which rises with the door of the sluice, and indicates the extent that the sluice is opened. This index is shown to a larger scale in Figs. 22 and 23. By taking the difference in the level of the water behind and in front of the sluice, and the area of the opening through which the water is discharged, the application of the proper formula determined by experiment affords at all times the means of ascertaining the quantity of water passing through.

Where the water is finally discharged into the Godley reservoir it is passed through a basin, A, Fig. 27, page 240, in one side of which a gauge plate, B, is erected, whereby the quantity of water passing is daily measured. This plate contains three rectangular openings, each 6 ft. wide by 6 in. high, but with the approaches to the openings varied, as shown in the vertical sections, Figs. 24, 25, and 26. The first opening, Fig. 24, presents a flat surface and knife-edge to the water flowing out through it in the direction shown by the arrow, and has a curve outside, which is the quadrant of a circle of $2\frac{1}{2}$ in. radius; the second opening, Fig. 25, is made with a curve of the same radius placed inside, so as to facilitate the discharge of the water; and the third opening, Fig. 26, has a double curve of the same radius, so as to present a curve to the water both in entering and leaving. These three different openings were arranged for the purpose of careful experiment, and the facts determined by the experiments made are very important. The ordinary rule for determining the practical velocity of the discharge of water through an orifice in a thin plate is to multiply the square root of the head or pressure by the coefficient 5.1 or 5.4. The coefficients for velocity, however, determined by the experiments made with these three openings were 5.6 for the opening with the curve outside, 7.0 for the curve inside, and 7.6 for the double curve both inside and outside; the third opening thus giving a velocity

nearly equal to the whole theoretical velocity due to the height of fall, for which the coefficient is 8.04. The openings in the gauge plate were entirely submerged on the inside, the depth of water in the basin, A, Fig. 27, varying from about 1 ft. to 4 ft. above the centre of the openings, and the water had a free discharge on the outside, as indicated in Fig. 27, falling into a tank, C, of a given size, so that the quantity passing during any time was correctly measured.

Before the water service leaves the Godley reservoir, and again before it leaves the Denton reservoirs, it is strained through copper wire-gauze strainers, the whole vertical area through which the water passes being about 800 square feet. The copper wire-gauze first tried consisted of 72 strands per

FIG. 28.

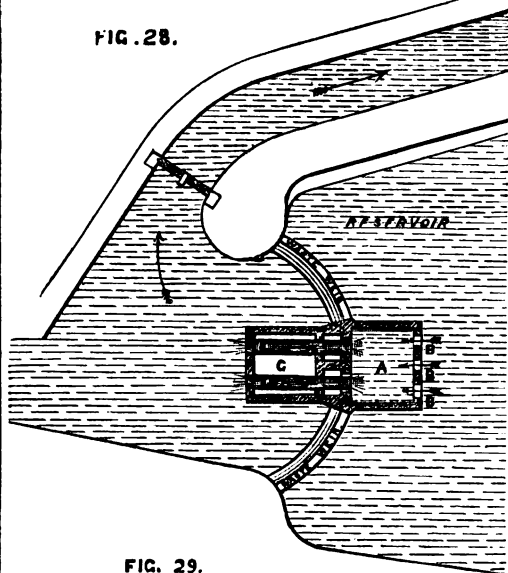
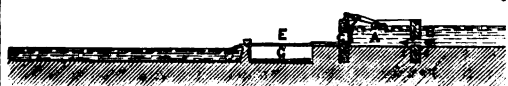


FIG. 29.



square inch, but that was found to be too fine, as the apertures got rapidly closed, and the gauze became as tender as brown paper, and was easily torn and broken. The gauze now used consists of copper wire made with 40 strands per square inch, which seems well suited for the purpose. No other filtration of the water is attempted or needed, as the water is always perfectly pure. The service reservoirs are from 18 to 20 ft. deep, carefully paved on the slopes and bottom, and there is no vegetation in the reservoirs or in the conduits; and the only object of the strainers is to prevent extraneous floating matter in the water from passing into the pipes. The system of separation adopted as previously described wholly supercedes the necessity of filtration.

There remains to be noticed the means adopted for gauging the compensation water that has to be given off the millowners. This is shown in Fig. 28, which is a general plan of the arrangement, and Fig. 29 is a longitudinal section through the gauge basin and test basin; Figs. 30 to 34, page 240, show the principal details to a larger scale. The water is first admitted into the masonry gauge basin, A, in which the level is carefully regulated by means of sluices, B. It then passes through two apertures in vertical gauge plates, C, by which the quantity of water passing through may be accurately computed according to the pressure on the aperture, by employing the coefficient determined by the Godley experiments. In order to ensure a uniform discharge of water under a varying head, the gauge plates, C, Figs. 30 to 32, are each fitted with a slide actuated by the float, D, whereby the size of the gauging orifice is rendered self-adjusting, and varies inversely as the height of the water in the gauge basin, A, thus giving a constant discharge. But in order to prevent the possibility of dispute, the water discharged from each gauge aperture, C, into the river below is carried by a trough, E, across a square test basin, G, 80 ft. square and 10 ft. deep. In the bottom of each trough, E, Fig. 30, is placed a tumbler, I, in a horizontal position, turning on an axis in the centre, and this tumbler ordinarily forms the floor of the trough, and the water passes over it, as shown enlarged in Fig. 33. But on drawing back the hand lever, H, into the position shown by the dotted line, so that the extremity of the tumbler just clears the edge, F, of the trough, the tumbler is instantaneously reversed by the stream of water and turned vertically across the trough, where it is caught by the stop, J, as shown in Fig. 34. In this position the water is discharged through the opening in the bottom of the trough into the test basin below, and at the same time the tumbler opposes an effectual barrier to its passing along the trough beyond the opening. The previous level of the water in the basin being noted, together with the time at which the stream is turned into it, the tumbler is again replaced at the end of a given interval in its original position, shown in Fig. 33, by raising the stop, J, by the handle, K, so as to release the tumbler; the discharge of the water into the test basin is thus instantly arrested, and the water allowed to pass along

the trough, E, as before into the river below. The height to which the basin has been filled during the time noted is then ascertained, and the quantity discharged is thereby accurately determined. This gauge is opened to the inspection of all who are interested in the supply of the compensation water, and the quantity discharged may at any time be tested by this means.

THE CORLISS ENGINE.

TO THE EDITOR OF ENGINEERING.

SIR,—In your number of August 31st, one of your correspondents made considerable mention of my initials, but without, as I think, much reference to the substance of my previous short note.

It is stated by "J. W." that my letter is founded on my ignorance. This may be so, but the assertion is never considered a very strong argument to use against those who differ from you in opinion, and in this discussion it has been so often used as to have lost any force it may once have had.

"J. W." states, among the claims of this Corliss valve motion, "the exhaust ports being separate" &c., and "the steam ports being close to the end of the cylinder." As my knowledge tells me these were in use long before the date of the Corliss invention, it is useless to discuss them as novelties.

I am further told that "a long way within the bounds of the speed with which the valves can be closed, there is practically 'an end to all wire-drawing.'" Now, Sir, this was precisely the opinion which induced me to suggest that some means should be taken to show if this rapid cut off is necessary, and (however stupid it may be of me to persist in my opinion) the rapid cut off is the essential feature of the Corliss motion, and the one which causes the objectionable details.

With the letter from a "Yarn-Spinner" in your columns, I cannot understand how it can be asserted of these engines that "all are giving satisfaction to their owners," unless, indeed, unpalatable evidence is to be ignored. This mode would certainly get over the difficulty, but it is well to remember that owners of steam-engines do not readily condemn, and when they do so, the fact is not very generally published. The statement of Mr. Stuart is quoted to prove the facility with which the Corliss engine adapts itself to its work. I have heard of quite as good results being obtained by other governor-regulated motions, and those who inquire into the subject can hear the same. With reference to the saving of fuel, "J. W." states it to be from 15 to 35 per cent., but the economy effected by the Corliss motion, *per se*, must be a definite amount, not subject to such variations as from 15 to 35 per cent. The fact is, that very many causes unite to produce these stated results, but all are swept into the credit of the Corliss motion. I think careful engineers will want more uniformity in the data before they base any safe opinion on them, even though the hesitation may incur "J. W.'s" displeasure.

Mr. Inglis gives a case where the "Corliss" uses 38 per cent. less than a "horizontal engine of the usual construction fitted 'with slide valves, with cut-off slides working on the back of the main sides.'" If this statement is of any value, it means that suppose I have a horizontal engine, as described, say one of the Reading Ironworks Company's, working, as stated in *ENGINEERING*, at $2\frac{1}{2}$ to $2\frac{3}{4}$ lb. per horse power, I can save 38 per cent. by substituting a "Corliss motion." Is it one of the claims of this engine that it works at about $1\frac{1}{2}$ lb. per horse power? It is the general fault of partisans to injure their cause by claiming too much. I fear this is no exception. The Corliss engine has some good points, but they are not new. It has other qualities which should prevent its advocates announcing, with such a flourish as they do, that it is under all circumstances the best, and from asserting advantages which cannot be realised.

I am, Sir, your obedient Servant,

London, September 5, 1867.

J. C. E.

THE OPENING OF THE OAKS COLLIERY.—There was a good deal of excitement in the neighbourhood of the Oaks Colliery on Tuesday morning on its being made known that on the previous evening two men, incased in dresses on the diving-bell principle, had been enabled to go into the workings to some extent. The men who went in on Monday afternoon proceeded about 16 yards without finding the slightest obstacle or the smallest indication of fire. On Tuesday morning, on going down, the length of the air-pipe was extended, so the two men in their gas-proof dresses went past the No. 2 shaft, and then along the engine plane. On reaching some 36 yards up they found a part of the arch towards the end had fallen in, but not to such an extent as to stop them proceeding even further. They also found that the chamber in the engine plane used for pulling the corves had been blown away. The south level was made up to a considerable extent, while the box-hole, in which some four or five bodies are known to be, was completely blocked up with spoil, and nearly as firm as stone. In the stone-drift, which many persons considered to be the seat of the explosion, the men in groping their way—being without lamps and the gas overpoweringly strong—found a good deal of water, rather favouring the idea that the shot, instead of going through the drift, went into the steps. So far everything indicates that there is no standing fire in the workings—at least, in the vicinity of the bottom, and there is now a strong feeling that there should be extra shafts and more energy displayed in recovering the bodies, seeing that on Tuesday the men were only down some three or four hours altogether. What the explorers will have to endure may to some extent be imagined from the fact that there are the carcasses of no less than 42 horses in various parts of the pit, the first stables being about 100 yards from the box-hole. With regard to the number of bodies in the workings, it may be stated that at the time of the first explosion, on the 15th of December, there were 340 persons at work in the mine. In addition to that number there were 27 persons—four belonging to the colliery and 23 volunteers—who were killed by the following explosions. Of that total of 367 persons there were got out altogether 81, of whom 19 were alive and burnt, 1 alive and not burnt, 25 dead by burning, and 36 dead, but not from burning. Of those got out alive only 6 now survive, so that there will be at the present time no less than 286 bodies buried in the workings.

THE HISTORY OF REAPING-MACHINES.

By the Rev. PATRICK BELL.

In the outset of his paper, read before the British Association at Dundee, Mr. Bell gave an account of the reaping-machine in the various forms through which it had gone down to the present day. Noticing the two sickles from Egypt in the British Museum, he said that they were much like our own reaping-hooks, with smooth-cutting edges; and after remarking that from the earliest times down to our own day there had been little if any alteration made upon the reaping-hook since its invention, Mr. Bell described the ani-ani, a rude implement used in Japan for cutting corn, which was inferior to the reaping-hook in point of execution, though the principle of cutting was that of scissors, the same as in the reaping-machine. The heads of the grain only were cut off by the ani-ani. He then noticed the earliest real machines constructed for reaping, describing the principle adopted in each machine. He said that no fewer than thirty contrivances had been attempted to construct an efficient reaping-machine upon the principle of a circular cutter, though he was not sure that any of them ever reached maturity. Coming down to 1852, he said that in that year no fewer than thirty patents were taken out in this country for reaping-machines. In America, from the beginning of this century to the end of 1851, 98 contrivances were patented at Washington, embodying, like those in this country, almost every conceivable principle. The reaper which bore his (Mr. Bell's) name was invented in 1826, and used in the field in 1827, and had been in successful operation every season since. The most successful American reapers were upon his principle, and were patented at Washington in 1833-34, seven or eight years after his invention was known to the world, so that his neighbours in the Far West had ample time to make up their minds whether they would think for themselves, or quietly take a hint from a brother. Mr. Bell concluded his paper with the following account of the difficulties he experienced in completing his own invention: "Before I finally conclude, it may be expected of me to state in a few sentences the rise and progress of the reaping-machine known by my name. From my earliest years I had a liking and turn for the study and practice of mechanics. I am the son of a farmer, and was accustomed from my early youth to witness all the operations of the farm performed, and in most of them I engaged with my own hands. I was not a Presbyterian minister during the time in which I invented the reaping-machine, as is currently stated, but an alumnus of one of our national universities—the University of St. Andrews. A farmer's son in my day, at least, although an academic, would not have been allowed to study undisturbed in his *sanctum*, and was liable, especially in the harvest season, to be summoned to wield the fork or some other implement of toil. At a very early period of my life I was most painfully struck with the very severe nature of the toil to which the harvest workers were subjected—a toil made doubly oppressive sometimes by the heat of the weather, and always by the very awkward position in which they were obliged to stoop when engaged in their work. It may sound as an empty sentimentalism, but it is nevertheless true that a desire to mitigate such excessive toil led me to inquire whether there might not be a possibility of transferring part of it at least to beams of wood and bars of iron, supplemented by the bones and sinews of the horse. Sure I am that I had no intention of taking the people's bread from them; and had I been so taunted, I believe that even then I could have demonstrated that the multiplication and employment of machinery in agricultural work immediately promotes the increase of the people's bread, and does not ultimately tend to diminish the means of the people to obtain that bread. For years I had thought of the matter, and had diligently searched for some principle; and, taking up one after another, I duly weighed the possibilities of their application to the object in view, and abandoned them all as worthless. One evening after tea, while walking in my father's garden, my eyes caught a pair of gardener's shears sticking in the hedge. I seized them by the handles, which protruded, and I proceeded to snap at the twigs of the thorns. My mind was full of mechanics at the time, and many hours were spent in my workshop; and, contemplating the shears attentively, I insensibly said to myself, Here is a principle, and is there any reason why it should not be applied to the cutting down of the corn? Not altogether satisfied with my performance on the hedge, I brushed through it with the shears in my hand to a field of young oats adjoining, and commenced cutting them right and left. It was well that no neighbouring gossip saw me at the unwonted employment, else the rumour might have been readily circulated that the poor student had gone crazed. For weeks and for months, by night and by day, those shears were uppermost in my thoughts, and I searched anxiously and indefatigably for the mode in which they should be employed. Plan after plan presented itself to me, and were put upon paper. The merits of each, and the likelihood of its success, were carefully scrutinised and pondered, and eventually I fixed upon the plan now successfully in

operation. This took place in the summer of 1827. The next step was to construct a model, and to ascertain how thoughts would look when transferred to steel and iron. This was done, and it was during the process of making the little wooden frame and my puny cutters that the idea of a sloping canvas for conveying the cut corn to the side occurred to me. My first idea was to place the canvas level with the ground, and it was merely because that it was more conveniently situated in the model, and pleased the eye better, that the angular position was adopted, so that in reality the position and the angle of the canvas were more matters of accident than the result of consideration. Were the truth always known, I believe that much more important improvements in mechanical science would be found to have a similar origin. Having finished my model, and speculated as accurately and deeply as I was able upon the possibilities and probabilities of the actual results, I determined to have a machine constructed upon the large scale. For this purpose I had to pass out of my character of inventor into that of engineer and workman. The plan I took was this: After making my calculations as to size, &c., I joined a quantity of rough sticks together and called them a frame. Then I made cutters of wood of every part that required to be made of iron and steel. I sent these pieces by piece as I required them to the blacksmith, with the instructions to make a thing of iron as like the wooden ones sent as possible. When I got a few of the pieces from the smith, I finished them with the file, and secured each to its proper place. I remember the cutters gave me a world of trouble and vexation. When they came into my hands they were in a very rude state, and required much filing, grinding, and fitting. By dint of patient application I got the whole into a sufficiently perfect state, as I thought, for trial. It may amuse you, perhaps, if I give you some account of the first field I cut. That you may understand this, imagine an empty outhouse, rather long and narrow, having in one end a wright's bench, and in the other a rude-looking piece of mechanism, an embryo reaping-machine. For my subsequent operations I chose a quiet day—that is, a day when there were few people about the place. On that day an eavesdropper might have seen me busily but stealthily engaged in conveying earth in a common wheelbarrow into the workshop. When the place between the bench and the rude but ambitious candidate for the honours of the harvest-field was covered to the depth of some six inches, I proceeded to compress the loose mould with my feet. I next went to an old stack that happened to be in the barnyard, and drawing a sheaf of oats out of it, and carrying it to the workshop, I planted it stalk by stalk at about the same thickness which I knew it would have grown in the field. This done, I shut and barred the door, and then going behind the machine, I pushed it forward with all my might through my planted oats. As soon as I recovered my breath, I anxiously examined how the work had been done. I found that it had been all very well cut, but it was lying *higgledy-piggledy*, in such a mess as would have utterly disgraced me in the harvest-field. Upon the whole, however, I was not discouraged, but rather encouraged by this first experiment. The cutting was perfect, and that was the great point I then aimed at. Although by this experiment I had proved my new invention to be a cutting-machine, it certainly little deserved to be dignified with the name of a reaping-machine, and yet it was a reaping-machine I had set my heart upon constructing. Had I at this stage been content to summon a man with a rake to do the work of wheels and pinions, my machine was complete; and, had I been contented with a combination, I would have saved myself a host of trouble, and what to me at the time was no small expenditure of money. My workshop was again speedily cleared of earth and loam, and made ready for the jack-plane and piles. I proceeded forthwith to put the canvas in order. One might naturally suppose that this would be an easy matter, but I did not find it so. After the rollers were put in position, the wheels for driving them adjusted, and the canvas stretched and fixed upon the rollers the proper tightness, I conceived in my simplicity that the work was done, and my object secured. The result was otherwise; for, on pushing the machine forward only the length of the house, I found that it twisted, and would have been torn in pieces if it had proceeded many yards forward. I proceeded now to make grooves at the ends of the rollers, in which I placed a small rope. To these ropes, one at the top and the other at the bottom of the rollers, I sewed the canvas, expecting that the ropes and canvas would move together in uniformity, and that my object would thus be obtained; but, upon trial, I was a second time disappointed. The ropes, from inequality in the grooves, moved irregularly, and the canvas became twisted as before. For a time I was nonplused and dispirited, but, plucking up courage, and ruminating over mechanical appliances, I thought of the pitched chains. Having made some six inches of such a chain out of a piece of old hoop iron, I sent the same as a pattern to the blacksmith, with an order to make for me so many feet of chain like the model sent. Having received the chains, and put them

in their places, the canvas was speedily attached, and a third trial was prepared for to meet the third alteration of its construction which had now been made. The wheelbarrow was again in requisition, and another visit made to the old stack in the barn-yard, and the process of dibbing another sheaf gone through. The door was again shut, and palpitating with expectation, I pushed the machine forward. To my unspeakable satisfaction the oats were not only nicely cut, but were lying almost unanimously by the side of the machine in one even continuous row, as I had confidently expected. You may smile, but I now complimented myself, sensibly, I think, on my success, being convinced that I had converted the implement from a cutting to a reaping machine. All this too place in 1828. Until the crops were ripe nothing more could be done. I was in high excitement and hope, and I waited impatiently for the ripening of the grain. In the mean time I revolved in my mind, with anxious and provident hope, everything that was likely to happen when the actual trial in the open field should come to be made. I was fearful that there should happen to me what had happened to many an experimenter before who performs his experiments to a wish in the laboratory or workshop, but who utterly fails when he actually adjourns to the actual domain of nature or of art. I had observed in experiment upon the pigmy and artificial field in the workshop, that while the oats upon the whole came to the canvas, and were regularly removed to its side, nevertheless some seeds straggled away capriciously in different and adverse directions. And yet I could not forget that in the workshop all was calm, and that I had the elements greatly under my own control, but that in the open field the blowing wind might multiply the capricious stragglers, and fan the flame of disunion, and damage the success of the operation. It was an anticipation of this kind that induced me to think of the reel or collector. Having plenty of time before harvest, I constructed this part of the implement, and laid it past to be used or not as the emergencies of the field might require. The period now approached that was to decide the merits of the machine. That night I will never forget. Before the corn was perfectly ripe (I had not patience to wait for that) a younger brother of mine and I resolved to have a quiet and unobserved start by ourselves. That could not be got while the sun was in the heavens, nor for a considerable time after he was set; and, accordingly, about eleven o'clock at night, in a dark autumn evening, when every man, woman, and child were in their beds, the machine was quietly taken from its quarters, and the good horse Jock was yoked to it, and we trio wended our way through a field of lea to one of standing wheat beyond it—my brother and I the mean while speaking to one another in whispers. We reached our destination, and the machine was put in position right in the end of a ridge. My duty was to look ahead, and my brother's to guide the horse. I gave the word of command to go on, and on the implement went; but it had not proceeded above five or six yards when I called upon my brother to stop. Upon examining the work we found it far from satisfactory. The wheat was well enough cut, but it was lying in a bundle before the machine. For a moment we were both downcast; but, recollecting myself, I had yet great hope, and said so, the whole of the machine not being used, the reel or collector having been left behind. I ran across the field and brought the reel and everything connected with it upon my shoulders, and adjusted it as well as the darkness of the night would permit, and we were soon ready for a second start. Taking our positions respectively as before, the machine moved forward, and now all was right. The wheat was lying by the side of the machine as prettily as any that has been ever cut by it since. After this we merely took it back again to the edge of the ridge, and made a cut with the open edge to ascertain how the swathes would lie upon the stubble, with which being well pleased, we, after some pardonable congratulations, moved the machine back to its old quarters as quickly and quietly as possible. I have extracted from the paper published in the *Quarterly Journal of Agriculture*, which I wrote at the time for that periodical, these remarks so far as relating to myself. The paper in full will be found in the number of January, 1854. I consider it unnecessary to follow out the history further, as the implement is now well known, and may be seen in operation in most parts of the country every harvest."

UP THE AMAZON.—At the meeting of the British Association a paper was read, contributed by Messrs. Wallace and Mayne, "On the Peruvian Expedition to the River Ucayali." This expedition was undertaken at the instance of the Peruvian Government with the view of discovering a river route to the eastern slopes of the Andes in Peru, by which the produce of the country might be sent to Europe without crossing the Andes. The vessels penetrated two rivers hitherto almost unknown, and reached towns not far from Lima, thus establishing a navigable route on the Amazon and its tributaries for 3700 miles, by which goods might be shipped from Peru to Europe or vice versa. The engineering arrangements are under the management of Mr. Daniel Clark, who has a small engineering factory at Iquitos, and who has steamers running on the river.

BRITISH ASSOCIATION, 1857: DUNDEE.
REPORT ON SCIENTIFIC EDUCATION IN SCHOOLS.

(Continued from page 194.)

iii. BOTANY has also strong claims to be regarded as a subject for scientific training. It has been introduced into the regular school course at Rugby (where it is the first branch of natural science which is studied); and the voluntary pursuit of it is encouraged at Harrow, and at some other schools, with satisfactory results. It only requires observation, attention, and the acquisition of some new words; but it also evolves the powers of comparison and colligation of facts in a remarkable degree; of all sciences it seems to offer the greatest facilities for observation in the fields and gardens; and to this must be added the fact that boys, from their familiarity with fruits, trees, and flowers, start with a considerable general knowledge of botanical facts. It admits therefore pre-eminently of being taught in the true scientific method. The teaching of science is made really valuable by training the learner's mind to examine into his present knowledge, to arrange and criticise it, and to look for additional information. The science must be begun where it touches his past experience, and this experience must be converted into scientific knowledge. The discretion of the teacher will best determine the range of botany at which it is desirable to aim.

6. The modes of giving instruction in the subjects which we have recommended are reducible to two. I. A compulsory system of instruction may be adopted, similar to that which exists at Rugby, where science has now for nearly three years been introduced on precisely the same footing as mathematics and modern languages, and is necessarily taught to all boys. II. A voluntary system may be encouraged as has been done for many years at Harrow, where scientific instruction on such subjects as have been enumerated above is now given in a systematic series of lectures, on which the attendance of all boys who are interested in them is entirely optional.

Of these systems it is impossible not to feel that the compulsory system is the most complete and satisfactory. The experience of different schools will indicate how it may best be adopted, and what modifications of it may be made to suit the different school arrangements. It will often be very desirable to supplement it by the voluntary system, to enable the boys of higher scientific ability to study those parts of the course of experimental physics which will rarely, if ever, be included in the compulsory school system. Lectures may also be occasionally given by some non-resident lecturer with a view of stimulating the attention and interest of the boys. We add appendices containing details of these two systems as worked at Rugby and Harrow,* and we believe that a combination of the two would leave little or nothing to be desired.

The thorough teaching of the physical sciences at schools will not, however, be possible, unless there is a general improvement in the knowledge of arithmetic. At present many boys of thirteen and fourteen are sent to the public schools almost totally ignorant of the elements of arithmetic, and in such cases they gain only the most limited and meagre knowledge of it; and the great majority enter ill-taught. It is a serious and lasting injury to boys so to neglect arithmetic in their early education; it arises partly from the desire of the masters of preparatory schools to send up their boys fitted to take a good place in the classical school, and from the indifference of the public schools themselves to the evil that has resulted.

7. With a view to the furtherance of this scheme, we make the following suggestions:

- i. That in all schools natural science be one of the subjects to be taught, and that in every public school at least one natural science master be appointed for the purpose.
- ii. That at least three hours a week be devoted to such scientific instruction.
- iii. That natural science should be placed on an equal footing with mathematics and modern languages in affecting promotions, and in winning honours and prizes.
- iv. That some knowledge of arithmetic should be required for admission into all public schools.
- v. That the universities and colleges be invited to assist in the introduction of scientific education, by making natural science a subject of examination, either at matriculation, or at an early period of a University career.
- vi. That the importance of appointing lecturers in science, and offering entrance scholarships, exhibitions, and fellowships for the encouragement of scientific attainments be represented to the authorities of the colleges.

With reference to the last two recommendations, we would observe that, without the co-operation of the universities, science can never be effectively introduced into school education. Although not more than 35 per cent., even of the boys at our great public schools, proceed to the university, and at the majority of schools a still smaller proportion, yet the curriculum of a public school course is almost exclusively prepared with reference to the requirements of the universities and the rewards for proficiency that they offer. No more decisive proof could be furnished of the fact that the universities and colleges have it in their power to alter and improve the whole higher education of England.

APPENDIX A.

I. OXFORD.

The natural science school at Oxford was established in the year 1853. By recent changes the university allows those who have gained a first, second, or third class in this school to graduate without passing the classical school, provided they have obtained honours, or have passed in three books at least, at the second classical examination, viz., moderations (which is usually passed in the second year of residence); honours in this school are thus placed on an equality with classical honours. The first classical examination, "responsions," is generally passed in the first term of residence. Arithmetic and two books of Euclid, or algebra up to simple equations, are a necessary part of this examination.

The university offers ample opportunities for the study of physics, chemistry, physiology, and other branches of natural science. At present only a few of the colleges have lecturers on this subject; while for classics and mathematics every

college professes to have an adequate staff of teachers. At Christ Church, however, a very complete chemical laboratory has been lately opened.

A junior studentship at Christ Church and a demysip at Magdalen College, tenable for five years, are, by the statutes of those colleges, awarded annually for proficiency in natural science. A scholarship, tenable for three years, lately founded by Miss Brackenbury at Balliol College for the promotion of the study of natural science, will be given away every two years. With the exception of Merton College, where a scholarship is to be shortly given for proficiency in natural science, no college has hitherto assigned any scholarships to natural science. The number of scholarships at the colleges is stated to be about 400, varying in annual value from 100*l.* to 60*l.* With these should be reckoned college exhibitions,* to the number of at least 220, which range in annual value from 145*l.* to 20*l.*, and exhibitions awarded at school, many of which are of considerable value.

The two Burdett-Coutts geological scholarships, tenable for two years, and of the annual value of 75*l.*, are open to all members of the university who have passed the examination for the B.A. degree, and have not exceeded the 27th term from their matriculation. Every year a fellowship of 200*l.* a year, tenable for three years (half of which time must be spent on the Continent) on Dr. Radcliffe's foundation, is at present competed for by candidates who, having taken a first class in the school of natural science, propose to enter the medical profession.

At Christ Church two of the senior studentships (fellowships) are awarded for proficiency in natural science; at the examination for one of these, chemistry is the principal subject, and for the other physiology.

At Magdalen College it is provided that, for twenty years from the year 1857, every fifth fellowship is assigned to mathematics and physical science alternately. In the statutes of this and of every college in Oxford (except Corpus, Exeter, and Lincoln) the following clause occurs:—"The system of examinations shall always be such as shall render fellowships accessible, from time to time, to excellence in every branch of knowledge for the time being recognised in the schools of the university." This clause, so far as it relates to the study of natural science, has been acted on only by Queen's College and at Merton College, where a natural-science fellowship will be filled up during the course of the present year.

At Pembroke College one of the two Sheppard fellows must proceed to the degree of Bachelor and Doctor of Medicine in the university. At the late election to this fellowship natural science was the principal subject in the examination. The number of college fellowships in Oxford is at present about 400.

II. CAMBRIDGE.

It is important to distinguish between the university and the colleges at Cambridge as at Oxford.

There is a natural-science tripos in which the university examines in the whole range of natural sciences, and grants honours precisely in the same manner as in classics or mathematics.

The university also recognises the natural sciences as an alternative subject for the ordinary degree. As the regulations on this point are comparatively recent, it will be well to state them here.

A student who intends to take an ordinary degree without taking honours has to pass three examinations during his course of three years:—the first, or previous examination, after a year's residence, in Paley, Latin, Greek, Euclid, and arithmetic, and one of the Gospels in Greek; the second, or general examination, towards the end of his second year, in the Acts of the Apostles in Greek, Latin, Greek, Latin prose composition, algebra, and elementary mechanics; and the third or special examination, at the end of his third year, in one of the following five subjects:—1. Theology; 2. Moral Science; 3. Law; 4. Natural Science; 5. Mechanism and applied science.

In the natural-science examination a choice is given of chemistry, geology, botany, and zoology.

There are only five colleges in Cambridge that take any notice of natural science, namely, King's, Caius, Sidney Sussex, St. John's, and Downing. At King's two exhibitions have been given away partly for proficiency in this subject; but there are no lectures, and it is doubtful whether similar exhibitions will be given in future. At Caius there is a medical lecturer and one scholarship given away annually for anatomy and physiology. At Sidney Sussex two scholarships annually are given away for mathematics and natural science; and a prize of 20*l.* for scientific knowledge. There is also a laboratory for the use of students. At St. John's there is a chemical lecturer and laboratory; and though at this college there is no sort of examination in natural science either for scholarships or fellowships, it is believed distinction in the subject may be taken into account in both elections. Downing was founded with "special reference to the studies of law and medicine;" there is a lecturer here in medicine and natural science, and in the scholarship examinations one paper in these subjects; no scholarship is appropriated to them, but they are allowed equal weight with other subjects in the choice of candidates. It is believed that the same principle will govern the election to fellowships in this college, though no fellowship has yet been given for honours in natural science. We believe that, owing to the new university regulations (mentioned above), the authorities of Trinity College have determined to appoint a

* At Magdalen College there will be twenty exhibitions tenable for five years, and of the value of 75*l.* a year, to be held by persons in need of support at the university; in the election to these, "the subjects of examination, for one exhibition at least in each year, shall be mathematics and physical science alternately."

† These colleges exercised the powers of making statutes granted to them by the Oxford University Act of 1854, 17 and 18 Vic., cap. 81. In the statutes of Exeter College it is provided that, in the election of fellows, "preference shall be given to those candidates in whom shall be found the highest moral and intellectual qualifications, such intellectual qualifications having been tested by an examination in such subjects as the college from time to time determine." In the statutes of Lincoln College the following clause occurs:—"Pateat aatem societas non his tantum, qui in literis Græcis et Latinis se profecisse probaverint, sed etiam aliarum bonarum artium peritis juvenibus." And in the statutes of Corpus Christi College, "Quicumque se candidatos offerant examinentur in bonis literis et scientiis, sicut Presidenti of sociis videbitur."

lecturer in natural science; the matter is under deliberation in other colleges, and it is not improbable that the same considerations will induce them to follow this example.

It must always be remembered that the practice is rare in Cambridge of appropriating fellowships and scholarships to special subjects. At present public opinion in the university does not reckon scientific distinction as on a par with mathematical or classical; hence the progress of the subject seems enclosed in this inevitable circle—the ablest men do not study natural science because no rewards are given for it, and no rewards are given for it because the ablest men do not study it. But it may be hoped that the disinterested zeal of teachers and learners will rapidly break through this circle; in that case the subject may be placed on a satisfactory footing without any express legislative provision.

III. THE UNIVERSITY OF LONDON.

At the University of London the claims of science to form a part of every liberal education have long been recognised. At the matriculation examination the student is required to show that he possesses at least a popular knowledge of the following subjects:

- a. In *Mechanics*: the composition and resolution of forces; the mechanical powers; a definition of the centre of gravity; and the general laws of motion.
- b. In *Hydrostatics, Hydraulics, and Pneumatics*: the pressure of liquids and gases; specific gravity; and the principles of the action of the barometer, the syphon, the common pump and forcing-pump, and the air-pump.
- c. In *Acoustics*: the nature of sound.
- d. In *Optics*: the laws of refraction and reflection, and the formation of images by simple lenses.
- e. In *Chemistry*: the phenomena and laws of heat; the chemistry of the non-metallic element; general nature of acids, bases, &c.; constitution of the atmosphere; composition of water, &c.

At the examination for the degree of B.A. a more extensive knowledge of these subjects is required, and the candidate is further examined in the following branches of science:

- f. *Astronomy*: Principal phenomena depending on the motion of the earth round the sun, and on its rotation about its own axis; general description of the solar system, and explanation of lunar and solar eclipses.
- g. *Animal Physiology*: the properties of the elementary animal textures; the principles of animal mechanics; the processes of digestion, absorption, assimilation; the general plan of circulation in the great divisions of the animal kingdom; the mechanism of respiration; the structure and actions of the nervous system; and the organs of sense.

Besides the degree examination, there is also an examination for honours in mathematics and natural philosophy, in which, of course, a much wider range of scientific knowledge is required.

We would venture to remark that, if a similar elementary acquaintance with the general principles of sciences were required for matriculation at Oxford and Cambridge, it is certain that they would at once become a subject of regular teaching in all our great public schools.

There are also two specially scientific degrees, a Bachelor of Science and a Doctor of Science. For the B.Sc. there are two examinations of a general but highly scientific character. The degree of D.Sc. can only be obtained after the expiration of two years subsequent to taking the degree of B.Sc. The candidate is allowed to select one principal subject, and to prove his thorough practical knowledge thereof, as well as a general acquaintance with other subsidiary subjects.

IV. THE COLLEGE OF PRECEPTORS.

In the diploma examinations at the College of Preceptors, one branch of science, viz., either chemistry, natural history, or physiology, is required as a necessary subject for the diploma of Fellow. In the examinations for the lower diploma of Associate or Licentiate some branch of science may be taken up by candidates at their own option. The council recently decided to offer a prize of three guineas half-yearly for the candidate who showed most proficiency in science, and who at the same time obtained a second-class in the other subjects.

In the examinations of pupils of schools, natural philosophy, chemistry, and natural history are optional subjects only, and are not required for a certificate for the three classes. Two prizes are given to those candidates who obtain the highest number of marks in these subjects at the half-yearly examinations; and it is an interesting fact that last year, out of a total of 651 candidates, 100 brought up natural history, and 36 brought up chemistry as subjects for examination. Two additional prizes were consequently awarded.

V. THE FRENCH SCHOOLS.

In France the "Lycées" correspond most nearly to our public schools, and for many years science has formed a distinct part of their regular curriculum. A strong impulse to the introduction of scientific teaching into French schools was given by Napoleon I., and since that time we believe that no French school has wholly neglected this branch of education. The amount of time given to these subjects appears to average two hours in every week.

The primary education is that which is given to all alike, whatever may be their future destination in life, up to the age of eleven or twelve years. After this period there is a "bifurcation" in the studies of boys. Those who are intended for business or for practical professions lay aside Greek and Latin, and enter on a course of "special secondary instruction." In this course mechanics, cosmography, physics, chemistry, zoology, botany, and geology occupy a large space; and the authorised official programmes of these studies are very full, and are drawn up with the greatest care. The remarks and arguments of the Minister of Public Instruction (Mons. Duruy) and others, in the "Programmes officiels, &c., de l'enseignement secondaire spécial," are extremely valuable and suggestive; and we recommend the syllabuses of the various subjects, which have received the sanction of the French Government, as likely to afford material assistance to English teachers in determining the range and limits of those scientific studies at which, in any special system of instruction, they may practically aim. Th "Enseignement secondaire spécial" might very safely be taken

* See Appendices B and C.

as a model of what it is desirable to teach in the "modern departments" which are now attached to some of our great schools.

The boys who are destined to enter the learned professions continue a classical course, in which, however, much less time is devoted to classical composition than is the case in our public schools. Nor is science by any means neglected in this course, which is intended to cover a period of three years. Besides the "elementary division," there are five great classes in these schools, viz., a grammar division, an upper division, a philosophy class, and classes for elementary and special mathematics.

In the grammar division there is systematic instruction on the physical geography of the globe.

In the second class of the upper division the boys begin to be taught the elements of zoology, botany, and geology in accordance with the ministerial programmes; and in the rhetoric class descriptive cosmography (which seems to be nearly co-extensive with the German *Erkunde*) forms the subject of a certain number of weekly lessons.

In the class of philosophy, the young students are initiated into the elementary notions of physics (including weight, heat, electricity, and magnetism, acoustics, and optics), and of chemistry, in which, at this stage, the teaching is confined to "general conceptions on air, water, oxidation, combustion, the conditions and effects of chemical action, and on the forces which result from it."

In the classes of elementary and special mathematics this course of scientific training is very considerably extended; and if the authorised programmes constitute any real measure of the teaching, it is clear that no boy could pass through these classes without a far more considerable amount of knowledge in the most important branches of science than is at present attainable in any English public schools.

VI. THE GERMAN SCHOOLS.

In Germany the schools, which are analogous to public schools in England are the *Gymnasien*, where boys are prepared for the universities, and *Bürgerschulen* or *Realschulen*, which were established for the most part about thirty years ago for the purpose of affording a complete education to those who go into active life as soon as they leave school. An account of the Prussian *Gymnasien* and *Realschulen* may be seen in the Public School Commission Report, Appendix G; further information may be obtained in "Das höhere Schulwesen in Preussen," by Dr. Wiese, published under the sanction of the Minister of Public Instruction in Prussia, and in the programmes issued annually by the school authorities throughout Germany.*

At the *Gymnasien* natural science is not taught to any great extent. According to the Prussian official instructions, in the highest class two hours, and in the next class one hour, a week are allotted to the study of physics. In the lower classes two hours a week are devoted to natural history, i.e., botany and zoology. The results of the present training in natural science at the *Gymnasien* are considered by many eminent university professors in Germany to be unsatisfactory, owing to the insufficient time allotted to it.

In the *Realschulen* about six hours a week are given to physics and chemistry in the two highest classes, and two or three hours a week to natural history in the other classes. In these schools all the classes devote five or six hours a week to mathematics, and no Greek is learnt. In Prussia there were in 1864 above 100 of these schools.

APPENDIX B.

On the Natural Science Teaching at Rugby.

Before the summer of 1864, a boy on entering Rugby might signify his wish to learn either modern languages or natural science; the lessons were given at the same time, and therefore excluded one another. If he chose natural science he paid an entrance fee of 1*l.* 1*s.*, which went to an apparatus fund, and 5*l.* 5*s.* annually to the lecturer. Out of the whole school, numbering from 450 to 500, about one-tenth generally were in the natural science classes.

The changes proposed by the Commissioners were as follows: That natural science should no longer be an alternative with modern languages, but that all boys should learn some branch of it. That there should be two principal branches—one consisting of chemistry and physics, the other of physiology and natural history, animal and vegetable; and that the classes in natural science should be entirely independent of the general divisions of the school, so that boys might be arranged for this study exclusively according to their proficiency in it.

Since, owing to circumstances which it would be tedious to detail, it was impossible to adopt literally the proposals of the Commissioners, a system was devised which must be considered as the system of the Commissioners in spirit, adapted to meet the exigencies of the case.

The general arrangement is this,—that new boys shall learn botany their first year, mechanics their second, geology their third, and chemistry their fourth.

In carrying out this general plan certain difficulties occur, which are met by special arrangements depending on the peculiarities of the school system. We need not here enter upon these details, because it would be impossible to explain them simply, and because any complications which occur in one school would differ widely from those which are likely to arise in another.

Next, as to the nature of the teaching.

In botany the instruction is given partly by lectures and partly from Oliver's Botany. Flowers are dissected and examined by every boy, and their parts recognised and compared in different plants, and then named. No technical terms are given till a familiarity with the organ to be named or described has given rise to their want. The terms which express the cohesion and adhesion of the parts are gradually acquired until the floral schedule, so highly recommended by Henslow and Oliver, can be readily worked. Fruit, seed, inflorescence, the forms of leaf, stem, root are then treated, the principal facts of vegetable physiology illustrated, and the principle of classification into natural orders explained, for the arrangement of which Bentham's "Handbook of the British Flora" is used. Contrary to all previous expectation, when this subject was first introduced it became at once both popular and effective among the boys.

The lectures are illustrated by Henslow's nine diagrams, and by a large and excellent collection of paintings and diagrams made by the lecturers and their friends, and by botanical collections made for use in lectures. When the year's course is over, such boys as show a special taste are invited to take botanical walks with the principal lecturer, to refer to the School Herbarium, and are stimulated by prizes for advanced knowledge and for dried collections, both local and general.

In mechanics the lecturer is the senior Natural Science Master. The lectures include experimental investigations into the mechanical powers, with numerous examples worked by the boys; into the elements of mechanism, conversion of motion, the steam-engine, the equilibrium of roofs, bridges, strength of material, &c. They are illustrated by a large collection of models, and are very effective and popular lectures.

The lectures in geology are undertaken by another master. This subject is only temporarily introduced, on account of the want of another experimental school. When this is built the third year's course will be some part of experimental physics, for which there already exists at Rugby a fair amount of apparatus. It is very desirable that boys should obtain some knowledge of geology, but it is not so well fitted for school teaching as some of the other subjects on several grounds. Perhaps a larger proportion of boys are interested in the subject than in any other; but the subject presupposes more knowledge and experience than most boys possess, and their work has a tendency to become either superficial or undigested knowledge derived from books alone. The lectures include the easier part of Lyell's Principles, i.e., the causes of change now in operation on the earth; next, an account of the phenomena observable in the crust of the earth, stratification and its disturbances, and the construction of maps and sections; and, lastly, the history of the stratified rocks and of life on the earth. These lectures are illustrated by a fair geological collection, which has been much increased of late, and by a good collection of diagrams and views to illustrate geological phenomena.

For chemistry the lecturer has a convenient lecture-room and a small but well-fitted laboratory,* and he takes his classes through the non-metallic and the metallic elements; the lectures are fully illustrated by experiments. Boys, whose parents wish them to study chemistry more completely, can go through a complete course of practical analysis in the laboratory, by becoming private pupils of the teacher. At present twenty-one boys are studying analysis.

This being the matter of the teaching, it remains to say a few words on the manner. This is nearly the same in all the classes, *mutatis mutandis*: the lecture is given, interspersed with questions, illustrations, and experiments, and the boys take rough notes, which are recast into an intelligible and presentable form in note-books. These are sent up about once a fortnight, looked over, corrected, and returned; and they form at once the test of how far the matter has been understood, the test of the industry, care, and attention of the boy, and an excellent subject for their English composition.

Examination papers are given to the sets every three or four weeks, and to these and to the note-books marks are assigned which have weight in the promotion from form to form. The marks assigned to each subject are proportional to the number of hours spent in school on that subject.

There are school-prizes given annually for proficiency in each of the branches of natural science above mentioned.

This leads us, lastly, to speak of the results.

First, as to the value of the teaching itself; secondly, as to its effects on the other branches of study.

The experience gained at Rugby seems to point to these conclusions: That botany, structural and classificatory, may be taught with great effect and interest a large number of boys, and is the best subject to start with. That its exactness of terminology, the necessity of care in examining the flowers, and the impossibility of superficial knowledge are its first recommendations; and the successive gradations in the generalisations as to the unity of type of flowers, and the principles of a natural classification, are of great value to the cleverer boys. The teaching must be based on personal examination of flowers, assisted by diagrams, and everything like cram strongly discouraged.

Mechanics are found rarely to be done well by those who are not also the best mathematicians. But it is a subject which in its applications interest many boys, and would be much better done, and would be correspondingly more profitable, if the standard of geometry and arithmetic were higher than it is. The ignorance of arithmetic which is exhibited by most of the new boys of fourteen or fifteen would be very surprising, if it had not long since ceased to surprise the only persons who are acquainted with it; and it forms the main hindrance to teaching mechanics. Still, under the circumstances, the results are fairly satisfactory.

The geological teaching need not be discussed at length, as it is temporary, at least in the middle school. Its value is more literary than scientific. The boys can bring neither mineralogical, nor chemical, nor anatomical knowledge; nor have they observed enough of rocks to make geological teaching sound. The most that they can acquire, and this the majority do acquire, is the general outline of the history of the earth and of the agencies by which that history has been effected, with a conviction that the subject is an extremely interesting one. It supplies them with an object rather than with a method.

Of the value of elementary teaching in chemistry there can be only one opinion. It is felt to be a new era in a boy's mental progress when he has realised the laws that regulate chemical combination, and sees traces of order amid the seeming endless variety. But the number of boys who get real hold of chemistry from lectures alone is small, as might be expected from the nature of the subject.

Of the value of experimental teaching in physics, especially pneumatics, heat, acoustics, optics, and electricity, there can be no doubt. Nothing but impossibilities would prevent the immediate introduction of each of these subjects in turn into the Rugby curriculum.

Lastly, what are the general results of the introduction of scientific teaching in the opinion of the body of masters? In

brief, it is this, that the school, as a whole, is the better for it and that the scholarship is not worse. The number of boys, whose industry and attention is not caught by any school study is decidedly less; there is more respect for work and for abilities in the different fields now open to a boy; and though pursued often with great vigour, and sometimes with great success, by boys distinguished in classics, it is not found to interfere with their proficiency in classics, nor are there any symptoms of overwork in the school. This is the testimony of classical masters, by no means specially favourable to science, who are in a position which enables them to judge. To many who would have left Rugby with but little knowledge, and little love of knowledge, to show as the results of their two or three years in our middle school, the introduction of science into our course has been the greatest possible gain; and others who have left from the upper part of the school, without hope of distinguishing themselves in classics or mathematics, have adopted science as their study at the universities. It is believed that no master in Rugby School would wish to give up natural science and recur to the old curriculum.

APPENDIX C.

On the Teaching of Science at Harrow School.

From this time forward natural science will be made a regular subject for systematic teaching at Harrow, and a natural science master has been appointed.

But for many years before the Royal Commission for Inquiry into the public schools had been appointed, a voluntary system for the encouragement of science had been in existence at Harrow. There had been every term a voluntary examination, on some scientific subject, which, together with the text-books recommended, was announced at the end of the previous term. Boys from all parts of the school offered themselves as candidates for these voluntary examinations, and every boy who acquitted himself to the satisfaction of the examiners (who were always two of the masters) was rewarded with reference to what could be expected from his age and previous attainments. The text-books were selected with great care, and every boy really interested in his subject could and did seek the private assistance of his tutor, or of some other master. The deficiencies of the plan, if regarded as a *substitute* for the more formal teaching of science, were too obvious to need pointing out; yet its results were so far satisfactory that many old Harrovians spoke of it with gratitude, among whom are some who have since devoted themselves to science with distinguished success.

One of the main defects of this plan (its want of all system) was remedied a year ago, when two of the masters drew up a scheme, which was most readily adopted, by which any boy staying at Harrow for three years might at least have the opportunity during that time of being introduced to the elementary conceptions of astronomy, zoology, botany, structural and classificatory, chemistry, and physics. These subjects were entrusted to the responsibility of eight of the masters, who draw up with great care a syllabus on the subject for each term, recommend the best text-books, and give weekly instruction (which is perfectly gratuitous) to all the boys who desire to avail themselves of it; indeed a boy may receive, in proportion to the interest which he manifests in the subject, almost any amount of assistance which he may care to seek. Proficiency in these examinations is rewarded as before; and to encourage steady perseverance, the boys, who do best in the examination during a course of three terms receive more valuable special rewards.

As offering to boys a voluntary and informal method of obtaining much scientific information, this plan (which was originated at Harrow, and has not, so far as we are aware, been ever adopted at any other school) offers many advantages. It is sufficiently elastic to admit of many modifications; it is sufficiently comprehensive to attract a great diversity of tastes and inclinations; it cannot be found oppressive, because it rests with each boy to decide whether he has the requisite leisure or not; it can be adopted with ease at any school where even a small body of the masters are interested in one or other special branch of science; and it may tend to excite in some minds a more spontaneous enthusiasm than could be created by a compulsory plan alone.

We would not, however, for a moment recommend the adoption of any such plan as a *substitute* for more regular scientific training. Its chief value is purely *supplemental*, and henceforth it will be regarded at Harrow as entirely subordinate to the formal classes for the teaching of science which will be immediately established.

In addition to this, more than a year ago some of the boys formed themselves into a voluntary association for the pursuit of science. This Scientific Society, which numbers upwards of thirty members, meets every ten days at the house and under the presidency of one or other of the masters. Objects of scientific interest are exhibited by the members, and papers are read generally on some subject connected with natural history. Under the auspices of this society the nucleus of a future museum has already been formed, and among other advantages the society has had the honour of numbering among its visitors more than one eminent representative of literature and science. We cannot too highly recommend the encouragement of such associations for intellectual self-culture among the boys of our public schools.

ON THE IRON AND STEEL AT THE PARIS EXHIBITION.

At the recent meeting of the British Association at Dundee, Mr. John Fernie, of Leeds, spoke on the above subject before the Mechanical Section. He remarked that much had been said about the advance of French manufacture in this department as compared with the English. But such ideas would be dispelled by taking into consideration the effect of the protective tariff of the French customs, which interferes with our exports to France, and lessens the inducement for English manufacturers to exhibit their products in Paris. Mr. Fernie stated that the protective duties apply principally to manufactured iron, while coal and pig iron enter duty free; and the British department of the Paris Exhibition contained accordingly scarcely anything but the products of some Yorkshire houses who carry on some trade with France on account of the high quality and reputation of their products. In the French department some speci-

* See also Etude sur l'instruction secondaire et supérieure en Allemagne, par J. F. Minssen, Paris, 1866. A brief report addressed to the Minister of Public Instruction in France.

* Another and larger laboratory and school for Experimental Physics will shortly be built at Rugby.

mens of rolled iron had attracted much attention, since they were of a section far larger than any similar girders ever rolled in this country. The largest section was a double T exhibited by the Forges of Chatillon and Commentry; and next to those came some girders made by Messrs. Petin, Gaudet, of St. Etienne. Girders of that description had been made in England before this, and used for iron-plated ships; but the mode of manufacture was different, the girders being rolled as two simple T irons, and welded together in the web. The girders now made in France, on the contrary, are rolled in one piece from a single pile. These girders were very short comparatively with their other dimensions, and their manufacture should therefore be considered as a *tour de force* rather than as a practically useful innovation. In the manufacture of such girders, there was a large surface exposed, first to the action of the fire in the furnace, and then to the process of rolling, which was likely to deteriorate the iron. Consequently, even though this process was one which could be successfully adopted, there would be considerable doubt as to whether the strength of the girder made in this way would be equal to a girder made in the ordinary way—of boiler plate rivetted together. These girders, in the opinion of Mr. Fennie, had been made for the purpose of going beyond the English people, and not so much for their practical value. Another novelty was the process of stamping, lately introduced, and which has been very largely carried out by the French. This process was to make a complicated forging in small pieces fixed together, putting it in the furnace, raising it to a welding heat, and then completing the whole in a pair of dies by means of a few blows from a powerful hammer. This process had not come much into use in this country; but one English house had shown several specimens quite equal in manufacture to those exhibited by the French. The manufacture of steel in large masses, exhibited by Krupp and the Bochum Company, far exceeded in size anything as yet manufactured in England. The specimens from the Bochum Company were, in the opinion of Mr. Fennie, deserving of special mention. Twenty-two railway wheels of cast steel, all in one piece, and a still more beautiful casting of a locomotive cylinder were the finest steel castings ever exhibited. So far as France is concerned, England had not been excelled in any department in the manufacture of iron.

Professor Rankine wished to know by what process steel was manufactured at the Bochum Company.

Mr. Fennie said he believed it was by the crucible process. Mr. Ferdinand Kohn said he had been in Paris a considerable time, and had directed his attention specially to the iron department; and having had a conversation with the manager of the Bochum Company, he could state that the Bochum steel was not manufactured by the ordinary crucible process. The mode of manufacture was a secret, but he believed that the process consisted in the casting of material containing a greater quantity of carbon than steel, and afterwards subjecting these castings to a process of decarburization.

Mr. Fennie, in answer to a question put to him by Mr. P. Le Neve Foster, stated that the reason why an order had been given by the Great Eastern Railway Company to a French house to make forty locomotives was in consequence of the English locomotive makers having more orders than they could execute at the time. Now, however, there was an immense number of new houses, and the old firms, having added new branches to their businesses, he did not think that in future English orders would require to be given to foreign companies to execute.

INDIAN ENGINEERS.

EXAMINATION PAPERS

For Competitive Examination of Candidates for Appointments in the Engineer Establishment of the Department of Public Works in India, held at the India Office, London, in July, 1867.

As the papers given last July, at the examination held at the India Office, of candidate for appointments in the Public Works Department in India, have not been printed by Parliament, we have thought it desirable to publish them in the columns of *ENGINEERING*, since, no doubt, there are many who purpose going up for the examination in December next who would be glad to obtain a copy of them.

The papers given at former examinations have been printed by order of the House of Commons, and may be obtained from Messrs. Hansard, of Great Queen-street, Lincoln's-inn-fields. Their dates and numbers are as follows:

No. 135 of 1859, Sess. 2; No. 566, 1860; No. 499, 1861; No. 76, 1863; No. 473, 1863; No. 426, 1865; No. 454, 1866.

In addition to the above, it may also be useful to give the following list of schools and colleges hitherto recognised by the Secretary of State as possessing efficient classes for instruction in engineering:

England.—University College, London; King's College, London; Royal Military Academy, Woolwich; Proprietary College, Bath; Grosvenor College, Bath; The College, Chester; School of Practical Science and Metallurgy, Sheffield.

Scotland.—University, Glasgow; Gymnasium, Old Aberdeen; Madras College, St. Andrews; High School, Edinburgh; Dollar Institution, by Stirling; Perth Academy.

Ireland.—Queen's College; Trinity College, Dublin.

Foreign.—McGill College, Montreal, Canada; Belgian School of Civil Engineers, Ghent; Ecole Polytechnique, Zurich.

Algebra.

REV. J. CAPE.

1. Reduce to their simplest forms:

$$\frac{x^3 + 3ax^2 + 3a^2x + a^3}{x^3 - 3a^2x + 3a^2x^2 - a^3} \dots (1)$$

$$\frac{x^4 - xy(x^2 + y^2) + y^4}{x^4 - xy(3x^2 - 4xy + 3y^2) + y^4} \dots (2)$$

$$\sqrt[3]{a^4 + \sqrt{a^2b^2 + \sqrt{a^2b^2}}}$$

$$\sqrt[3]{a^4 + \sqrt{a^2b^2 + \sqrt{a^2b^2}}}$$

2. Show that $a^2 - (b - c)^2 + b^2 - (c - a)^2 + c^2 - (a - b)^2 = 1$.

Also that $(x + y + z)^3 - (x^3 + y^3 + z^3) = 3(x + y)(x + z)(y + z)$.

3. Solve the following equations:

$$\frac{2x + 25}{13} + \frac{80 - x}{8} = \frac{10x - 32}{19} \dots (1)$$

$$(x - 3)(x - 2) + (x - 3)(x - 1) + (x - 2)(x - 1) = 2 \dots (2)$$

$$(ax + by)^2 + (ay - bx)^2 = 2\left(\frac{a}{b} + \frac{b}{a}\right)^2 \dots (3)$$

$$\frac{x}{y} + \frac{y}{x} = 2 \frac{a^2 + b^2}{a^2 - b^2} \dots (4)$$

$$x(x + 1) + 3\sqrt{2x^3 + 6x + 5} = 25 - 2x \dots (5)$$

$$xy = 231, xcy = 420, xzw = 660, yzw = 1540 \dots (6)$$

4. Extract the square root of $\frac{1051}{25}x^2 - \frac{6}{5}x - \frac{14}{5}x^2 + 9$

+ 49x⁴; also, of $41 - 12\sqrt{5}$; and simplify

$$\frac{\sqrt{18a^2b^2} + \sqrt{50a^2b^2}}{\sqrt{8ab^2} + \sqrt{2a^2b} - 8a^2b^2 + 8ab^2}$$

5. If $a : b :: c : d$,

$$\text{show that } \frac{4a + 5b}{3a - 7b} = \frac{4c + 5d}{3c - 7d}$$

6. Find the series in arithmetical progression in which the 5th and 9th terms are 11 and 9 respectively.

7. Sum the following series:

$$\frac{5}{7} + \frac{2}{9} - \frac{17}{63} + \dots \text{to 99 terms} \dots (1)$$

$$\frac{1}{5} - \frac{2}{15} + \frac{4}{45} + \dots \text{to 7 terms} \dots (2)$$

$$\frac{1}{3} + \frac{8}{9} + \frac{5}{27} + \dots \text{to infinity} \dots (3)$$

8. Find the middle term of $(a^{\frac{1}{2}} + b^{\frac{1}{2}})^{10}$ and the two middle terms of $(a^2 - 8a^2b^2)^{12}$; also, expand $\frac{3a}{(ax - x^2)^{\frac{1}{2}}}$ to five terms.

9. A rectangular area of 8 acres 480 yards has a perimeter of 840 yards. Find its length and breadth.

10. Goods are marked for a sale at a price which gives a profit of n per cent. on the selling price, and $(n + 50)$ per cent. of the cost price. Find n .

11. A man has 4 hours at his disposal. How far may he ride in a coach travelling 10 miles an hour, so that he may be able to walk back in time, his rate of walking being 4 miles an hour?

12. The rent of a farm is paid in a certain fixed number of quarters of wheat and barley. When wheat is at 55s. and barley at 33s. per quarter, the portions of rent by wheat and barley are equal; but when wheat is at 65s. and barley at 41s. per quarter, the rent is increased by 7l. What is the corn-rent?

Euclid.

REV. J. CAPE.

1. Define the terms *superficies*, *circle*, *scalene triangle*, and *parallelogram*; and state what is meant by a straight line being at right angles to another straight line.

2. If two angles of a triangle be equal to one another, the sides also which subtend or are opposite to the equal angles, shall be equal to one another.

In a triangle, if the lines bisecting the angles at the base be equal, the triangle is isosceles, and the angle contained by the bisecting lines is equal to an external angle at the base of the triangle.

3. To bisect a given finite straight line, that is, to divide it into two equal parts.

Show how to trisect—(1) a right angle; (2) one-fourth of a right angle.

4. The opposite sides and angles of parallelograms are equal to one another, and the diameter bisects them, that is, divides them into two equal parts.

If in the diagonal of a parallelogram any two points be taken equidistant from its extremities, and joined with the opposite angles, a figure will be formed which is a parallelogram.

5. If the square described upon one of the sides of a triangle be equal to the squares described upon the other two sides of it, the angle contained by these two sides is a right angle.

If from the vertex of a plane triangle a perpendicular is let fall on the base, or the base produced, the difference of the squares on the sides is equal to the difference of the squares on the segments of the base.

6. The angle at the centre of a circle is double of the angle at the circumference upon the same base, that is, upon the same part of the circumference.

7. In a circle, the angle in a semicircle is a right angle; but the angle in a segment greater than a semicircle is less than a right angle; and the angle in a segment less than a semicircle is greater than a right angle.

8. To describe an isosceles triangle, having each of the angles at the base double of the third angle.

Let ABD be the isosceles triangle, A the vertex, C the point in which AB is divided. If in the base BD, DE be taken equal to BC, prove—(1) that the rectangle contained by BE and BD is equal to the square on DE; (2) that CE is parallel to AD.

9. The sides about the equal angles of equiangular triangles are proportional; and those which are opposite to the equal angles are homologous sides, that is, are the antecedents or consequents of the ratios.

An angle ACB of a triangle is bisected by the line CD, which cuts the base AB in D. If E be a point in AB produced such that EC is equal to ED, prove that BE, DE, AE are in continued proportion.

10. If two straight lines meeting one another be parallel to two others that meet one another, and are not in the same plane with the first two, the first two and the other two shall contain equal angles.

Arithmetic, Trigonometry, and Mensuration.

REV. J. CAPE.

1. Reduce $\frac{2}{3} - \frac{2}{9} + \frac{5}{81}$ to a simple fraction, and then to a decimal.

2. Which is the cheapest—a coat that costs 3l. 16s., and will last 9 months, or one that costs 2l. 5s., and will only last 7 months? How much will a man save in 7 years 14 weeks by regularly wearing the cheaper one?

3. Find the square root of .007, and also of $\frac{.00125}{.72}$, to four places of decimals.

4. Divide the weekly wages 104l. 8s. among 100 labourers, 5 foremen, and 1 superintendent; the superintendent having thrice as much as each foreman, and a foreman twice as much as a labourer.

5. A man who owes 1873l. 6s. 8d. settles his bill by paying 1308l. 2s. What rate of discount is allowed him?

6. A man bought Brighton Railway shares some years back at 119. He is now obliged to sell some, and can only realise 63. What is his loss per cent. on the stock sold?

7. Find the numerical values of $\sin 45^\circ$, $\cos 30^\circ$, $\tan 18^\circ$, $\cot 75^\circ$, by geometrical construction, without using any tables.

8. Determine an expression for the sine of any angle of a triangle in terms of the sides of the triangle, and hence deduce a convenient expression for the area of a triangle.

Ex.—The three sides of a triangle are 450, 500, 570 ft.; find its area, and greatest angle.

9. What is the height of an inaccessible object which has an angle of elevation 30° 16' at A, and after retreating directly from the object to B, a distance of 325 yards, the angle of elevation is diminished to 22° 13' 10"?

10. A man observes that the angle of elevation of a tower on the opposite side of a river is 60°, and of another tower of the same height, half a mile lower down the stream, the angle of elevation is 45°. Also the angle subtended by the feet of the two towers is 120°. Find the breadth of the stream, and the height of each tower.

11. Find the following by the help of logarithms:

$$(1.) \text{The values of } \sqrt[3]{43.725}, (.2476)^{\frac{1}{2}},$$

$$\sqrt[3]{5.962}, (.0045)^{\frac{1}{2}}$$

$$(2.) \text{A fourth proportional to } (41.06), (.00056)^{\frac{1}{2}}, (120)^{\frac{1}{2}}.$$

$$(3.) \text{The natural sine of } 48^\circ 25' 37'' \text{ from a table of logarithmic sines.}$$

$$(4.) \text{The angle whose logarithmic cosine is } 9.8472693.$$

12. What is the weight of a 13 in. shell, its thickness being 2 in., a solid shot of 4 in. diameter weighing 9 lb.?

13. How much earth must be excavated in laying a mile of 18 in. drain pipes, the lower side of the pipes being 4 ft. below the surface; and how much earth will have to be carted away, supposing the earth returned to be so rammed as to occupy the same space after the disturbance as before?

14. A cylindrical boiler with hemispherical ends, being 17 ft. long and 5 ft. in diameter, how many gallons of water will it hold, the water not rising higher than within 18 in. of the horizontal top?

15. Required the number of gallons a cask holds, the length of which is 40 in., while the girths at the two ends are 70 in., at the middle 101.2 in., and at 10 in. distance from each end 90 in., the thickness of the cask being everywhere uniformly $\frac{1}{4}$ an inch.

16. A canal has to be cut 100 ft. long, the bottom being 12 ft. wide throughout, and the sides being inclined at an angle of 45° to the horizon. The depths at successive distances of 10 ft. are: 5, 5.4, 5.7, 6.1, 6.7, 7, 7.9, 7.2, 6.8, 6.1, 6.4 ft.

How much earth must be removed?

Mechanics and Hydrostatics.

REV. J. CAPE.

1. If two forces acting on a point are represented in magnitude and direction by two straight lines, prove that their resultant is represented in magnitude and direction by the diagonal of the parallelogram of which those two lines are the sides.

Two forces represented by 7 and 9 acting on a point, are inclined to one another at an angle of 60°. Find the magnitude of their resultant.

2. A boy weighing 96 lb. sits on a gate 4 ft. from the post on which the gate hangs by hinges, one 3 ft. above the other. Find the additional horizontal pressure which he causes on the hinges.

3. On a uniform straight lever weighing 7 lb., and 7 ft. in length, weights of 1, 2, 3, 4, 5, 6 lb. are hung at distances 1, 2, 3, 4, 5, 6 ft. respectively from the extremity. Find the position of the fulcrum on which the lever will balance.

4. Find the relation that the power bears to the weight in the following machines:

(1.) The system of pulleys in which the same rope passes round all the pulleys, the weight of the pulleys being neglected.

(2.) The wedge without friction.

(3.) The inclined plane with friction, the power being inclined at an angle α to the inclined plane.

5. A weight of 500 lb. is placed on an inclined plane, the angle of inclination being 45°, and the coefficient of friction being $\frac{1}{3}$. Find the least force which will keep the weight from sliding down the plane, and the least force which will draw it up the plane.

6. A line is drawn parallel to the base of a triangle, and cutting off a triangular piece the area of which is $\frac{1}{4}$ of the area of the whole triangle. Find the position of the centre of gravity of the remaining trapezium.

7. What is meant by the mechanical terms—*Work*, *Unit of Work*, *Friction*, *Modulus*, *Horse Power*?

8. A train weighs 75 tons, and the friction is 7 lb. per ton. What horse-power must an engine be to draw it up an incline of 1 in 250, at a uniform rate of 24 miles an hour?

9. A shaft 12 ft. in diameter is to be sunk 130 fathoms through chalk (S. G. 2.315). How long will a 2 horse-power engine take to raise the earth excavated, being kept at work 9 hours a day?

10. When a body is moving under the influence of a uniform accelerating force, show that $s = \frac{1}{2}ft^2$.

Ex. The Monument is 210 ft. high; how long would a stone take in falling from the top to the ground?

11. Explain how the heights of mountains and depths of mines may be calculated by means of the pendulum.

Ex. If a pendulum, when carried to the top of a mountain, loses in 24 hours twice as much as it does in the same time when taken to the bottom of a mine close by; show that the height of the mountain is the same as the depth of the mine.

12. With what velocity, and at what elevation, must a stone be thrown, to hit the ground at a distance of 875 yards in 11 seconds, the resistance of the air not being taken into consideration?

13. Describe the hydraulic ram, and state the defects and advantages attending its use.

14. What weight will an empty 96 gallon cask support in water, the weight of the cask being 52 lb., and 8 cubic feet of wood being used in making it?

15. What must at least be the size, in cubic feet, of an inflated balloon, that it may be able to rise in the air when inflated with gas, whose specific gravity, compared with air, is .09, the weight of a cubic inch of air being .3 grains, and the balloon, car, and contents weighing 750 lb.

On Water Supply, Reservoirs, Dams, &c.

GEORGE PRESTON WHITE, C.E., Examiner.

1. Describe briefly the different means employed to supply towns with water, and give illustrative examples.

2. Describe the gravitation and pumping systems, pointing out the comparative advantages, and state the principal conditions and requirements to be considered and attended to in adopting either system.

3. Describe briefly what are impounding, compensating, depositing, storage, and service reservoirs, residuum lodges, and collecting grounds.

4. Describe the geological formations which are the best water-bearing strata, and explain why the flow of water is generally more regular through the chalk than through the clay formation.

5. In constructing dams for impounding water, specify the precautions which should be adopted for security, and to render them impervious to water, and specify the difference between the forms of construction employed in this country and France.

6. Describe some of the most approved means for forming filter beds, as for example at the Lambeth, York, Chelsea, and other waterworks, as first introduced by Mr. Simpson, C.E.; specify the best materials to employ for the purpose, and explain whether the action is chemical or mechanical, and what head of water is necessary.

7. If employed to supply a town with water, state some of the principal conditions which would guide you as to the mode of supply; how you would ascertain the probable amount of supply, the quality of the water, and the number of gallons per day, on the average, it would be desirable to provide for per head of population.

8. Make a free-hand sketch to illustrate the most approved forms for cast-iron water-pipes; describe the different means used for jointing pipes, pointing out the advantages or defects of each system. What are turned and bored joints, and specify when they are particularly applicable.

9. In preparing a specification for cast-iron pipes, explain why it is desirable that large pipes should be cast perpendicularly with the faucet end downwards. Also as to the nature of the material which should be employed to cast them in, the quality of the metal, and the mixtures most approved; and describe how the pipes should be tested to ascertain their strength, and freedom from laps, air-holes, or other imperfections.

On Pumping-Engines, &c.

10. To how many atmospheres of pressure would it be desirable to test water-pipes as compared with the head of water to which they would be actually subjected in practice? And when under pressure what further test is then desirable?

11. Illustrate with free-hand sketches, and describe the uses of the following, viz., bib-cocks, crutch-key cocks, spigot and faucet joints, flange-joints, stand-pipes, reducing-pipes, branches and bends, air-vessels, scour-cocks, hydrants, sluice-valves.

12. Calculate the number of gallons of water which a pipe, 30 in. diameter, is capable of delivering in 24 hours, with a fall of 20 ft. per mile.

13. Describe briefly the different kinds of pumps and other contrivances for raising water; give a free-hand sketch of a bucket and plunger pump with its suction and delivery valves, and state under what circumstances centrifugal pumps are most applicable.

14. Describe the mode of ascertaining the power of pumping-engines required in any given case, supposing the quantity of water to be delivered per hour, size and length of main, and difference of level between the water in pump-well and top of stand-pipe or service reservoir, be given.

15. The following is a practical application of the foregoing question: It is required to construct pumping machinery, consisting of two engines, two pumps, and two boilers, capable together of forcing 50,000 gallons of water per hour through 8600 yards of 12 in. main, and into a reservoir 370 ft. above level of water supply. How would you determine the dimensions of the principal parts of the machinery?

16. Calculate head due to friction in preceding question.

17. Having ascertained head due to friction, which, if unable to give the formula for, assume at 36 ft., making a total lift of 406 ft., calculate the net horse power required, taking a horse power at 33,000 lb. raised 1 ft. high per minute.

18. Having ascertained the net horse power, and added thereto 20 per cent. to obtain the indicated horse power, what would be the diameter of cylinder required, supposing 40 lb. of steam in boiler, and an expansion, say, at half stroke, assuming 30 lb. mean average pressure per square inch of piston during stroke, length of stroke being 3 ft. and number of revolutions 30 per minute?

19. Supposing a bucket and plunger pump to be used, with stroke of 30 in., and 30 strokes per minute, calculate diameter of bucket or pump-barrel for delivering each 25,000 gallons per hour, bearing in mind that there are 277 cubic inches to a gallon.

20. Assuming that at the pressure of 40 lb. in boiler the relative volume of steam to water is as 640 to 1, calculate the number of cubic feet of water consumed per hour in each boiler.

21. Assuming that 22 square feet of heating surface of boiler is required for evaporating a cubic foot of water, and that a single-flued Cornish boiler, shell 6 ft. diameter, with flue 3 ft.

6 in. diameter, be supplied for each engine, calculate the length of boiler required.

22. Make free-hand sketches and describe the rain gauge and hygrometer, and explain their uses for engineering purposes.

23. Describe the wrought-iron tube employed by Mr. Simpson, C.E., for the Bristol Waterworks, for continuing the aqueduct across the Combe or Ravine; explain the arrangements to provide for expansion and contraction, and also to prevent leakage at the points of junction with the stone aqueduct.

24. Give the names of standard works of reference on the subject of water supply, and name, as examples, some of the principal works which have been executed in this country and abroad for the supply of cities with water.

On Harbours, Docks, Groins, &c.

The accompanying plan* represents a harbour, possessing considerable natural advantages, but requiring certain engineering works to render it suitable for the purposes of commerce and navigation.

1. If professionally employed to make a report on this harbour as to its capabilities, and as to the works necessary to render it suitable for a naval station and harbour of refuge, state how you would proceed to make the necessary surveys, take soundings and reduce them to a common datum, ascertain the nature of the bottom, and whether affording good anchorage, and also the direction of the prevailing currents, &c.

2. It will be seen that several rivers flow into the harbour; describe how you would gauge them, ascertain the volume of water discharged, the drainage area, and the amount of solid matter either held for a time in solution or finally deposited.

3. There is a tendency to silt up at the head of the harbour; explain the usual cause of this, and how you would avail yourself of back-water or tidal water to counteract this deposition, and describe the means adopted for this purpose by Smeaton, at Ramsgate, or any other well-known example.

4. Should it appear on investigation that in particular states of the wind or tide additional shelter is required in the outer harbour, mark on chart the position where you would recommend a breakwater to effect this object; give a cross section of it, showing sea slope or face, and specify how you would make the foundations, and the character of the masonry you would recommend for the purpose. Explain the nature of "pierre perdue" foundations.

5. Specify the character of the lime you would employ for the submarine portion of the work; and in the event of not being able to obtain, conveniently, natural hydraulic lime, explain how artificial hydraulic lime could be produced according to the experiments of Sir Charles Pasley and M. Vicat; describe the chemical difference between ordinary and hydraulic lime. In what time should good hydraulic lime set and harden?

6. If found necessary to remove some of the rocks in the harbour, dangerous to the navigation, describe the different means employed for the purpose, and if too large to be dealt with in this way, make a free-hand sketch of a simple form of beacon. If required to lay down permanent moorings, describe the Mitchell and mushroom anchor, and other forms in use.

7. One of the first requirements will be the formation of docks, quays, and landing stages. Mark on accompanying map where you would place them, showing position of locks and entrance gates.

8. It frequently occurs, as along the south-east coast of England, that there is a movement of shingles, sand, or other material, which deposits itself at the entrance of harbours, and proves most detrimental; describe some of the means employed to arrest this, and explain the use of wave-traps and beaching basins, and give some examples.

9. It will also be necessary to establish lighthouses and beacons. Mark on the map the position you would place them in; state the chief conditions which would guide you as to the height of lighthouse, and the nature of the lights you would employ, whether fixed, revolving, coloured, or with flashes at intervals.

10. If a landing-stage should be required, give a free-hand sketch of a simple form of one, and describe those at Liverpool, or any other well-known or important examples.

11. Having laid out the breakwater and other works included in the foregoing questions, point out what you consider will be the probable effect (if any) in altering the existing conditions of the harbour as to the currents and the deposition of mud and silt, or other material, &c., &c.

12. The railway commissioners recommended in their report that a railway should be carried over Gariash Island and across the harbour at the narrow entrance by a viaduct, where there is 60 ft. of water. Point out the engineering difficulties and disadvantages of such a line, and mark on map where you consider the best route for a railway, making the embankment subervient for docks and other purposes.

13. Give the names of standard works of reference and reports on the subject of harbour engineering, and the names of some of the engineers who have specially distinguished themselves in this most important branch of the profession.

On Lighthouses, Piers, and Miscellaneous Subjects.

1. The accompanying design represents a simple form of lighthouse, 60 ft. in height, suitable in cases where building materials are deficient, skilled labour expensive or not obtainable, or where there is a difficulty in forming foundations. It is intended to erect this structure on a sand bank, and found it on Mitchell's screw piles. Describe how you would get the piles into position, what depth it would be desirable to go to in sand or alluvial deposit, the size of pile, and diameter of screw. Make free-hand sketches of the piles, screw, braces, &c., showing the means of securing the work together. Give an approximate estimate of the cost of such a structure, exclusive of lantern, and name some successful examples of structures of this character which have been erected either in this country or abroad.

2. The accompanying design† represents a simple form of iron pier with T head, suitable in cases where there is a difficulty in

* A chart of the upper part of Bantry Bay, with Glengarriff Harbour, accompanied this question.

† A sketch of an iron screw-pile lighthouse accompanied this question.

‡ A sketch of a screw-pile pier accompanied this question.

obtaining a good foundation for structures of the ordinary character, or where suitable building materials or skilled labour cannot easily be obtained. Make free-hand sketches to illustrate the details of the work. Describe the form and material of the screw, the mode of manufacturing solid iron piles, the means of getting them into position, what batter it would be desirable to give, and the mode of bracing together the beams, girders, and other parts of the work.

3. What are the comparative advantages of the hollow cast-iron pile and the solid wrought-iron pile? Explain the mode usually adopted for getting the former into position.

4. Give the names of any important examples of structures of this kind which have been erected either in this country or in India.

5. Describe the effect of sea water on iron, and specify what steps should be taken as a prevention to injury.

6. Describe and make free-hand sketches of the following forms of wrought-iron girders—the Trellis, the Warren, the Tubular, and the Brunel girder. Specify which form would be most desirable for India, taking into consideration expense of carriage, facility of erection, or where skilled labour was either expensive or difficult to obtain, and describe which of the above forms require staging to get them into position, and what forms can, under certain conditions, be erected without staging.

7. Describe and make free-hand illustrations of some of the most approved modes for scarfing and trussing timber.

8. Name the different kinds of stone employed in building under the following heads, viz., Siliceous, Argillaceous, Calcareous, Stratified, and Unstratified.

9. Describe with free-hand illustration the means adopted in the main sewers for the drainage of London to provide for storm water, and to prevent sewers from blowing up.

10. Describe and make free-hand illustration of the weirs employed at the Manchester Waterworks to separate the storm and turbid water from that suited for the town supply.

11. Illustrate with free-hand sketches and give the meaning of the following terms: Facing Point, Falling Point, Blind Siding, Back Shunt, Check Block; and state what are the objections to facing points.

12. Photography, for the purpose of making "Photographic Reports," to illustrate the progress of works, copying drawings, &c., is most valuable for engineering purposes, especially in India; attention is therefore directed to the subject. State if you are able to use Photography for this purpose.

NOTE.—On the present occasion I have specially directed attention to the subject of water supply and harbour engineering, two of the most important but at the same time difficult branches of the profession, and which are yearly becoming more necessary in India, only a few of the principal cities being at present supplied with water; much, therefore, remains to be done in this way. Whilst, as regards harbour engineering, a wide field presents itself, as India, considering her extensive seaboard, is very deficient in natural harbours. I would, therefore, suggest these subjects as being deserving of especial attention.

The President of the Institution of Civil Engineers in his recent admirable address has truly remarked that "The dock and harbour engineer requires the general and much of the special knowledge of the railway engineer, such as that which belongs to railways and tramways, and warehouses for goods; and to this he must add a vast amount of other special knowledge not required by the railway engineer."

"For example, he must understand the laws which govern the ebb and flow of the tides, the rise and fall and time of high and low water; and he must have a knowledge of marine surveying, or the best means of ascertaining the set and speed of currents, and their tendency to increase depth of water by scour, or to diminish it by silting; he must also know, in the case of docks, what kind and extent of entrance accommodation to provide, whether the general plan should comprise only a simple lock, or be combined with a half-tide basin; whether single or double gates should be used; and whether it would be necessary to have a tidal basin or a recessed space, or both."

"The nature of the trade to be accommodated in the proposed docks must also be carefully ascertained, in order to provide a proper proportion of quay space and water space, and proper width of quays, warehouses for bonding or for goods to be deposited, sheds for temporary protection, entrance for barges into warehouses from the docks, graving docks, and workshops, with mechanical appliances for gates, sluices, and pumping; and for shipping or discharging minerals or goods."

"He may have to deal with solid foundation, and enjoy a facility of procuring suitable materials for construction, as at Liverpool; or he may have the bad foundations of Hull and other places, where alluvial silt of great depth has accumulated. It may be that good sound stone is too costly for the mass of his work, and that he must resort to brickwork, or rubble stone-work, or concrete, or to a combination of all three; but in determining such questions it is impossible that anything but previous experience and habits of careful investigation will enable an engineer to arrive at the best decision. For it is not enough that his work should be solid, permanent, and safe, but it should be rendered so at the smallest possible cost."

"The dock and harbour engineer is also required to report upon, and to construct, harbours of refuge, piers, landing stages, lighthouses, forts, canals and their appliances, river improvements, and many other hydraulic works; and, in short, of this branch of engineering it may be truly said that questions are continually arising which require special study and mechanical invention to a greater extent than in almost any other branch of the profession."

On Surveying.

LIEUTENANT-COLONEL C. D. NEWMARCH, R.E., Examiner.

1. Describe the course of instruction in surveying which you have undergone. What surveys or levelling operations have you been employed upon? Produce any finished drawings or survey plans, *bond fide* of your own execution, with certificate, stating whether plotted from your own surveys or otherwise.

2. The Gunter's chain is 66 ft. long—why? What is the length of a link of the Gunter's chain in yards, in feet, and in inches?

3. A survey being plotted and laid down to a scale of 6 in. to 1 statute mile, what proportion does that plan bear, both lineally and superficially, to the actual size of the ground?

4. Describe the mode of using a plane table, and state under what circumstances you would employ it.

5. What is the use of a triangulation, and in what manner is it carried out? Illustrate, by a diagram, how, when the measured base is unavoidably short, the sides of the principal triangles may be made rapidly to increase, without admitting any ill-conditioned triangles.

6. Describe the process of taking a round of horizontal angles with the theodolite, supposing it to be in correct adjustment, giving the reasons for using two verniers, and for making 60° and 120° zero points. Point out the particular advantages or disadvantages of a tower, a spire, or a tree, as trigonometrical station.

7. Suppose that P is the centre of a station where it is not possible to place the theodolite, S a satellite at 20 ft. distance, A and B other stations from which P has been observed, 63° 30' and 92° 15' the angles PSA and PSB respectively, and P A, P B, 5000 and 6000 ft. approximately ascertained, what will be the true value of the angle APB?

8. Explain the principle upon which inaccessible heights and distances are measured in the field by the aid of the pocket sextant, as illustrated in the following examples:

(1.) In order to obtain the breadth, A B, of a river, I set off the angle A B C a right angle, and from C, 50 yards from B, I found A C B 26° 34'; on B C produced I found another station, D, 100 yards from C, where A C B was 7° 8'; the scale of tangents corresponding to these angles gave the numbers 2 and 8 respectively; find the distance A B.

(2.) From a point A on a horizontal plane the angle of elevation of a hill was 7° 8'; upon approaching it 1000 ft. the angle was 14° 2'. The tangents corresponding to these angles are 8 and 4 respectively taken from the divisor tables. Find the height of the hill above the horizontal plain.

9. Find by construction the relative position of a point X, when A X B = 19°, B X C = 25°, A B C = 160°, A B = 800 ft., B C = 1100 ft., and state the distances A X and C X.

10. The measured distance between A and B was found to be 956 links; the reciprocal angles of elevation and depression were 2° 4' and 2° 7'; the horizontal readings +2' and +3'. The chain was 66.21 ft. in length. Required, the horizontal and vertical distances in feet between A and B.

Examination in Surveying.

Examiner, LIEUT.-COLONEL C. D. NEWMARCH, R.E.

1. Accompanying* is a traverse survey of a plot of ground near Shooter's Hill. All the angles, bearings, and measurements are recorded on the plan. From the data thus given compile a "Field Book," in the form and manner in which such observations are usually recorded when surveying in the field. The object of this question is to test your ability to keep a field book so far as that can be tested otherwise than in the field. You will therefore regard the plan as a piece of country, on the survey of which you are supposed to be engaged, and proceed to book your observations accordingly, just as you would do if actually in the field.

2. The accompanying† lithographed map represents the Lakes of Killarney, and portions of the counties of Kerry and Cork in their vicinity. You are requested to consider this as a tract of country on the survey of which you are proposed to be employed more especially with reference to the selection of the proposed new line of railway to Kenmare.

State in what manner you would proceed to execute such a survey, firstly, with reference to the production of such a map as you now see; and further, with reference to the more detailed surveys necessary for the selection and demarcation of the proposed new line of railroad.

The accuracy of the survey is supposed to be checked by the positions of the principal points being determined trigonometrically. You will accordingly select your own base line, and suitable trigonometrical stations.

The plan may be drawn over in any way that you think proper in illustration of your proposed mode of procedure; and the following points should be attended to:

- Show, by a thick red line, the position of the proposed base; and, by thin red lines, the proposed system of triangulation.
- Compute, as accurately as the scale will admit, the length of the proposed new line of railway.
- Colour in the road, rivers, lakes, sea, &c., shown on the plan, finishing off the map neatly.
- Compute the area of water embraced by the larger lake, or Lough Leane.
- Sketch in, on a separate piece of paper, and on an enlarged scale, the group of hills in the vicinity of Mangerton Mountain. This should be done as a free-hand sketch, and may be executed either with the pen or the brush, and is merely required in illustration of your capability of doing such work.
- Explain how, in practice, you would obtain the delineation of such hills, contouring being supposed, in this instance, to be considered as an unnecessarily expensive process; detail the process of sketching in ground in the field, and state what are the necessary previous preliminary checks upon the work.

NOTE.—A portion of the afternoon sitting will be devoted to the examination of some of the candidates in the practical use and adjustment of instruments.

Questions on Levelling and Practical Surveying.

Examiner, LIEUT.-COLONEL C. D. NEWMARCH, R.E.

1. When are two points on the surface of the earth said to be on the same level? What instruments are used in levelling?

2. What is the effect of the curvature of the earth on the apparent place of any object? Prove that two-thirds of the square of the distance, in miles, is the amount, in feet, of the correction for curvature.

3. What do you understand by refraction, and how do you

* A traverse survey of Shooter's Hill accompanied this question.

† A map of the Lakes of Killarney accompanied this question.

explain the law in optics on which the effect of refraction depends? How do you ascertain the amount of refraction at any time when the atmosphere is in an abnormal condition?

4. Suppose that in running a section line up a very flat slope, the levelling staves are placed as far apart as will allow of distinct vision, what will be the result on the height, omitting curvature and refraction?

5. At a horizontal distance of 8000 yards, the vertical angle observed with a theodolite, 5 ft. high, to the top of a tower, was 2° 6'. The tower was 150 ft. high, and the observer's position 260 ft. above the sea level. What was the height of the foot of the tower above the sea, curvature and refraction being taken as usual?

6. How do you trace contour lines upon the ground with a spirit level or theodolite, when required to be marked out with great accuracy? At what vertical distance apart may contour lines most usefully be applied, according to the scale of the plan, the nature of the country, and the purpose for which they are required?

7. Explain the mode of ascertaining the longitude of any point by the occultation of Jupiter's satellites, or by a lunar observation.

8. The apparent time, by observation at A, was 11 a.m. A chronometer, 10 minutes fast for Greenwich, showed 8 hours 20 minutes a.m. The equation of time was 16 minutes, mean time being before apparent time. Find the longitude of A.

9. Explain the meaning of the term circum-meridian altitudes, and show how such observations are applied to finding the latitude.

10. A star's zenith distance was 68° on the meridian, its north declination 60°; the observer south of the star, but north of the equator, and the allowance for refraction 1'. Find the latitude.

11. In order to lay down a magnetic meridian line upon a plan, what observations are necessary to be taken upon the ground, and how is it laid down? How can you, at certain times, by means of the sun's amplitude, ascertain the variation of the compass?

12. Explain how you would ascertain the height of a hill by means of boiling water, in the absence of any table of values.

13. Describe the different methods of marking out curves on the ground, when the radii are supposed to be of considerable length, as in the case of canals, &c.

Examination in Plotting and Plan Drawing.

Examiner, LIEUT.-COLONEL C. D. NEWMARCH, R.E.

1. Accompanying* is a lithographed Field Book, comprising the details of the traverse survey of a road in the vicinity of the Great Northern Railway. The measurements are given in feet. You are required to plot it on a scale of 2 chains to an inch. On this scale the plan will work into the general dimensions of 18 in. by 12 in. It will be as well to commence your plot towards the upper right-hand corner of the paper.

Finish off the plan neatly, colouring in the roads, houses, &c., and showing the traverse lines in red on the plan. Put in the meridian line from the compass observation taken at the first station. Print as a heading the words "Traverse Survey of the road through Audover, near the Great Northern Railway, plotted by (name)."

2. The following Field Book exhibits a line of levels taken for the construction of an embankment to protect low land against inundation. The crest of the embankment is to be raised 4 ft. above the highest known rise of the flood waters; its exterior slope to be two to one, and interior slope one to one; the breadth of the embankment at top to be 10 ft.

You are required to plot a longitudinal section, showing thereon the proposed level of the embankment, as also the flood level. Also to plot a transverse section of the embankment at its highest point. The horizontal scale of the sections to be 100 ft. to an inch, and the vertical scale 10 ft. to an inch. The height to which the embankment will require to be raised to be marked on the section at every 50 ft.

FIELD BOOK OF LEVELS.

No. of Station.	Back.			Height of Instrument.	Fore.			Rise.	Fall.
	Bearing.	Distance.	Level.		Level.	Distance.	Bearing.		
1	35°	50	2.01	5.01	7.47	50	215°	...	5.46
2	...	...	...	...	11.46	...	...	...	4.55
3	...	50	1.57	4.97	6.12	50	...	...	...
4	...	50	5.08	4.98	6.01	50	...	...	.93
5	...	50	4.02	5.02	4.99	50	...	...	.97
6	...	50	7.21	5.00	4.57	50	...	2.64	...
7	...	50	3.68	4.97	6.98	50	...	...	3.30
8	...	50	5.62	4.96	7.01	50	...	...	1.39
9	...	50	2.78	5.01	6.99	50	...	...	4.21
10	...	50	6.12	4.99	2.29	50	...	3.83	...
11	...	50	8.10	4.98	3.99	50	...	4.11	...
12	...	50	6.49	4.98	3.42	50	...	3.07	...
13	...	50	8.97	5.02	2.11	50	...	6.86	...

NOTE.—A portion of the afternoon sitting will be devoted to the examination, in the Practical Use and Adjustment of Instruments, of such of the Candidates as there may not have been time so to examine on the previous day.

INDIAN RAILWAY MATERIALS.—The shipment of railway materials and stores to British India appears to have commenced in 1853. In that year the value of this description of shipments was 29,363L.; in 1854, 34,113L.; in 1855, 20,832L.; in 1856, 347,233L.; in 1857, 950,967L.; in 1858, 989,552L.; in 1859, 1,233,578L.; in 1860, 1,706,002L.; in 1861, 1,903,304L.; in 1862, 1,509,580L.; in 1863, 1,165,852L.; in 1864, 1,267,240L.; and in 1865, 685,632L.

* A lithographed field-book accompanied this question.

† Reading of flood level at this point.

LOCAL TOPOGRAPHICAL INDICATOR.

At the recent meeting of the British Association at Dundee, Mr. J. V. N. Bazalgette read a paper, under the above title, on an instrument invented by him for the purpose of supplying reliable topographical information. His local indicators should be placed upon summits which are periodically visited by tourists. The local indicator would consist of a circular table of stone or metal engraved with radial lines pointing in the direction of any object of interest. Upon the line would be engraved the name of the object, its distance from the point of view, and in the case of mountains, their correct height above the sea. A table of three feet in diameter would be sufficiently large to embrace a district of thirty miles in radius, which would generally be found sufficient. To facilitate reference, concentric lines representing distances of five miles would be engraved upon the table, within which circles the names of places at such distances would appear. Upon an outer circle the names, directions, and distances of large cities, cathedrals, dockyards, headlands, and other objects of interest, beyond the thirty-mile circle would be shown. In the centre of the table may be placed a telescope, with an indicating hand, arranged so that on placing the hand in the direction of any object, the object itself, if within the range of sight, would be brought within the field of the telescope. The table would be removable, unless in cases where it might be deemed advisable to cover in the table with a light ornamental building, which would also serve as a shelter for visitors. Arrangements are now being made by the author for the erection of a local indicator with a telescope and light ornamental shelter upon the summit of the Malvern Beacon Hill, in Worcestershire. A smaller and less complicated form of indicator would be found useful in open places in large towns—the direction and distances to churches, railway stations, theatres, &c., being given. The tops of letter pillar-boxes being provided with such information would assist strangers, and even residents, as to distances and cab fares.

THE WATERWITCH, VIPER, AND VIXEN.

TO THE EDITOR OF ENGINEERING.

SIR,—Your correspondent, "W. B.," declines to make for himself the comparative analysis I suggested to him between the performance of the Waterwitch and that of the single-screw frigate, the Royal Alfred. I shall be happy to send him the heads of it, if he would like to see the result it leads to, though I promise him it will sadly derange the assumptions and reasoning of his last letter; but it is a thankless task, albeit in the cause of simple truth, to multiply arguments in support of the unpalatable conclusion I have already been constrained to arrive at in various ways, that the useful effect obtained by the Waterwitch is only somewhere about 18 per cent.

I would, however, now recommend to his notice another test, direct instead of comparative, which, with sufficiently exact experimental data, will be conclusive, and place the matter beyond the reach of further argument.

Let him ascertain, upon accurate and reliable experimental authority, the velocity of discharge at the mouth of the nozzles. The weight of water (W) discharged per second will then be known; and this, multiplied by the excess of the velocity of discharge over that of the vessel, in feet per second, and divided by 32.2, will give the vessel's resistance (R). Multiply R by the vessel's rate, in feet per second, and divide by 550; the result is the horse power utilised. Lastly, divide this by the gross or indicated engine power, and multiply by 100; the result is the useful effect per cent. for propulsion.

There is no room here for extraneous and irrelevant disquisition on the good or bad qualities of the vessel's lines. The process is simple, straightforward, and clear, and, what is still more to the purpose, altogether independent of the shape of the vessel.

This is the test I first applied (see *The Engineer* for November 9, 1866), and it is as infallible as the laws of motion can make it. Not a shred of an argument, as far as I know, has been or can be advanced against it. The only uncertainty, from first to last, has been about the actual velocity of discharge. Again and again I have urged the importance of ascertaining this element authoritatively from experiment; and I am not without hope that it may yet be satisfactorily settled at some future trial. Only one effort that I am aware of has been made in this direction, and it gave a result obviously too low, and against the efficiency of the vessel.

The almost querulous complaint, conveyed in the form of an interrogation in the last paragraph of "W. B.'s" letter, is not merited at least by me. I believe in the many very great advantages of hydraulic propulsion; and no one would rejoice more than myself to see it practically utilised, howsoever and by whomsoever; but I cannot blind my eyes to the results so far accomplished with the Waterwitch.

If "W. B." can propose any method of effectually serving the cause of hydraulic propulsion other than that of "starting from the point that the new propeller gives out something more than 50 per cent. of the power employed," which no sane person could think of doing, I will gladly take it up, and do all I can to promote it by hearty co-operation. The moderate limit I have contended for, as attainable only under the most favourable conditions, is 45 per cent., much better than the worst examples of the screw, but worse than the best.

The whole question of the efficiency of screw-propulsion, with its apparent anomalies (for they are only apparent), under different forms of application and for different forms of vessel, is too wide and important to be dealt with in a short letter. It is intimately bound up with the true theory of resistances, which I hope shortly to enter into fully. For the present it is enough to say that in the worst examples of vessel, as the Viper and Vixen, it gives an apparent efficiency little better than that of the Waterwitch; in better examples, as the Plover, an efficiency nearly double; in the best, as the Royal Alfred, probably something like threefold.

J. A. L. AIRY.

3, Residentary Houses, St. Paul's, London,
September 9, 1867.

ON THE BIRMINGHAM WIRE GAUGE.*

By MR. LATIMER CLARK.

THE Birmingham wire gauge is a scale of numbers extensively employed, both in this country and abroad, to designate a set of arbitrary sizes of wire varying from about half an inch down to the smallest sizes usually drawn.

The origin of this system and the date when it was introduced appear to be unknown, and as there is no authorised standard in existence, it happens that a great number of gauges have come into extensive practical use under the common name of the Birmingham wire gauge, but which differ from each other to a most serious extent.

A table is subjoined containing the sizes in decimal parts of an inch of twelve different wire gauges collected from various sources, and it is probable that many others might be found. The difference in weight of wires of the same denomination, according to different tables, amounts frequently to 10, 15, and even to 20 per cent. and upwards, and this among gauges which are in extensive daily use. The author has, in fact, recently been concerned in a contract in which the choice of one or other of two so-called Birmingham wire gauges, in equally common use and of equal authenticity, would make a difference of more than 8000% to the contractor.

This discrepancy of gauge has not escaped the attention of practical men. In 1857, Mr. Joseph Whitworth, at a meeting of the Institution of Mechanical Engineers of Manchester, proposed the adoption of a wire gauge in which the number of each size corresponded to its diameter in thousandths of an inch; for example, a

wire .095 inch in diameter would be called No. 95, and so on.

In 1858, Mr. James Cocker, of Liverpool, proposed to introduce a new Birmingham wire-gauge, closely approximating to the gauges in ordinary use, but with some of the more glaring irregularities smoothed over, so as to render the gauge more regular in its gradations; he also introduced a very convenient instrument for measuring the sizes of wire in thousandths of an inch, which bears his name, and which has proved a great convenience to practical men; he also employed the word "mil," as signifying the thousandth part of an inch, an innovation which has been also found of extreme convenience in practice.

Before making any suggestions for obviating the inconvenience arising from the great confusion among the gauges in common use, I would remark that I agree with others in entirely approving of the system of measurement in decimal fractions of an inch, and I employ this system in my own practice; there is, however, so much practical convenience in the use of a limited number of gauges, which become familiarised to the memory and to the eye, and the system is in such universal adoption throughout the world, that I see no hope or prospect of its abolition.

Under these circumstances it would appear desirable to bring into use one standard wire-gauge, approximating as closely as possible to the present wire-gauges, and sufficiently so to render it possible to make the present numbers still available, but formed on a systematic plan, and introduced with sufficient authority to ensure its universal reception.

I am of opinion that if the British Association would appoint a committee to investigate and report upon the subject, and were to issue a gauge under their authority, and bearing the title of the "British Association Gauge,"

or "British Gauge," that they would confer a great boon on the commercial community, and that the gauge recommended by them would soon obtain universal adoption.

I have been unable to ascertain which of the gauges given in the subjoined Table is entitled to the greatest authority, but I am inclined to attribute greater weight to that given in page 1013 of Mr. Holtzapfel's book on turning, both on account of his known accuracy and the early date at which his measurements were made.

I have investigated some of the gauges with a view to discover the basis on which they were originally formed. The irregularities in gradation are very great, but when plotted they gave a curve approximating to a logarithmic curve, such as would be formed by the constant addition of 10 or 12 per cent. to the diameter of each preceding size.

Upon the whole, I am inclined to think it probable that the original gauge was formed by taking as its basis No. 16 bell-wire, having a diameter of $\frac{1}{16}$ of an inch, and that each succeeding size up to No. 1 was formed by successive additions of 25 per cent. to the weight, this would be equivalent to successive increments of 11.8 per cent. to the diameters, and would give a logarithmic curve, which can be extended indefinitely in either direction.

I subjoin a column showing the diameters and sectional areas of wires of the various sizes formed on this basis—that is to say, by constant increments of 25 per cent. in sectional area or weight, and it will be found to approximate so closely to the Birmingham wire-gauges at present in use, that it might be substituted for them without much inconvenience, and I feel confident that if such a gauge were issued under the name and sanction of the British Association it would speedily obtain universal adoption.

TABLE SHOWING SOME OF THE VARIATIONS EXISTING IN THE WIRE GAUGE, AS GIVEN BY DIFFERENT AUTHORITIES.

DIAMETERS IN DECIMALS OF AN INCH.															PROPOSED GAUGE.		
Number.	From Wells and Hall's Price List.	Number.	W. T. Henley (received from).	Culley's "Handbook of Practical Telegraphy," Second Edition, p. 286.	Culley's "Handbook of Practical Telegraphy," Second Edition, p. 280.	Ryland Brothers (extracted from the "Electrician," vol. i., p. 191.	Ryland Brothers (May, 1866).	Holtzapfel's Book on Turning, p. 1013.	Molesworth's Pocket-Book. 1867.	Captain Shaw, R.E., ex "Electrician," vol. ii., p. 8.	Mr. James Cocker, proposed gauge, 1858.	Supplied by Mr. Bartholomew.	Mr. James Cocker (steel wire), ex "Electrician," vol. i., p. 286.	Mr. Whitworth on Standard Decimal Measures. 1858.	Diameters deduced from Table of Areas, or successively increasing by 11.8 per cent.	Areas successively increasing by 25 per cent.	
		00000	.456														
		0000	.425	.454													
		000	.394	.425													
		00	.363	.380	.363	.380											
		0	.331	.340	.331	.340	.326										
		1	.300	.289	.300	.300	.300	.300	.310	.3125	.300	.315	...	.300	.3465	.0943123	1
		2	.280	.276	.280	.280	.274	.284	.280	.2927	.280	.290	...	.280	.3099	.0754498	2
		3	.260	.247	.260	.260	.250	.259	.260	.2708	.260	.264	...	.260	.2772	.0603598	3
		4	.240	.221	.240	.240	.229	.238	.240	.2500	.240	.248	.246	.240	.2479	.0482879	4
		5	.220	.214	.220	.220	.209	.220	.220	.2291	.220	.223	.226	.220	.2217	.0386303	5
		6	.200	.194	.200	.200	.191	.203	.200	.2084	.200	.209	.198	.200	.1983	.0309042	6
		7	.185	.171	.185	.185	.174	.180	.187	.2075	.180	.184	.183	.180	.1774	.0247234	7
		8	.170	.161	.170	.170	.159	.165	.166	.1718	.160	.1685	.175	.165	.1587	.0197787	8
		9	.155	.143	.155	.155	.146	.148	.158	.1562	.140	.150	.160	.150	.1419	.0158229	9
		10	.140	.126	.140	.140	.133	.134	.137	.1406	.130	...	.136	.135	.1269	.0126583	10
		11	.125	...	.125	.125	.117	.120	.125	.1250	.120	.125	.128	.120	.1135	.0101267	11
		12	.110	...	.110	.110	.100	.109	.109	.1125	.110	.1105	.107	.110	.1015	.0081013	12
		13	.095	...	.095	.095	.090	.095	.095	.1000	.100	.0995	.100	.095	.0908	.0064811	13
		14	.085	...	.085	.085	.079	.083	.083	.0875	.090	.085	.092	.085	.0803	.0051848	14
		15	.075	...	.075	.075	.069	.072	.072	.0750	.080	.0755	.079	.070	.0726	.0041479	15
16	.062	16	.065	...	.065	.065	.0625	.065	.065	.0625	.070	.0685	.070	.065	.0650	.0033183	16
17		17	.057	...	.057	.057	.053	.058	.056	.0572	.060	.062	.063	.060	.0581	.0026547	17
18	.043	18	.050	...	.050	.050	.047	.049	.049	.0521	.050	.053	.057	.050	.0520	.0021237	18
19		19	.045	...	.045	.045	.041	.042	.042	.0468	.045	.0445	.047	.040	.0465	.0016990	19
20	.041	20	.040	...	.040	.040	.036	.035	.035	.0416	.040	.0355	.042	.036	.0416	.0018591	20
21		21	.035	...	.035	.035	.03125	.032	.032	.0364	.035	.0325	...	.032	.0372	.0010873	21
22	.032	22	.030	...	.030	.030	.028	.028	.028	.0312	.030	.030	...	.028	.0333	.0008699	22
23		23	...	...	...	...	...	.025	.025	.0281	.025	.0275	...	.024	.0297	.0006959	23
24	.025	24	...	...	.025	...	...	.022	.022	.0250	.022	.025	...	.022	.0266	.0005567	24
25	.023	25	...	...	.023	...	...	.020	.020	.0229	.020	.0225	...	.020	.0238	.0004454	25
26	.019	26	...	...	.019	...	...	.018	.018	.0208	.018	.0185	...	.018	.0213	.0003563	26
27	.018	27	...	...	.018	...	...	.016	.016	.0187	.016	.017	...	.016	.0190	.0002851	27
28	.016	28	...	...	.016	...	...	.014	.014	.0166	.014	.0144	...	.014	.0170	.0002280	28
29	.015	29	...	...	.015	...	...	.013	.013	.0146	.012	.013	...	.013	.0152	.0001824	29
30	.014	30	...	...	.014	...	...	.012	.012	.0125	.011	.0122	...	.012	.0136	.0001459	30
31	.012	31	...	...	.012	...	...	.010	.010	...	.010	.0115	...	.010	.0122	.0001167	31
32	.010	32	...	...	.010	...	...	.009	.009	...	.009	.0105	...	.009	.0109	.0000934	32
33		33	...	...	.0096	...	...	.008	.008	...	.008	.0085	...	.008	.0097	.0000747	33
34	.0096	34	...	...	.0087	...	...	.007	.007	...	.007	.0075	...	.007	.0087	.0000597	34
35	.0087	35	...	...	.0079	...	...	.005	.005	...	.006	.0055	...	.005	.0078	.0000478	35
36	.0079	36	...	...	.0067	...	...	.004	.004	...	.005	.004	...	.004	.0069	.0000382	36
37		37	...	...	.0058	...	...	...	...	...	...	...	...	...	...	...	...
38	.0067	38	...	...	.0042	...	...	...	...	...	...	...	...	...	...	...	...
		39	...	...	.0039	...	...	...	...	...	...	...	...	...	...	...	...
		40	...	...	.0033	...	...	...	...	...	...	...	...	...	...	...	...

FRENCH RAILWAYS.—It appears that between July 1, 1866, and June 30, 1867, new railways were brought into operation in France to the extent of 658½ miles. The increase in the average distance worked in the year ending June 30, 1867, was 591½ miles, as compared with the immediately preceding twelve months. The earnings of all the French lines in the first six months of 1867 were 11,971,864L, showing an increase of 566,322L, as compared with the corresponding six months of 1866.

TURIN AND SAVONA RAILWAY.—It is reported that the works of this line will shortly be resumed. This result is attributed to an arrangement concluded between the company and the Upper Italy Railway Company.

AMERICAN STEAM SHIPPING.—The American company known as the Pacific Mail Company, in obtaining a contract from the Federal Government for the establishment of a line of steamers between San Francisco, Japan, and China, engaged to cause its steamers to stop monthly at Honolulu, so as to establish a regular communication between California and the Sandwich Islands. The Pacific Mail Company, however, on the plea that this arrangement diverted its steamers too much from their route for Japan, has obtained from the United States Congress a dispensation from its obligation; and a new contract, approved by the American legislature, has been concluded with the California, Oregon, and Mexican Steamship Company, which engages, in consideration of an annual sub-

vention of 15,000L, to carry correspondence to Honolulu and to make twelve voyages annually to the Sandwich Islands, during a period of ten years, dating from January 1, 1868.

ANOTHER STEAM LINE.—A new line of steamers has just been inaugurated between Buenos Ayres, Montevideo, Rio de Janeiro, Gibraltar, and Marseilles.

PUBLIC WORKS IN TURKEY.—There is a good deal of talk just now of public works in Turkey.—A concession of a railway from Belgrade to Constantinople is under consideration, and the construction of roads in Roumelia and Anatolia is also proposed. A Franco-Belgian Company is said to be assured a contract for docks at Constantinople.

ON MACHINERY FOR THE PREPARING AND SPINNING OF COTTON.*

By Mr. JOHN PLATT, of Oldham.

(Continued from page 222.)

Carding.—In the carding process the felted fleece delivered by the lap-machine of the scutcher, with its fibres crossed in all directions, is combed out a great number of times so as to straighten the fibres; and the light impurities still adhering to it are taken out, such as short fibres and bits of the moss-like covering of the seeds, which if allowed to remain in the sliver produced by this operation would give a roughness to the yarn. For making coarse yarns one carding process only is employed; but for finer yarns the fleece is first passed through a "breaker" carding engine, which performs the first rough carding, and the slivers delivered by this are then "doubled" by laying together a large number of slivers, side by side and overlapping one another, into a new fleece, so as to obtain sufficient thickness and breadth of material to allow of a further carding; and the lap formed of this new fleece is then fed into a second or "finisher" carding engine. As many as 96 slivers from the breaker card, each drawn out of a separate can, are laid together by the doubling machine into a single fleece for the supply of the finisher, in order that the mixing of the cotton may be more thoroughly effected, and more perfect uniformity ensured in the sliver delivered by the finisher. For the finest qualities of yarn the finisher card is itself used as a breaker, and the sliver delivered by it is afterwards combed by a combing machine.

The roller and clearer carding machine employed at the present time as a breaker card for performing the first carding of the fleece is shown in section in Fig. 7, page 252; and consists of a main carding cylinder, A, round which are arranged a series of pairs of carding rollers or "workers," B B, and clearing rollers or "strippers," C C. The surfaces of all these are covered with cards, and they are made to revolve so close together as to allow the tips of the card teeth just to clear one another. The cards are a kind of wire brush with inclined teeth, as shown full size in Fig. 9, and are made of staples, D, of fine steel or iron wire, each about $\frac{3}{8}$ in. long and $\frac{1}{8}$ in. wide, with a side bend in the middle of their length. These are fixed close together into a strip of webbing about $1\frac{1}{2}$ in. wide, which is wound tight round the cylindrical rollers in a continuous spiral, keeping the staples pressed home in the cloth by the surface of the cylinder, so that they have an elastic firmness which keeps their points up to the work.

The working width of the machine is about 40 in. on the card teeth, corresponding with the breadth of the fleece in the lap, E, by which the carding engine is fed. The unlapping of the fleece is performed by the rollers, F, on which the lap rests, and the fleece is then drawn forwards under the feed roller, G, and delivered to the taker-in roller, H, revolving in the direction of the arrow. At this point the carding or combing action commences, the fleece being held by the feed roller, G, travelling at the slow speed of only about $\frac{1}{2}$ ft. of surface per minute, while the taker-in, H, runs much faster, at about 800 ft. per minute surface speed; and the carding teeth on the taker-in being bent forwards in the direction of motion, the points of the teeth strike down into the fleece held by the feed roller, and comb out the fibres, while the impurities separated, fall to the ground. The fibrous tufts of cotton are carried round on the underside of the taker-in to the main carding cylinder, A, which revolves in the same surface direction with a speed of about 1600 ft. per minute. The teeth of the carding cylinder being bent forwards in the direction of motion sweep off the cotton from the taker-in teeth inclined in the same direction, but running at only half the speed, and carry it forwards to the dirt roller, J, the teeth of which face those of the carding cylinder, and travel with a very slow motion of only about 16 ft. per minute. The dirt roller thus assists in combing out the fibres, and holds in the interstices of its wires any impurities that it receives from the cotton, which are carried forwards and stripped from it by a vibrating comb, so that they accumulate in a roll on the upper surface of the dirt roller, to be taken away by hand at intervals.

The carding cylinder then carries the cotton forwards to the several pairs of workers and strippers, one of which is shown to a larger scale in Fig. 8; and at each pair in succession the fibres undergo a further combing out and straightening. The motion of the teeth of all these pairs of rollers is in the same direction as that of the adjacent teeth on the main carding cylinder, as shown by the arrows in Fig. 8, but at a much lower speed; and the teeth of the strippers, C, are inclined forwards in the direction of motion, while those of the workers, B, are set the opposite way, so as to present the points of the teeth facing those on the carding cylinder, A. The cotton on the carding cylinder is therefore carried past the stripper, C, without being caught by its teeth, and is caught upon the teeth of the worker, B, running at only about 20 ft. per minute, so that a combing action for straightening the fibres and dividing the tufts of cotton is obtained by the access of speed in the carding cylinder running at the high velocity of 1600 ft. per minute. All fibres failing to pass the worker, B, are carried round upon its teeth to the stripper, C, which runs at a surface speed of about 400 ft. per minute, being thus intermediate in speed between the slow worker, B, and the quick carding cylinder, A; the teeth of the

stripper therefore sweep off the cotton from the worker, and are themselves stripped in the same way by the carding cylinder running at the higher speed. After passing the six pairs of workers and strippers, the fleece of straightened fibres is taken off in a continuous sheet from the carding cylinder, A, by the doffer, K, the teeth of which face those of the cylinder and move in the same direction, but at a much slower speed of only about 65 ft. per minute; the fleece thus receives a further straightening and stretching in quitting the carding cylinder, and is carried round on the underside of the doffer to the vibrating comb, I, which describes a short arc of $1\frac{1}{2}$ in. vertical motion, and is driven by balanced cranks at about 800 double vibrations per minute. This comb strips the fleece from the face of the doffer in its down stroke and clears itself in rising; and the thin fleece, of the full width of the machine, 40 in., is then gathered in by lateral guides to a width of 6 in., and finally into a smooth bell-mouthed round funnel, L, having a hole only $\frac{1}{2}$ in. diameter, through which the contracted ribbon or sliver is drawn by the two pairs of drawing rollers, M, the second pair running one-half faster than the first, whence it passes to the coiler, N, and can, O.

The coiler consists of a revolving plate, N, having an eccentric aperture, through which the sliver is passed from the pair of rollers, P, above the plate, so that it is delivered into the can in circular coils. The can, O, however, is also made to revolve with a slow motion in the opposite direction to the coiler, and the centre line of the coiler, N, is eccentric to the axis of the can, whereby the sliver delivered from the coiler describes a succession of hypocycloid curves in the can, the circles of sliver being laid into the can so that the outsides of the coils touch the inside of the can. The sliver thus forms coils continually crossing one another, so that the can is filled up solid throughout, and when taken to the doubling-frame, the coils of sliver come out again without adhering to one another.

The flat carding machine employed at the present time as a finisher card for performing the second carding operation, is shown in Fig. 10, page 253; and consists of a main carding cylinder, A, as in the breaker card; but the pairs of workers and strippers employed in the first carding are here replaced by a series of flat cards, D D, connected together by links, so as to form an endless travelling lattice. The lap, E, formed of a number of slivers from the breaker card laid together into a fleece by the doubling-machine, is supplied to the carding cylinder, A, by the feed-roller, G, and taker-in, H, in the same way as in the breaker-card; and the carding cylinder, A, is driven at the same speed of about 1600 ft. of surface per minute. A single worker, B, called the fancy roller, with a stripper, C, is placed immediately beyond the taker-in, H, running in the same direction as the adjacent surface of the carding cylinder, A; but in this case the teeth of the fancy roller, B, are bent forwards in the direction of motion, and it therefore requires to be driven at a higher velocity than the carding cylinder, and has accordingly a surface speed of 2000 ft. per minute. It thus seizes the cotton from off the teeth of the main carding cylinder, A, and throws it against the teeth of the stripper, C, facing those of the fancy roller; and the fibres having thus been subjected to a preliminary carding are again swept off the teeth of the stripper, moving at only 400 ft. per minute, by the higher speed of the main carding cylinder, A.

The cotton is then carried forwards by the carding cylinder to the series of flat cards, D D, Fig. 12, page 253, which are made of cast-iron bars faced with card teeth, as shown to a larger scale in Figs. 14 and 15; these extend the entire width of the machine, and rest at each end upon a circular guide on the top of the side frames of the machine, which is concentric with the main carding cylinder, A, so that the teeth of the flats are kept in close proximity to the teeth of the carding cylinder during the whole of their forward traverse. The teeth of the flats, D, are set to face those of the carding cylinder, A, and travel forwards in the same direction as the surface of the cylinder, but at a very slow rate of only 1 in. per minute; and the cotton thus undergoes a very thorough carding and straightening in passing the twenty-one cards that are always in contact with the top of the carding cylinder. The flats are arranged to work at a slight inclination to the surface of the carding cylinder, so that the delivering side of each flat is closer to the cylinder, and a wider space is left at the entering side between the flat and the cylinder for the cotton to enter, as shown half full size in Fig. 15. The angle thus formed is called the bevil of the flat, and the correct adjustment of this inclination is a point of great importance and delicacy; the bevil is obtained by cutting a bevil groove, Q, in each end of the flat at the part where it is to rest upon the circular guide on each side of the machine, as shown enlarged in Figs. 14 and 15, where the dotted circle, X X, represents the edge of the guide on which the flat travels, and the dotted circle, Y Y, indicates the surface of the main carding cylinder, A.

The endless lattice of flats, D D, is carried over the three shafts, P P P, and on quitting the carding cylinder, A, each flat in turn is stripped of any fibres or impurities adhering to it by the vibrating comb, R, which describes an arc of 1 in., and is driven at the rate of 40 double strokes per minute by the cam, S, Fig. 13. The flats are further cleaned by the brush, T, shown in plan in Fig. 11, running at a surface speed of 50 ft. per minute; and they are then passed over a guide, U, which holds them up against an emery wheel, V, running at the high speed of 550 ft. per

minute, and traversing across the machine along the length of the flats, whereby the faces of all the cards are successively ground to a true surface whilst at work, and the points of the wires sharpened. The same mode of grinding is also employed for keeping true the surfaces of the carding cylinder and doffer. The fleece of straightened fibres is taken off in a continuous sheet from the carding cylinder by the doffer, K, and vibrating comb, I, and is contracted into a sliver and coiled down into the can, O, in the same manner as previously described.

In Arkwright's improved form of the early carding engine the upper portion of the carding cylinder was covered over by a series of bars of wood called "top flats," the underside of which was covered with card teeth facing the teeth of the cylinder. These flats were stationary, held in their places by pins fixed in the framing, and were adjusted to the required bevil by two set-screws at each end; and they were lifted off and stripped of their refuse by hand cards at intervals. The stripping by hand labour, however, was an unhealthy and disagreeable process; and as bad work and spoiled cotton were the consequence whenever it was not done regularly and thoroughly, many arrangements have been introduced from time to time for stripping the flats mechanically. In this direction Messrs. Buchanan, of Catrine, and Mr. Bodmer, of Manchester, led the way, although the machinery employed by them was never generally adopted. Within the last few years, however, a much simpler mechanism for this work has been introduced by Mr. Wellman, an American, the application of which has received a great stimulus from the difficulty of obtaining men to perform the stripping by hand; and it is now extensively used. Metal flats were introduced by Mr. Smith, of Deanston, and these were linked together in the form of an endless lattice, which was made to travel slowly forwards over the carding cylinder; and each flat was adjusted to the proper bevil by two screws at each end, which travelled over two circular guides concentric with the carding cylinder. Another short flat guide at the back of the flats brought them into contact with a stripping brush, which was cleaned by a comb, and the comb teeth were scraped clear by a tin knife. These flats were used in several of the Scotch mills, but few of them were introduced into Lancashire. The flat carding machine was further improved by Mr. Evan Leigh, by cutting the bevil on the ends of the flats, as shown at Q Q, Fig. 14, and making the circular guides over which they travel adjustable for wear; at the same time a second face was formed on the back of the flats, to work over the guides, U, Fig. 12, which hold them up in the right position for being ground by the emery wheel, V; and the vibrating comb, R, was also added for stripping the flats before they are finally cleaned by the brush, T, instead of the brush alone being used for the purpose.

The finisher carding machine until recently was constructed without the taker-in roller, H, Fig. 10, the main cylinder taking the fleece direct from the feeding roller, G. This caused the fibres to clog the cards, and any impurities passing the feed roller damaged the teeth of the main cylinder, which was of serious importance on the large extent of surface of the cylinder. By using the taker-in, however, these evils are prevented, the fibres being delivered to the carding cylinder in a more divided state, and more equally distributed over its surface. Carding machines are also sometimes made which are a combination of the breaker and finisher card, having rollers and clearers on the side of the cylinder next the feeder, and flats on the side next the doffer.

The practical difficulty originally experienced with the carding-engine consisted in getting the cards to work sufficiently near to one another without occasionally coming in contact, which destroyed the carding points. The surfaces on which the cards were fixed were generally constructed of wood, and therefore varied with every change of the atmosphere from the shrinking or swelling of the wood, so that the faces of the cards had to be made true each time by grinding down the points of the wires at the full parts. Moreover the cylinders and rollers were not carefully constructed so as to run with a steady motion; and the fixings for carrying the different journals were not capable of a fine adjustment, nor were they steady after being set. These defects are now overcome by using iron instead of wood, and by the aid of machinery and tools adapted for making all the parts accurately; fine adjustments are provided, and the adjustable portions are made as firm when set as if fixed. These improvements cause less grinding and stripping to be required, as the finer and truer the points of the wires can be maintained, the clearer the cards continue in working; and thus the carding-engines have now been brought into their present successful and extensive operation.

Drawing.—The slivers from the finisher card are next taken to the drawing-frame, shown in section in Fig. 16, page 253; which contains generally four pairs of drawing rollers, A, each pair running faster than the preceding, and the front pair running at six times the surface speed of the back pair. Six slivers, B, in separate cans from the carding-engine are fed up together to the back pair of drawing rollers, being combined together by passing between two guide pins, C; and after being laid together and drawn out to six times the original length, the single sliver so produced is passed through a funnel to the pair of calendar rollers, D, by which it is delivered to the coiler, E, and coiled down into the can, F, in the same manner as in the

carding-machines. This combined sliver having been doubled six times and drawn six times is the same weight per foot as each of the original slivers fed up to the back pair of rollers and the object sought in the doubling and drawing process is to equalise the distribution of the cotton fibres, and produce slivers of more uniform strength and texture by the combination. The process is repeated three times in this machine, and the extent or combination or intermixture obtained in the ultimate slivers is therefore represented by the cube of six or 216 times, in comparison with each of the original slivers first supplied to the machine.

In order to ensure the drawing rollers being always supplied with the full numbers of six slivers, each of the slivers fed up to the rollers is passed over a guide, G, turning on a centre pin and nearly balanced, so as to turn with a slight pressure; and during the working of the machine this guide is depressed by the weight of the sliver into the position shown by the full lines. But in the event of the sliver breaking or running out, the tail of the guide being overweighted drops into the position shown by the dotted lines, and catches the vibrating finger, J, which is worked by an eccentric on the shaft, H, running at 70 revolutions per minute. This shaft is driven at the end by a small crown ratchet-clutch, held in gear by a spiral spring behind, and driving by the inclined faces; so that whenever the shaft, H, is stopped by the tail of a guide, G, catching one of the vibrating fingers, J, and the ratchet is consequently held stationary, the clutch is thrown out of the ratchet by the inclination of the teeth, and the end motion thus produced releases a catch which holds the strap fork of the machine; the fork is then reversed by a spring always acting upon it to throw off the strap from the fast to the loose pulley, thus stopping the machine. After the sliver run out has been renewed, or the broken sliver joined up by the attendant, the machine is set in motion again by moving the starting rod, I, which extends the whole length of the drawing-frame.

The improvements made in the drawing-frame since its introduction by Arkwright include amongst other details, the construction of the roller supports so as to be easily set and adjusted to the different distances required to suit the different lengths of cotton fibre worked; the addition of the self-acting stop motion for stopping the machine when any one of the slivers breaks or run out; a simpler mode of suspending the weights from the top rollers; and the use of an endless travelling cloth over the surfaces of the top rollers, as shown in Fig. 16, for cleaning off the waste or "fly" from the rollers. The top rollers are also made with dead spindles and loose bosses, the bosses being driven by independent motions. In drawing frames used to prepare slivers for the finer counts of yarn, an additional stop apparatus is provided for stopping the machine whenever a breakage of the sliver occurs between the front pair of drawing rollers and the calendar rollers, D, Fig. 16, or when the can, F, is full or a given length of sliver has been delivered; this stop action is worked from the same shaft, H, as that employed for breakages of the supply slivers.

Slubbing, Intermediate, and Roving.—The slivers delivered from the drawing frame are conveyed to the slubbing frame, into which they are fed either single or double, passing over a guide, like that in a drawing frame, to a set of three pairs of drawing rollers; the last pair runs at five times the speed of the first, so that the sliver is again increased in length five times in passing through the rollers. From the drawing rollers the sliver, now called "slubbing," passes to a revolving flier carried upon a vertical spindle, by which it is twisted and then wound upon a bobbin revolving loose upon the same spindle. The flier runs at a constant speed, while the bobbin is driven by means of a differential motion at a speed varying according to its increasing diameter as the slubbing is wound on; and the lifting movement, for raising and lowering the bobbin upon the spindle so as to wind on the slubbing in regular coils, is also worked by the same differential motion. The speed of the flier is 500 revolutions per minute, and the slubbing is delivered from the drawing rollers at the rate of 50 ft. per minute, so that the number of twists put into it in this machine is $\frac{1}{2}$ twist per inch of length.

The bobbins from the slubbing frame are next supplied in pairs to the intermediate frame, in which the slubbings are doubled by passing two of them together through a set of three pairs of drawing rollers, and then twisting them into one by means of a flier, and winding on a bobbin in the same manner as in the slubbing machine. In this process, "intermediate" between the slubbing and roving, the amount of drawing produced by the rollers is 5 times; and $1\frac{1}{2}$ twists are put into the double slubbing by the flier per inch of length delivered from the rollers.

In the roving frame, shown in Fig. 17, page 253, the contents of two bobbins, A, A, from the intermediate frame are again doubled, drawn, and twisted as before; and the cotton, now called "roving," is wound upon bobbins ready for being finally spun into thread. The extent of drawing in the three pairs of drawing rollers, B, is six times, and the front pair runs at a surface speed of 29 ft. per minute; the flier, C, is driven at 900 revolutions per minute, and thus puts $2\frac{1}{2}$ twists per inch into the roving. The bobbins, A, A, supplying the cotton for the rovings are fitted upon wood spindles called "skewers," pointed at the lower end where they rest upon their bearings, which are shallow cups made of glazed earthenware; these are found very durable, lasting for twenty years before requiring renewal, but when brass or cast-iron bearings were previously tried

they were found to be worn through in as many months, whilst the skewers made of lance wood were but little worn. The spindles, D, carrying the fliers are driven by skew-bevel wheels on the shafts, E, at the bottom of the machine. The bobbins, F, are loose upon the spindles, and are driven by skew-bevel wheels on the shafts, G, carried in the bobbin lifter, H, which supports the bobbins and gives them the vertical movement on the spindles, D, for winding the roving in uniform coils from top to bottom of the bobbins.

As the winding is effected by the difference of speed between the bobbin and flier, both of which revolve in the same direction, the speed of the bobbin may either exceed that of the flier, or the converse; and both plans are in use in the present machines. When the bobbin runs in advance of the flier, the speed of revolution of the bobbin has to be gradually diminished as its diameter increases by each successive layer of roving wound on; otherwise the delicate roving would be irregularly stretched or broken by the relatively increasing surface speed of the bobbin, as the speed of the drawing rollers, B, and the flier, C, is required to be constant in order that an equal amount of twist may be put into the roving throughout its entire length. On the other hand, when the bobbin follows the flier, its speed of revolution has to be gradually increased as its diameter increases by winding. In either case the vertical reciprocating movement of the bobbin-lifter, H, has to be gradually retarded, to allow a longer time for winding each successive layer of roving upon the increasing circumference of the bobbin; and the length of the vertical motion is also diminished at each reciprocation, so as to give the required conical form to the ends of the bobbin, which is effected by means of a separate shortening motion.

The arrangement employed at the present time for obtaining the differential speed of the bobbin and bobbin-lifter in the slubbing, intermediate, and roving frames, is Houldsworth's ingenious and successful Differential Motion, which was introduced in 1826, and is shown in Fig. 18, page 253. It consists of three portions, the first of which is driven at a constant speed, and drives the spindles and fliers; the second is driven from the first at a speed varying in proportion to the increase of diameter of the bobbins; and the third portion, from which the bobbins and bobbin-lifter are driven, receives a differential motion compounded of the other two, and therefore also varying with the increasing diameter in winding. The shaft, K, being driven at a constant speed by the driving-strap over the pulley, L, imparts a uniform speed to the spindles and fliers by the pinion, M, which is fast upon the shaft. The pinion, N, driving the bobbins and bobbin-lifter, runs loose upon the shaft, and is driven through the differential bevil-gearing, O, by the bevil-wheel, P, keyed upon the shaft, K. The two bevil-wheels, O, O, through which the differential motion is obtained, are centred in the disc-wheel, Q, running loose upon the shaft, K. If the disc-wheel were held stationary, the pinion, N, would be driven through the wheels, O, O, at the same speed as the wheel, P, but in the contrary direction, and would, therefore, drive the bobbins at the same speed as the spindles; but if the disc-wheel, Q, were made to revolve upon the shaft, K, at half the speed of the wheel, P, but in the contrary direction, the pinion, N, driving the bobbins, would run at double the speed of the wheel, P. If, therefore, the disc-wheel, Q, be driven at an intermediate speed, and this speed be also made to vary in proportion to the increasing diameter of the bobbins, the pinion, N, will receive and impart to the bobbins and bobbin-lifter a differential speed, which also will vary in the ratio of the diameter of the bobbins. This object is obtained by driving the disc-wheel, Q, through the pair of regulating cones, R and S, which are parallel, but reversed end for end in respect to each other; the first cone, R, is driven at a constant speed direct from the shaft, K, and drives the second cone, S, through the strap, T, which is made to travel gradually from one end of the cones to the other. Hence the disc-wheel, Q, which is driven by the second cone, S, runs at a varying speed depending upon the position of the strap upon the cones; and by making the strap travel along the cones at a rate corresponding with the increasing diameter of the bobbins, the speed of revolution of the bobbins is accurately proportioned to their diameter, so as to give the required uniformity in surface speed throughout the winding. The travel of the strap, T, is effected by a rack motion, I, and ratchet-wheel, J, Fig. 17, each vertical reciprocation of the bobbin-lifter releasing the ratchet-wheel, J, one tooth, and allowing the strap to be drawn forwards the corresponding distance along the cones R and S, by the weight W, constantly acting upon the strap-fork.

In the case shown in Fig. 18, it will be seen that the speed of the first cone, R, is one-half that of the driving-shaft, K; and the speed of the disc-wheel, Q, is one-fifth that of the second cone, S, and its rotation is in the contrary direction to the driving-shaft, K. The diameters of the cones being 6 in. at the large ends, and $3\frac{1}{2}$ in. at the small ends, when the strap is at the end, U, as shown by the dotted lines, the ratio of speed of the disc-wheel, Q, to the driving-shaft, K, is $\frac{1}{2} \times \frac{6.0}{3.5} \times \frac{1}{5} = \frac{1}{17.5}$ nearly; that is the disc-wheel makes one revolution for every six of the driving-shaft, and in the contrary direction; and therefore the bobbin-pinion, N, makes 8 revolutions for every 6 of the flier-pinion, M. Similarly when the strap is at the end, V, of the cones, the ratio of speed of the disc-wheel to the driving-shaft, K, is

$\frac{1}{2} \times \frac{3.5}{6.0} \times \frac{1}{5} = \frac{1}{17}$ nearly; that is, the disc-wheel makes 1 revolution for every 16 of the driving-shaft, and in the contrary direction; and therefore the bobbin-pinion, N, makes 18 revolutions for every 16 of the flier-pinion, M. Hence the ratio of speed of the bobbin-pinion to the flier-pinion, is 32 to 24 in the first case, and 27 to 24 in the second; and the total reduction of speed of the bobbins, whilst the strap travels along the entire 30 in. length of the cones is 5-32nds, or 16 per cent. of their original speed, which is the range of variation required to allow for the increasing diameter of the bobbins in winding.

The differential motion affords the means of obtaining this delicacy of adjustment with a compact and easily worked apparatus; and by virtually magnifying the range of variation required avoids the use of cones with too small a taper for good working. The arrangement shown in Fig. 18 is for the case of the bobbin running in advance of the flier, when the speed of the bobbin has to be reduced as its diameter increases in winding; and the action of the differential motion is exactly similar in the converse case of the bobbin following the flier, the only difference being that the disc wheel, Q, must then be made to rotate in the same direction as the driving shaft, K, instead of in the contrary direction. As the advance of the driving strap, T, along the cones is a uniform amount at each reciprocation of the bobbin-lifter, the driving cone, R, requires to be shaped with a concave outline, and the driven cone, S, with a corresponding convex outline; since the absolute increase made in the diameter of the bobbin by each successive layer of roving bears a continually diminishing ratio to the increasing diameter of the bobbin, requiring the variation of speed therefore to be effected also in a continually diminishing ratio.

Arkwright's can frame was the first machine invented of the class now comprising the slubbing, intermediate, and roving frames above described; it consisted of a row of revolving cans, into which the sliver was delivered from a set of drawing rollers similar to those used in the drawing frame. The cans were driven by bands passing round pulleys at the bottom, and the top of each can was contracted into a tubular neck, forming a bearing, which ran in a bush in the framing of the machine, and through which the sliver from the drawing rollers was delivered into the can in irregular coils. There were three or four pairs of drawing rollers in this can-frame, and two of the slivers from the drawing-frame being fed into the rollers were doubled and drawn into one of about eight times the original length, which was delivered into the can; and when the can was full the sliver or roving was taken out, and wound upon bobbins by a separate winding machine. As the sliver was merely delivered into the can of the can-frame through the central orifice at the top, it did not receive any regular coiling into the can, and the amount of twist imparted to it was therefore irregular; the can made about 100 revolutions per minute, and the sliver being delivered from the rollers at about 16 ft. per minute, the average twist amounted to only about $\frac{1}{2}$ turn per inch of roving. Hence the delicate roving was liable to be injured in being conveyed to the winding machine.

The next step in improvement was made by substituting spindles, fliers, and bobbins, in place of the cans in the can-frame; and the spindles and fliers being driven at a constant speed, the differential motion was applied for driving the bobbins and bobbin-lifter at the varying speed required by the increasing diameter of the bobbins. The differential speed was obtained by means of a cone-drum, or friction pulleys, or an expanding drum, which were made to slide endways upon the shaft driving the bobbins, the distance of sliding being regulated by a ratchet-toothed rack with a pawl working into it; the teeth of the rack were cut to suit the fineness of the roving to be wound, and hence any change in the size of roving made for different counts of yarn necessitated a change of rack. This was found very inconvenient, and was at length obviated by the introduction of Houldsworth's differential motion already described, which requires only a single rack and pinion of uniform pitch, with ratchet wheels of varied pitches for giving motion to the rack-pinion; so that for a change in the fineness of the roving it is only necessary to change the ratchet wheel, which is readily effected and is much more convenient than having to change the rack. When this form of the differential motion was first applied, one cone drum only was used, with counter pulleys, and a weighted pulley for keeping the strap tight; but latterly the two cone drums shown in Fig. 18 have been used instead, made with corresponding concave and convex surfaces so that the strap continues equally tight in all positions.

Spinning.—The final operation of spinning into threads the rovings delivered from the roving frame has been the subject of so great an exercise of inventive abilities, and has undergone so many practical improvements in detail down to the present time, that it is impossible to do more in the present paper than notice briefly the more important steps which have led to the remarkable perfection attained in the self-acting mules now employed for this purpose.

In the practical working of Arkwright's spinning-machine and Hargreaves' spinning-jenny, Figs. 1 and 2, page 220, it was found that the rovings and threads produced were both coarse and uneven, only fit for the manufacture of quiltings, and poorly adapted even for that purpose. A great improvement in this respect was effected in 1779 by Samuel Crompton's spinning-machine or "mule," which was a combination of Paul's or Arkwright's spinning-machine and

(Continued on page 264).

COTTON MACHINERY.

(For Description, see Page 250.)

FIG. 6. SINGLE SCUTCHER AND LAP MACHINE. 1866.

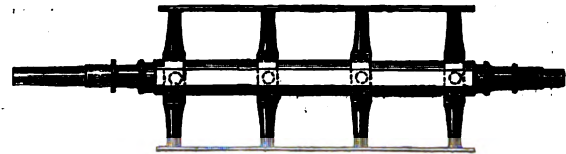


FIG. 6. PLAN OF BEATER.

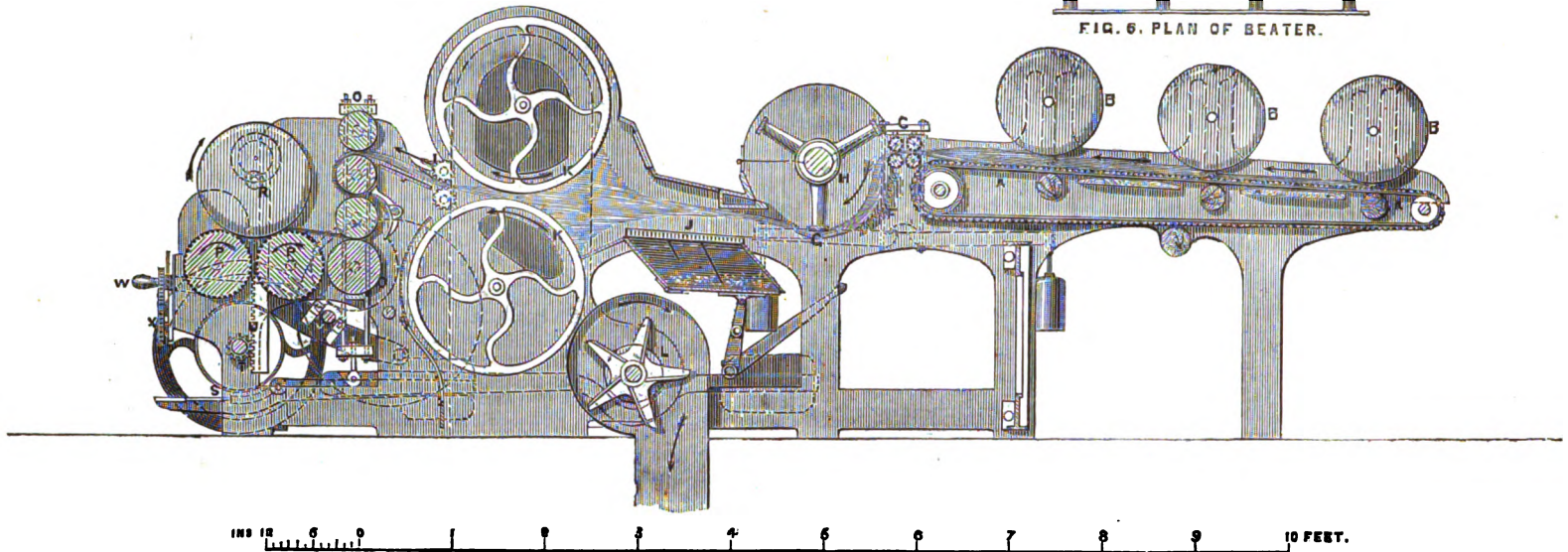


FIG. 8. ROLLER & CLEARER.



FIG. 7. ROLLER & CLEARER CARDING MACHINE 1866.

FIG. 9. CARD. FULL SIZE.

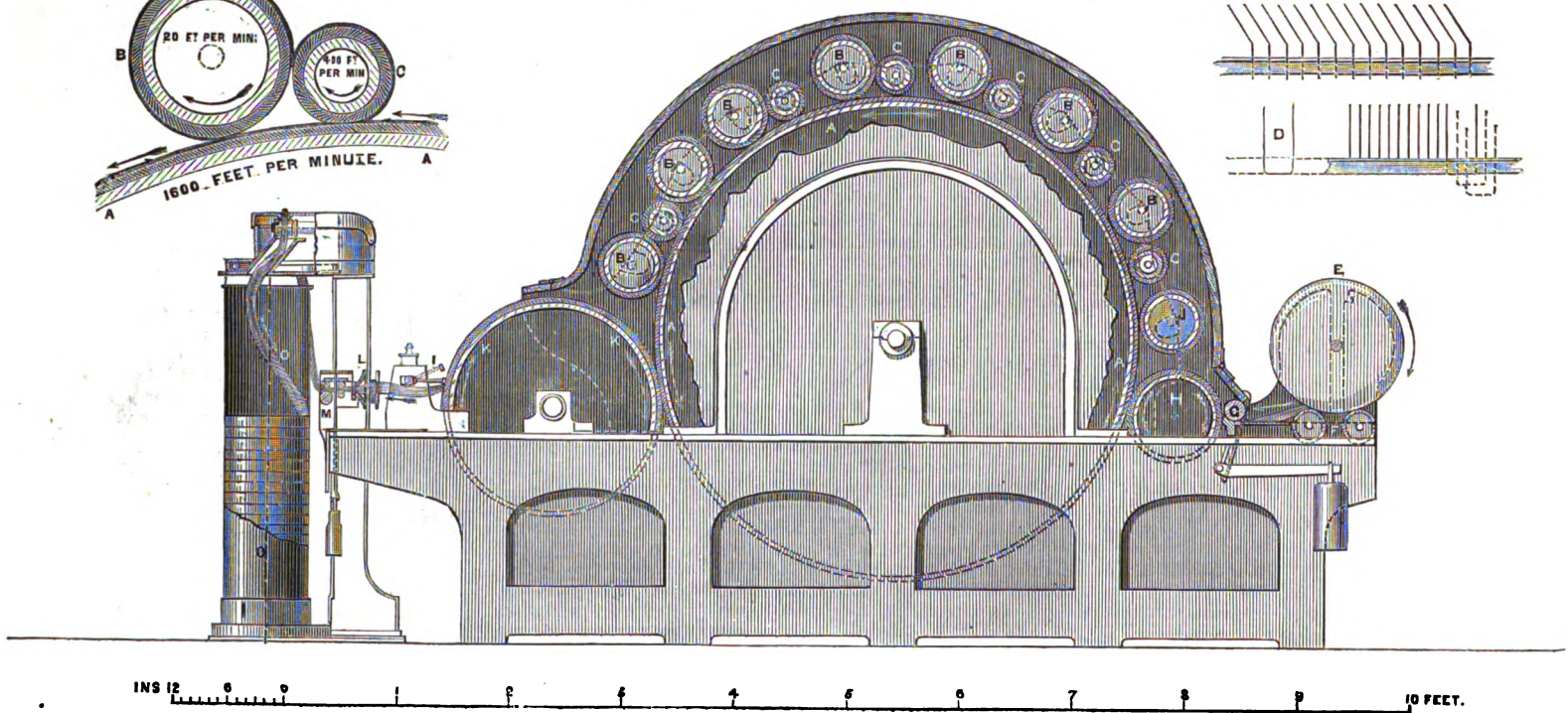
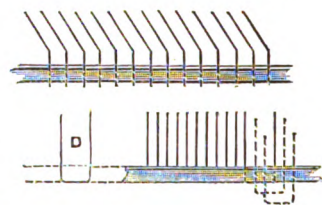


FIG. 3. COTTON OPENER. 1866.

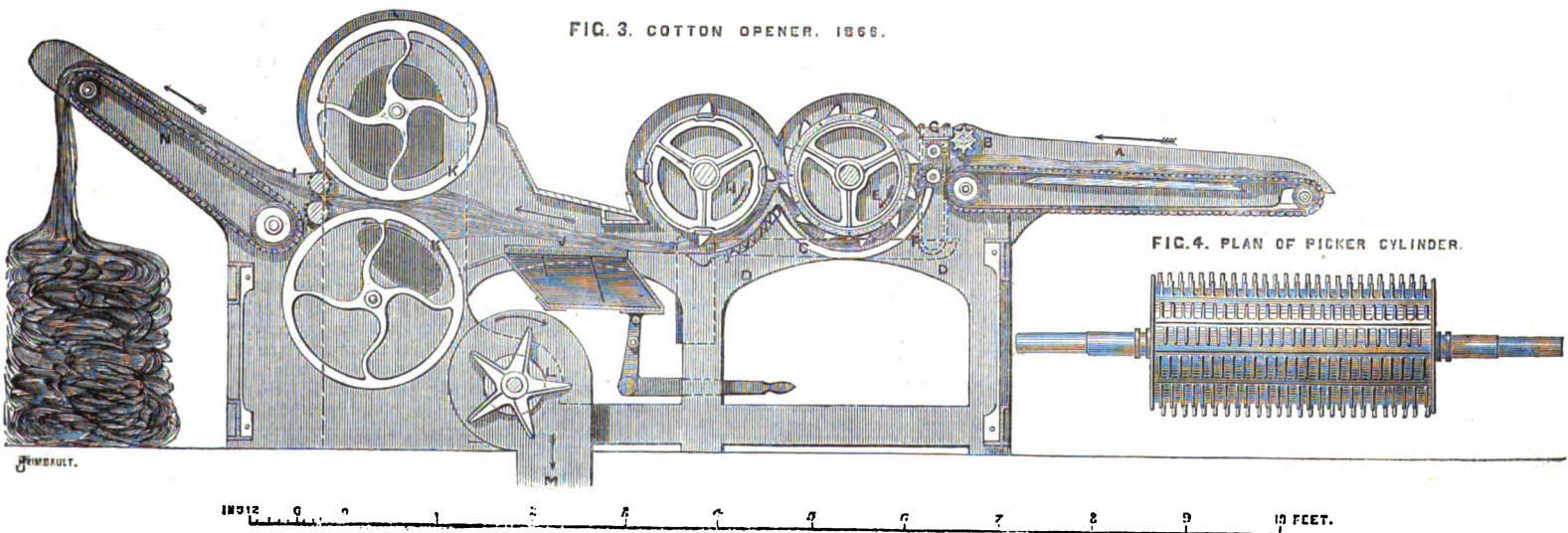
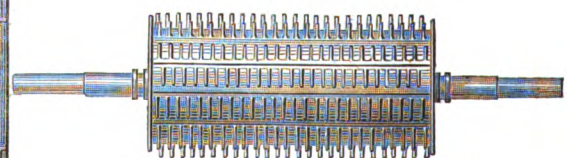


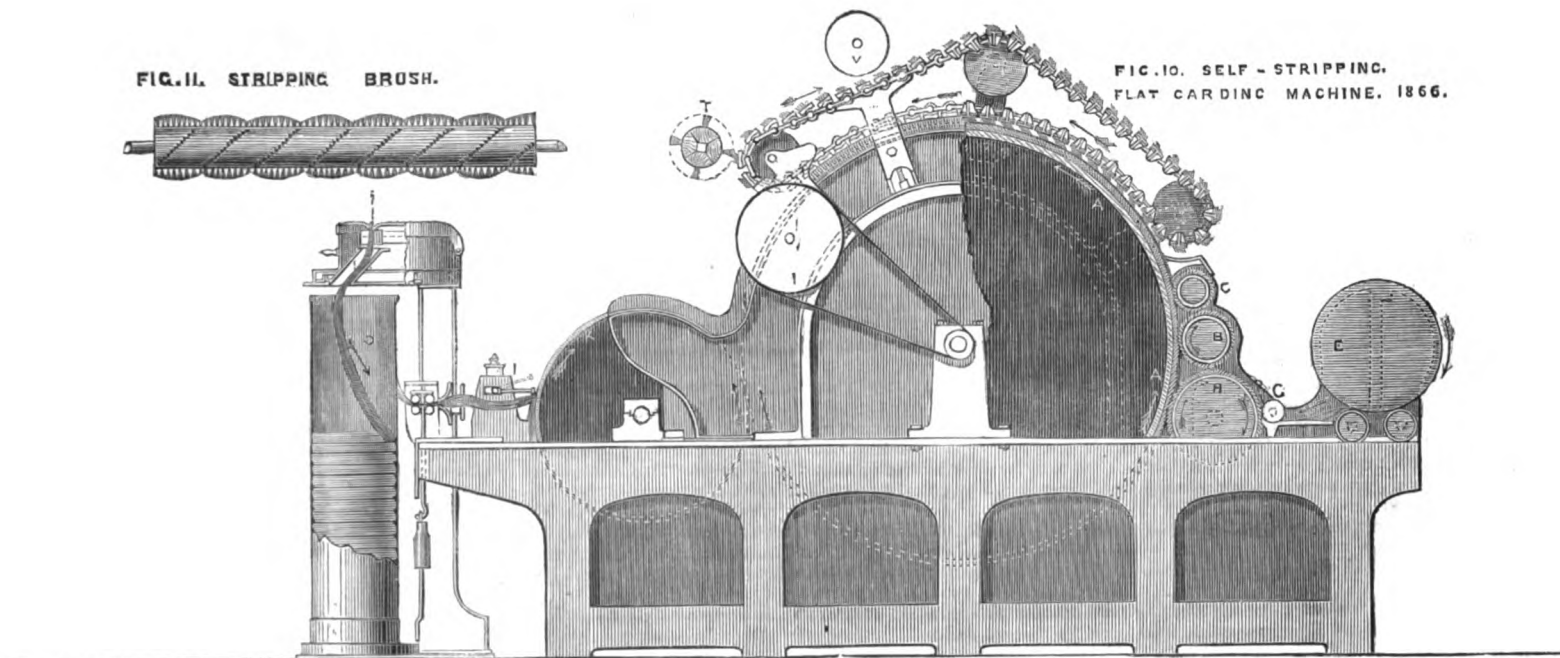
FIG. 4. PLAN OF PICKER CYLINDER.



COTTON MACHINERY.

(For Description, see Page 250.)

FIG. 11. STRIPPING BRUSH.

FIG. 10. SELF-STRIPPING.
FLAT CARDING MACHINE. 1866.

INCHES. 12 6 0 1 2 3 4 5 6 7 8 9 10 FEET

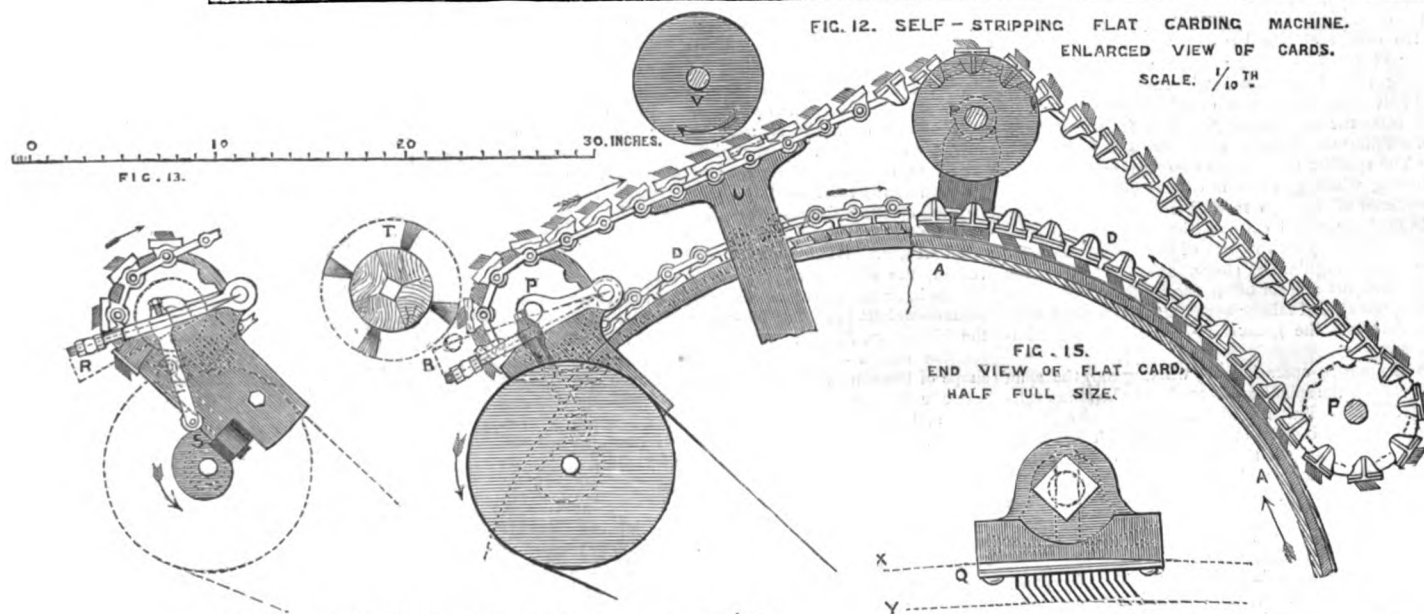
FIG. 12. SELF-STRIPPING FLAT CARDING MACHINE.
ENLARGED VIEW OF CARDS.SCALE. $\frac{1}{10}$ TH

FIG. 13.

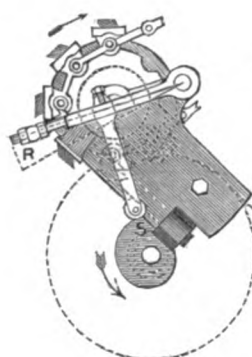


FIG. 14. FRONT VIEW OF FLAT CARD

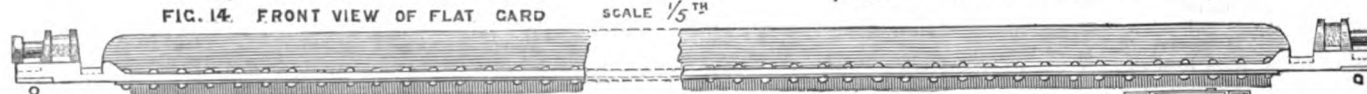
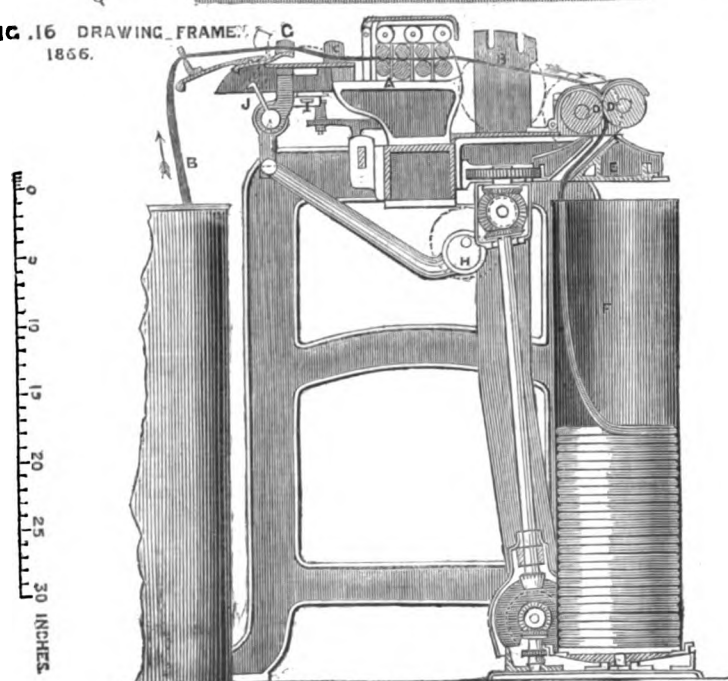
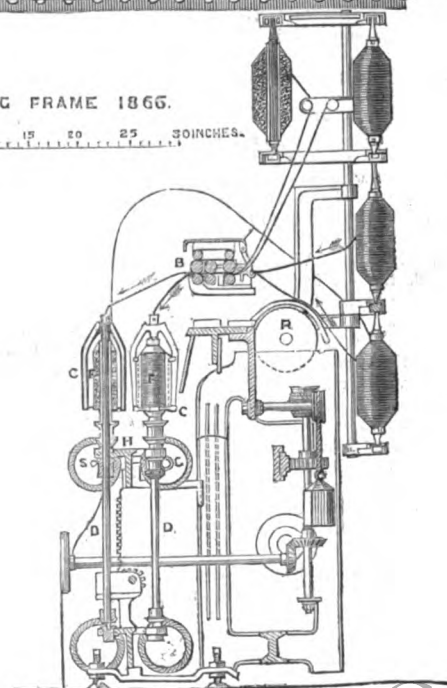
SCALE $\frac{1}{5}$ THFIG. 16. DRAWING FRAME.
1866.

FIG. 17. ROVING FRAME 1866.

0 5 10 15 20 25 30 INCHES.



(Cotton Machinery continued from page 251.)

Hargreaves' jenny, combining the drawing roller arrangement in the former with a modification of the sliding cross-bar and spinning spindles in the latter. In this machine the spindles were placed in a movable carriage, which had a stretch or run of about 54 in., and the rovings delivered from the drawing rollers in a soft state were further drawn by the spinner in pulling the carriage backwards from the rollers, and completely twisted by the receding spindles, ready for being wound upon the spindles during the run-in or return traverse of the carriage and spindles. In the spinning-jenny each successive lengths of the rovings was held by the clasp on the sliding crossbar, and the stretching of the rovings was done entirely by drawing back the crossbar by hand from the spindles; and in Arkwright's machine the stretching was performed entirely by the rollers; but in Crompton's mule the stretching was accomplished partially by the drawing rollers, when the carriage and spindles began to recede from the roller beam, and partially by the continued run-out of the carriage after the rollers had been stopped. The rollers were stopped when the carriage had receded nearly the length of its run, and they then acted as a clasp to hold the threads during the completion of the stretching and twisting.

Crompton's first mule contained about thirty spindles; and the threads spun by it were far superior in regularity, strength, and fineness to any ever spun before. They realised about double the prices obtained in 1743 for the same counts of yarn spun by other machines, and must therefore have been very superior in quality, having been produced much more cheaply; and, in order to show what could be done with the mule, small quantities were spun as fine as No. 80, which is such a quality of thread that 80 hanks of 840 yards each weigh together 1 lb. The adoption of these mules extended so rapidly that in 1811, thirty-two years after the first was made, there were 600 mills containing 4,209,000 spindles working on this plan, and only 810,500 spindles on Arkwright's plan, and 155,900 spindles on the spinning-jenny plan.

Many of the principal movements, however, in the working of Crompton's mule still required to be performed by hand by the spinner, the same as in the previous machines. This was the case with the backing-off motion, and with the working of the two faller wires, a second or counter-faller having now been added underneath the threads, which was lifted for the purpose of taking up the slack in the threads after the backing-off, the first faller being depressed for guiding the threads upon the cops during the winding. The speed of the spindles also required regulating by hand during winding, so as to correspond with the increasing diameter of the cops formed on the spindles, and to suit the conical-shaped ends of the cops. Great skill was therefore necessary on the part of the spinner, in order to make the cops regular in shape, size, and hardness, suitable for transport and for being uncoiled without waste. To supersede this skilled labour and render the mule self-acting was therefore the great aim in the subsequent improvements.

In 1818 the entire operation of winding up the spun threads into cops on the spindles was rendered altogether self-acting by Mr. William Eaton. This involved both a self-acting method of performing the backing-off, which has to be done at the conclusion of the twisting of each stretch, before the winding begins; and also a self-acting arrangement in connexion with the faller-wire, for guiding the threads regularly upon the cops during the winding, and a self-acting contrivance for regulating the speed of the spindles according to the increasing size of the cops.

The arrangement of Eaton's backing-off motion is shown in Figs. 19 and 20, page 220. The main shaft, or "rim-shaft," A, from which the driving motion of the spindles in the travelling carriage is derived, is itself driven in the forward direction during the twisting, and again during the winding, by the driving-strap running on the fast-pulley, B, as shown by the dotted lines in Fig. 20. The loose pulley, C, communicates a slow motion through intermediate pinions to the wheel, D, revolving loose upon the shaft, A, but in the contrary direction; and at the other end of the shaft, A, is a corresponding wheel, E, fast upon the shaft. The two toothed sectors, F F, are keyed upon a shaft, G, which is carried in the rocking-frame, H; and the weight, K, on the rocking-frame is constantly acting to draw the sectors back out of gear with the wheels, D and E; while the sectors themselves are only partly counterbalanced by the second weight, L, and are ready to fall down into gear with the wheels as soon as the catch, I, by which they are held up out of gear, is released. When the twisting of the threads is completed, the driving-strap is shifted to the loose pulley, C, and the forward motion remaining in the shaft, A, is arrested by a friction-brake carrying a ratchet-wheel, which is caught by a hook falling into gear at the moment of reversing the strap. The pull upon this hook extends a spiral spring, the recoil of which is made to release the catch, I; and the sectors, F, falling into gear with the wheels, D and E, a backward motion is then communicated to the shaft, A, from the loose pulley, C, running forwards, whereby the spindles are made to turn backwards through the few revolutions necessary for backing off the spiral coils of thread at the top of the spindles, preparatory to winding. As the form of cop employed was a simple cone, increasing in height at the same time as in diameter (as shown in Fig. 21), the length of the spiral coils that require backing off at the top of the spindles becomes less with the increasing height of the cops on the

spindles, and the number of backward turns in the backing-off has therefore to be gradually diminished as the cops approach completion; this is effected by an adjustable stop underneath the sectors, F, which is gradually elevated in proportion to the increasing height of the cops. This stop is connected with a lever catching against a stud at the lower extremity of the arm, H, of the rocking-frame; and the downward movement of the sectors, F, while in gear with the wheels, D and E, depresses the stop until at length the arm, H, is liberated; the weight, K, then withdraws the sectors out of gear, whereby the backward motion of the shaft, A, is stopped. By then shifting the driving-strap to the fast-pulley, B, the shaft, A, is again driven in the forward direction, and the threads previously spun are wound up on the spindles as the carriage runs inwards. The pin, J, fixed upon the carriage, travelling inwards in the direction of the arrow, now comes in contact with the tail of the lever, M, and lifts the sectors up again into their highest position, in which they are retained as before by the catch, I, at the other end of the lever, M; and when the run-in of the carriage is nearly completed, the same pin, J, comes in contact with the tail of a second lever, N, bearing against the extremity of the arm, H, of the rocking-frame, whereby the sectors are thrown forwards again in readiness for the next time of backing off.

Eaton's faller-motion is shown in Fig. 21, page 220, and was almost identical with that in use at the present time, the difference being that the faller-wire, A, was depressed by a weight, B, instead of, as in the present mules, by a chain passing round a pulley upon the faller-shaft, C. The direction of the run-in of the carriage, D, carrying the spindles and cops, E, is shown by the arrows; and during the run-out in the opposite direction the weight, B, is held up in the position shown by the catch, F, holding the tail of the lever, G. This catch is withdrawn by the downward movement of the sectors in the backing-off motion, and the weight, B, then brings the front end of the lever, G, down upon an arm on the front side of the faller-shaft, C, depressing the faller-wire, A, upon the threads, H. The roller, I, carried upon an arm on the back of the faller-shaft, is thus brought up against the pin, J, fixed in the parallel-motion bar, K, and is "locked" by the latch, L; so that by the vertical movement of the bar, K, the faller-wire, A, is raised and lowered during the winding of the threads, for guiding them upon the cops from end to end. The reciprocation of the bar, K, is obtained by its bottom end resting upon the shaper fusee or long tapered cam, M, which is driven by the pinion, N, from the toothed wheel, O, travelling along a rack, P, fixed upon the floor. As soon as the carriage has begun to run in, the weight, B, is lifted off the faller and raised again to its original position by the tail, R, of the lever coming in contact with a fixed stop, S. When the carriage arrives at the end of its run-in, the sliding-bolt, T, coming against a fixed stop, pushes back the latch, L, and unlocks the roller, I; and a balance-weight upon the back of the faller-shaft, C, raises the faller-wire, A, clear off the threads into the extreme position shown by the dotted lines. For regulating the shape of the cop as its size increases, the shaper fusee, M, is gradually traversed endways along its shaft, N, by the rack and pinion, U, driven by a worm-wheel from the ratchet, V, which is turned round one tooth at a time by the lever, W, coming against a stop, X, fixed on the floor at each end of the run of the carriage.

In 1825 further improvements were introduced by Mr. Maurice de Jongh, the backing-off motion being driven by a rack instead of by sectors; and with the backing-off was combined the process of putting down the faller-wire to the required part of the cops for the commencement of the winding. The working of the faller for guiding the threads during winding was effected by an arm on the back of the faller-shaft, carrying a roller, which travelled along a template or "copping-rail" extending the whole length of the stretch. The upper edge of this coping-rail was shaped according to the form of cop required, and the entire rail was gradually lowered by a regulating-screw at each end as the cop was built up. The winding of the threads on the cops was done by employing a slack strap or friction-strap for driving the main shaft, or "rim-shaft," of the mule during the run-in of the carriage; and this strap was tightened by a weight and two friction-pulleys pressing against it, the weight being adjusted so as to make the strap drive or slip as required for keeping the threads in proper tension.

It was also in 1825 that the late Mr. Richard Roberts's self-acting mule was first brought out, which, with the addition of further improvements subsequently introduced by himself and others, is the form of self-acting mule almost universally employed at the present time for spinning cotton. In this mule the faller-wire was for the first time put down by the agency of the "rim-shaft," or main driving-shaft of the machine, during the time that the shaft is turning the reverse way for backing off.

The arrangement of faller-wire motion as employed in the present spinning-mules is shown in Figs. 22 to 25, pages 220 and 256. A is the top-faller arm, which is made of the sickle shape shown in the drawing for the purpose of enabling it to put down the faller-wire to the bottom of the cops, J, without the arm itself being required to pass down between the cops, so as to save room in the length of the mule. On the front of the faller-shaft, I, is keyed the sector, C, and a chain, D, attached to the sector passes round the pulley, E, to a snail, F, upon the shaft of the tin roller, which is a long hollow cylinder made of tin, and

driving by separate cords the whole row of spindles, T. The snail, F, is geared to the tin roller by a ratchet-clutch, with the teeth set so as to engage only when the tin roller is driven the reverse way for backing off, as shown by the arrow in Fig. 23. Whilst the tin roller is running forwards during the spinning, and again during the winding, in the direction shown by the arrow in Fig. 22, the snail, F, is not in action; but as soon as the carriage, G, of the mule has run out to the end of the stretch, as shown in Fig. 23, the tin roller is turned through part of a revolution in the reverse direction, as indicated by the arrow, sufficiently for unwinding the coils in backing off; and the snail, F, then comes into action and winds up the chain, D, thereby bringing the top-faller wire, A, down upon the threads, W, and depressing them towards the bottom of the cops. On the back of the faller shaft, I, is fixed the curved arm, B, against which bears the vertical locking bar, H; and when the arm, B, is lifted by the depression of the faller, A, its extremity is caught by the recess in the bar, H, which is thrown forwards by the bell-crank lever, K, as shown in Fig. 24; the tail of this lever having been brought, by the run-out of the carriage, G, under the corresponding bell-crank, L, fixed in the end frame of the mule, has previously extended the spiral spring attached to the bell-crank, L, Fig. 23, the recoil of which throws the locking bar, H, forwards as soon as the arm, B, is sufficiently raised, Fig. 24. The pulley, E, is carried on a rocking lever, R, the tail of which presses against the stop, S, in the end frame of the mule during the time that the chain, D, is depressing the faller, Fig. 23; but at the moment when the locking bar, H, is thrown forwards to lock the faller arm, B, the stop, S, is lowered, as shown in Fig. 24, clear of the tail of the lever, R, allowing the pulley, E, to yield to the further pull of the chain, D, until the reverse motion of the tin roller in backing off is stopped; by this means the snail, F, Fig. 23, is prevented from depressing the faller wire, A, beyond the required distance down the height of the cop.

The faller being thus locked, the carriage, G, begins to run in in the opposite direction to that indicated by the arrows in Fig. 22; and while the spindles wind up the threads on the cops, the faller-wire is gradually allowed to rise by the locking-bar, H, running down the inclined coping rail, M, the curved arm, B, being kept constantly pressed home in the notch of the locking-bar by a counter-balance weight or spring acting on the back of the faller shaft, I, to raise the faller, A. The length of the stretch or run-in of the carriage, G, is 63 in., which is therefore the length of thread to be wound upon the cop, J, at each time of winding; and this whole length of 63 in. of spun thread in each stretch is wound upon the cop during each stroke of the faller-wire. The mode of building up the cop in successive stages is shown half full size in Fig. 26, page 256; and in order to allow for the increasing diameter of the cop, the successive layers of thread are wound upon it in more open coils as the size increases, as indicated by the dotted lines, which is effected by gradually increasing the range of the faller wire; at the same time the ends of the cop are made of the conical form shown in the drawing. The length of range or "chase" of the faller wire at the commencement of the cop upon the bare spindles is only from A to B; but this is gradually increased until the cop has attained its full diameter, C C, when the length of range is from C to D; after which the range is slightly diminished again to the length, E F, in finishing the cop. For the purpose of obtaining the requisite motion of the faller wire for giving these successive shapes to the cop during the winding, the extremities of the coping rail, M, Fig. 22, are supported on the two sliding wedges, N and O, which are kept at an invariable distance apart by a connecting-rod. In commencing the winding of a set of cops upon the bare spindles, as shown at A B, in Fig. 26, the coping rail is set at the top of the wedges, and is at its smallest inclination; and after each successive layer has been wound on, the two wedges are slid from under the rail by a traversing screw worked by a ratchet-wheel, which is advanced one or more teeth during each run-out of the carriage, G, Fig. 22. By this means the coping-rail, M, is gradually lowered at both ends, and at the same time its inclination is increased by the outer wedge, N, being made with a rather smaller angle at the top than the inner wedge, O, for the purpose of forming the cop with a more gradual taper at the top than at the bottom, as shown in Fig. 26. This increase of inclination continues until the cop has attained its full diameter, C C, and has assumed the shape, A C D; after which the inclination slightly decreases again until the cop is completed to the finished shape, A C E F, by the latter part of the outer wedge, N, being made slightly steeper than the corresponding portion of the inner wedge, O, as shown in Fig. 22. The inner end of the coping rail being the lowest, the winding of each stretch leaves off at the top; and at the commencement of winding each stretch the faller wire puts down the thread to the point at which the winding of the new layer is to be started, about three coils being wound on during the descent of the faller, as indicated by the spiral dotted line from F to E, in Fig. 27, and the remainder during the rise of the faller. When the spindles arrive at the rollers, P, as shown in Fig. 25, having wound up the 63 in. stretch of threads, the stop, U, pushed back the locking bar, H, thereby releasing the faller, A, which immediately rises clear of the threads, W.

The counter-faller wire is carried by the arm, V, from a second shaft behind the top-faller shaft, I, and during the winding it bears up constantly against the underside of the

threads W, as shown in Figs. 23 and 24, with a slight pressure from a counterbalance weight or spring acting on the shaft, so as to ensure keeping the threads in proper tension; during the spinning the counter-faller is held up just beneath the threads, but without touching them, as shown in Fig. 22. The arm, V, of the counter-faller is curved as shown in the drawing, so as to reach over the shaft, I, of the top faller, and also to avoid passing down between the cops; and the curved arm, B, on the back of the top-faller shaft, I, is shaped so as to clear the shaft of the counter-faller. The height of the counter-faller wire is employed as a means of regulating the speed of the spindles in winding, in the manner afterwards explained, so as to avoid the occurrence of any slack in the threads.

Roberts' Backing-Off Motion as employed in the present mules is shown in Fig. 28, page 256, which is a plan of the main driving shaft or "rim shaft," A, of the machine, carrying the large "rim wheel," Z, or double-grooved pulley driving the whole of the mule spindles by the endless cords, X X, Fig. 22, passing round the pulleys, Y Y. On the boss of the loose pulley, B, is a pinion, C, which through a train of intermediate wheels, D D, drives in the reverse direction and at the required slower speed the spur wheel and friction cone, E, also running loose upon the shaft, A, and sliding longitudinally upon it. This friction cone engages in a corresponding hollow cone inside the fast pulley, F, and when the driving strap is shifted from the fast pulley, F, to the loose pulley, B, for the purpose of backing off, the friction cone is also brought up against the fast pulley, thereby first arresting by friction the forward motion of the driving shaft, A, and then giving it the reverse motion for backing off.

Roberts' Winding Quadrant for regulating the winding of the threads by diminishing the speed of the spindles in proportion as the diameter of the cops increases, is shown in Fig. 29, page 256. This very ingenious contrivance has never been superseded, and is employed in almost every self-acting mule at the present day. The quadrant, A, turns upon a fixed centre, C, in the frame of the mule, and a pinion, B, gears into it, which is driven by a band and pulley receiving motion from the traverse of the carriage, G, the arrows indicating the direction of motion during the run-in of the carriage. The grooved arm, D, of the quadrant contains a double-threaded screw, by which the sliding nut, E, is traversed outwards from the centre of motion, C, towards the extremity of the arm, D. When the carriage is at the outer end of its stretch, the arm, D, stands inclined 12° outwards from the vertical, as shown by the dotted lines; and during the run-in of the carriage it turns inwards through an arc of 90° . A chain, F, attached to the nut, E, is coiled round a drum, H, inside the carriage, G, and as the carriage recedes from the quadrant arm during the run-in, the chain thus causes the drum to rotate, and thereby drives the spindles, T, through the intervention of the tin roller, I, geared to the drum, H. At the commencement of a set of cops, the nut, E, is at the bottom of the quadrant arm, D, nearest to the centre of motion, C, as shown dotted, and the number of revolutions then given to the drum, H, by the uncoiling of the chain during the run-in of the carriage is nearly as many as if the end of the chain at the nut were held stationary, and is sufficient to wind up on the bare spindles the length of threads spun in one stretch.

As the cops increase in diameter from their original size, A B, to their full diameter, C C, Fig. 26, the nut, E, is gradually advanced outwards along the quadrant arm, D, Fig. 29, so as to increase its arc of motion and thereby diminish the number of revolutions of the drum, H, and the speed of the spindles, T. This advance of the nut is obtained from the counter-faller, V, bearing against the underside of the threads, W, during the winding. The depression of the counter-faller towards the lower part of the cop, J, brings down the end of a governing lever upon a horizontal strap, which passes round a pulley on the headstock of the mule and round another on the centre shaft, C, of the quadrant; and on this shaft is a bevil pinion gearing into a second bevil pinion on the end of the double-threaded traversing screw in the arm, D; so that when the governing lever is depressed upon the strap by the counter-faller, the forward motion of the lever as the carriage runs in drags the strap along with it by friction and turns the shaft, C, forwards, sliding the nut, E, outwards towards the circumference of the quadrant. At the moment when the backing-off motion has ceased and the carriage begins to run in for winding up the stretch of thread spun, as shown in Fig. 24, the counter-faller wire, V, is at its highest working position, compensating for the additional length of thread that has been uncoiled from the top of the spindle in backing-off after the spinning of the stretch was completed. The nut, E, however, Fig. 29, is still at the same distance from the centre, C, of the quadrant as it was at the conclusion of winding the previous stretch; and therefore as the diameter of the cop is now greater by winding the new layer of thread outside the previous one, the winding of the new stretch commences rather too fast, and begins at once to take up the length of thread given out in the backing-off. The counter-faller, V, is thus depressed, and by means of the governing lever slides the nut, E, further out from the centre, C, until the speed of winding is sufficiently diminished to allow the counter-faller to rise again high enough for lifting the governing lever off the strap. It will be seen that, in consequence of the arm, D, describing the quadrant of a circle, the horizontal motion of the nut, E, in the winding of each stretch is greatest at the commencement of the winding and gradually diminishes as the carriage runs in;

and the effect of this is that the 'speed of winding is gradually increased towards the end of each stretch. By this means the threads are wound uniformly upon the cops, with an equal degree of tightness throughout.

The whole mule is driven by a strap $3\frac{1}{2}$ inches broad, running over the fast pulley, F, Fig. 28, on the rim shaft, A, and travelling at about 1670 ft. per minute, or about 19 miles per hour. The driving power required is about 1 indicated horse power per 230 spindles, or $4\frac{1}{4}$ horse power for each mule containing 1000 spindles. The speed of the endless cord, X, passing round the rim wheel, Z, Fig. 22, is 2640 ft. per minute, or about 30 miles per hour. The carriage of the mule makes 3 to $3\frac{1}{2}$ double journeys out and home per minute, the length of stretch being 63 inches; but the velocity varies at different parts of the traverse, the carriage being taken in by a pair of scrolls in the centre of the machine, and drawn out by three spiral grooved pulleys keyed upon a shaft running the entire length of the mule, one pulley being in the middle of the shaft and one at each end. The length of the carriage being upwards of 100 ft., a parallel motion is required for keeping the carriage straight; and this is obtained by a horizontal traversing pulley at each end of the carriage, traversing along fixed cords and thereby made to revolve; and these two pulleys being also coupled together by a crossed cord are compelled to revolve at the same rate, and consequently cause each end of the carriage to travel at the same rate. There are three pairs of drawing rollers, P, Fig. 22, by which the rovings are drawn about 8 times before being delivered for spinning. The last pair of rollers delivers the rovings at a speed of 26 ft. per minute, until the carriage, G, has run out the 63 in. length of stretch, when the rollers are stopped, and hold the threads fast during the winding up as the carriage runs in again. The actual length of roving delivered by the last pair of rollers for each stretch of 63 in. is about 61 in.

The spindles make about 1260 revolutions in twisting each stretch of 63 in., thus putting about 20 twists per in. into the threads; and the total time occupied is about $12\frac{1}{2}$ sec. In winding up the threads, as the total length to be wound up remains constant, namely, 63 in., the number of revolutions is diminished in each successive stretch, according to the increasing size of the cop, from about 70 revolutions at the commencement to 23 revolutions at the full diameter of the cop, with cops of an average size winding an average number of yarn, such as No. 32, which is such a quality that 32 hanks of 840 yards each weigh together 1 lb.; the time of winding each stretch is about $3\frac{1}{2}$ sec. The velocity of the spindles is about 390 revolutions per minute in winding, and in twisting the speed ranges from 8000 down to 800 for coarse work, a common average being about 6500 to 7000 revolutions per minute. In backing off the velocity of revolution is about $1\text{--}20\text{th}$ of that in twisting. The direction of rotation of the spindles is the same in twisting and in winding, and the thread is wound on in a right-handed spiral when spinning twist, and left-handed when spinning weft. Fig. 27, Plate 81, shows full size the conical form of the top of the spindles for the purpose of letting the thread slip off freely at each revolution in twisting; and the two lines, G and H, show the extreme inclinations of the thread to the spindles during the twisting. The larger angle shown by the dotted line, G, when the spindles are nearest to the drawing rollers, is about 145° ; and the smaller angle shown by the full line, H, is about 105° , when the spindles are at the outer extremity of the stretch. The spindles themselves are inclined inwards towards the drawing rollers at an angle of about 12° from the vertical, as shown in the drawing.

In a mule invented by Mr. John Robertson in 1834, and brought out with other improvements in 1839 by Mr. Smith, of Deanston, the chief feature was the use of a mangle wheel for performing the principal motions and changes, including a method of increasing the amount of twist put into the threads during the last few inches of each stretch. The mule of Mr. James Potter also possesses some features, which, although they have not been largely adopted, have much merit in them. The carriage is moved in and out by an arm travelling through half a revolution, so that the motion begins and ends slowly and is quickest at the middle of the stretch. The winding on is effected by an adjustable conical drum, the larger end of which is of the proper size for winding upon the bare spindles, and the smaller for the full cops; the drum is traversed longitudinally on its shaft by a screw of differential pitch, to the nut of which is attached the winding chain that coils on the drum; and the position of the chain on the drum is changed rapidly at the commencement of a set of cops, and more slowly as they fill up. This spiral cone drum was subsequently replaced by a contracting spiral pulley, which at full diameter drove the bare spindles, and gradually contracted as the cops approached completion.

The number of spindles in the self-acting mules has been gradually increased, until at the present time many mules contain 1000 spindles each. One pair of these mules requires the attendance of only one man and two boys, for cleaning the machines, setting in the rovings, attaching the broken threads, taking off the cops when full, and starting the machines, to work again. In spinning No. 32 yarn (in which the weight of 32 hanks, each containing 840 yards, is 1 lb.), the production of the pair of mules per week of 60 hours is 45,000 hanks, or 21,477 miles, per week, weighing 1406 lb. The floor space occupied by one of the mules containing 1000 spindles is about 116 feet by 10 feet, leaving about 4 feet for passages at the ends of the mules in the

modern mills of 120 feet width. The cost of a modern cotton mill for spinning No. 32 yarn, including building, machinery, and accessories, steam-engine and shafting, with fire-proof floors in the scutching and carding rooms, and timber floors in the spinning rooms, averages 18s. per spindle; and one mill was built, during the cotton panic caused by the American war, for 15s. per spindle.

The progress made in cotton manufacture during the last century is strikingly shown by the following comparison between the following comparison between the years 1760 and 1860:

	1760.	1860.
Total value of cotton yarn produced	200,000L.	85,000,000L.—425 times greater.
Weight of cotton imported	3,870,000lb.	1,083,000,000lb.—280 times greater.
Value of 1 lb. of No. 42 yarn.	10s. 11d.	11d.—12 times cheaper.
" " No. 100 " "	38s.	2s. 6d.—15 times cheaper.

As an illustration of the present extent of the manufacture, it may be mentioned in conclusion that the number of spindles employed at the present time in the cotton manufacture of Great Britain exceeds 36 million; and taking them as spinning on the average No. 32 yarn, when each spindle produces per week $22\frac{1}{2}$ hanks of 840 yards each, there is a regular production from the whole, of 64 million miles of yarn per day of 10 hours when in full work or a length of thread equal to more than four times round the earth every minute.

RESULTS OF EXPERIMENTS ON THE RIGIDITY OF GLASS, BRASS, AND STEEL.*

By DR. J. D. EVERETT.

(Continued from page 236.)

THE experiments were conducted in the Natural Philosophy Lecture Room. The box, F F, rested on the floor, the height of mirrors above floor being 270 millims. The scale reflected by them consisted of a large sheet of paper ruled in two directions at right angles to each other with lines about a tenth of an inch apart, and was firmly fixed at the height of 4597 millims. from the floor by stretching it on a board, and screwing this to two joists whose primary office was the support of a cistern. The light, which was naturally good, was improved by using a concave mirror to illuminate the scale. Two telescopes, not shown in the plate, were clamped to a firm three-legged table, their object-glasses being about 970 millims. above the floor. They were in fixed positions, directed one towards each mirror, and were as nearly vertical as was compatible with an unobstructed view of the reflection of the scale. Their deviations from two vertical planes, one parallel and the other perpendicular to the rod, were from $\frac{1}{2}$ to $\frac{3}{4}$ in. circular measure. They were inverted achromatic, of $1\frac{1}{2}$ in. aperture and 10 in. focal length, with cross wires in focus of eyepiece. A damper, consisting of a piece of thin card pressing lightly against the end, A, of the rod, was used on and after July 17th for the purpose of checking vibration.

The mode of observing for flexure was as follows:—The mirrors having been adjusted so as to bring the central portion of the scale into view in both telescopes, a pair of equal weights were placed, one in the scale-pan, P, along with the counterpoise, the other on the point, S, and readings were taken in both telescopes. Then the weight at S was transferred to S', and readings were again taken. The difference of readings in further telescope diminished by difference of readings in nearer telescope is assumed to measure the effect, on the portion of rod between the two mirrors, of a bending couple whose arm is the distance between the two points, S, S', and whose power is the force of gravity on the moveable weight.

The weight was then transferred first to T and then to T', both telescopes being read in each case. The differences were taken in the same way as above, and the result is assumed to measure the effect, on the same portion of the rod, of a twisting couple whose power is the same as above, and whose arm is the distance between the points T, T'.

The weight was then again transferred to S' and S, then again to T' and T, and so on several times, both telescopes being read in each position of the weight, and no change being made in any of the adjustments. The facility of thus passing from observations of flexure to those of torsion, and vice versa, gives the present form of apparatus a great superiority over that employed the previous year.

It has been observed that the arms of couple in flexure and torsion are the distances SS', T T' respectively, which, though nearly equal, are not absolutely identical. This defect was easily remedied by turning the crosspiece through a right angle, so as to make SS' change places with T T'.

Another source of error to be guarded against is want of perfect circularity in the rod operated upon. This is completely removed, if the deviation from circularity be small, by turning the rod itself through a right angle by means of the graduated circle, H. This change has no effect on the torsional rigidity; and its effect on the flexural rigidity is such that the mean flexure in the two positions is the true mean for all positions, inasmuch as the flexural rigidity in any position is proportional to the moment of inertia of a section about a horizontal diameter through its centre of gravity, and by a well-known theorem the sum of the moments of inertia about two rectangular diameters is constant.

For greater security the rod was turned into six different positions, differing by 30° among themselves, so that the first and fourth positions furnished one mean, the second and fifth another, and the third and sixth another. In every one of the six positions observations of both flexure and torsion were taken; and the operation of turning the crosspiece through a right angle so as to make the arms of couple for flexure and torsion change places occurred between the third and fourth positions.

* Paper read before the British Association at Dundee.

COTTON MACHINERY.

(For Description, see Page 250.)

ROBERTS'S SELF-ACTING MULE 1866

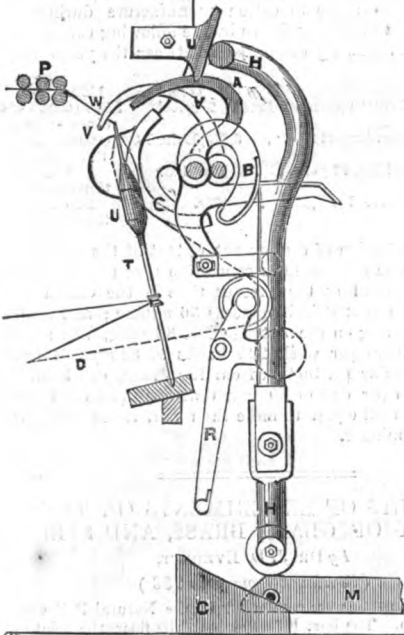
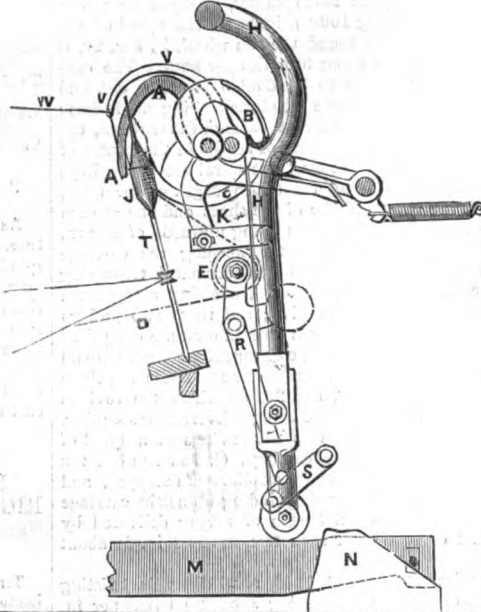
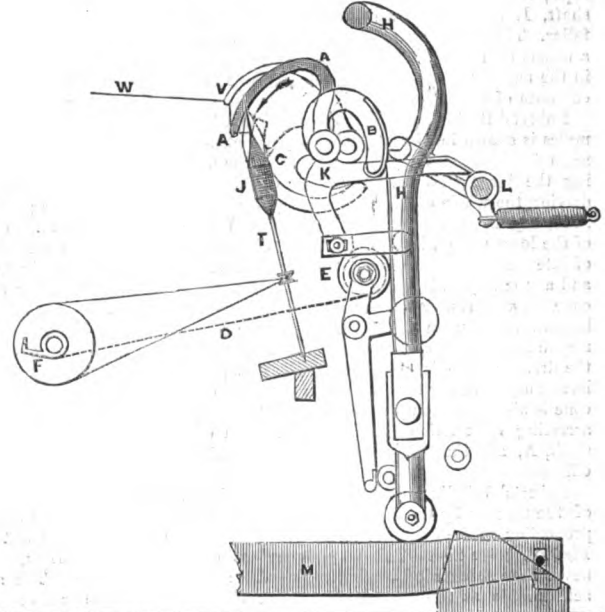
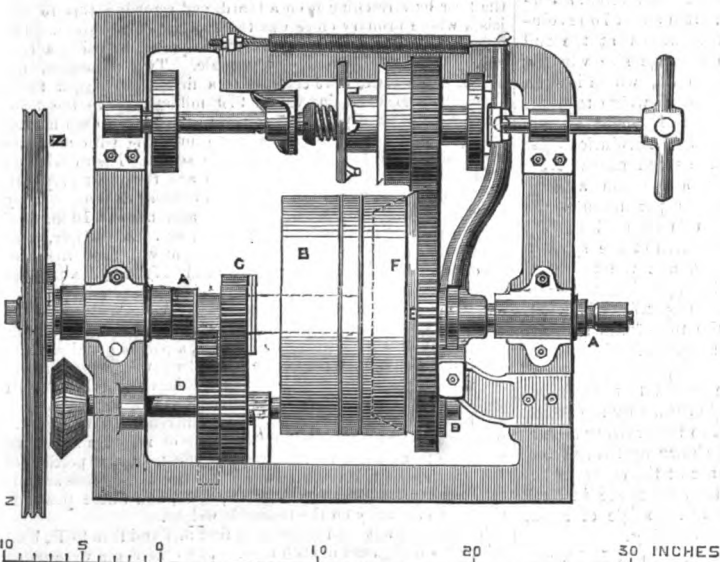
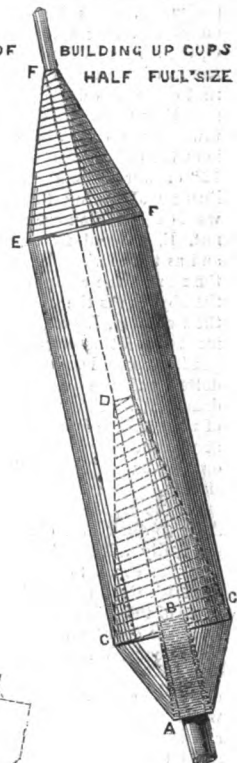
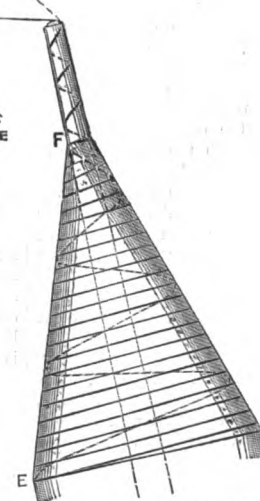
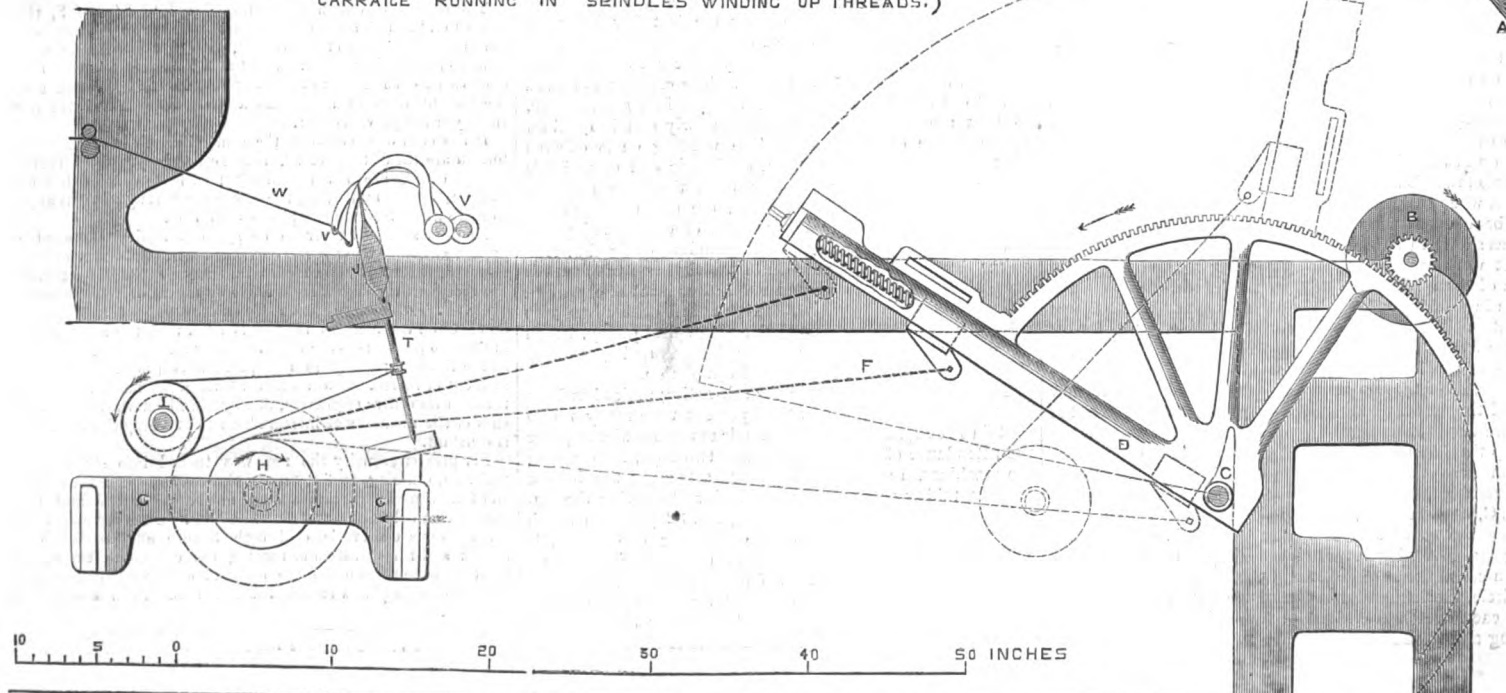
FIG. 25 UNLOCKING OF FALLER
AT END OF WINDING.FIG. 24 LOCKING OF FALLER
PREVIOUS TO WINDING.FALLER MOTION
FIG. 23 PUTTING DOWN OF FALLER
DURING BACKING-OFF.

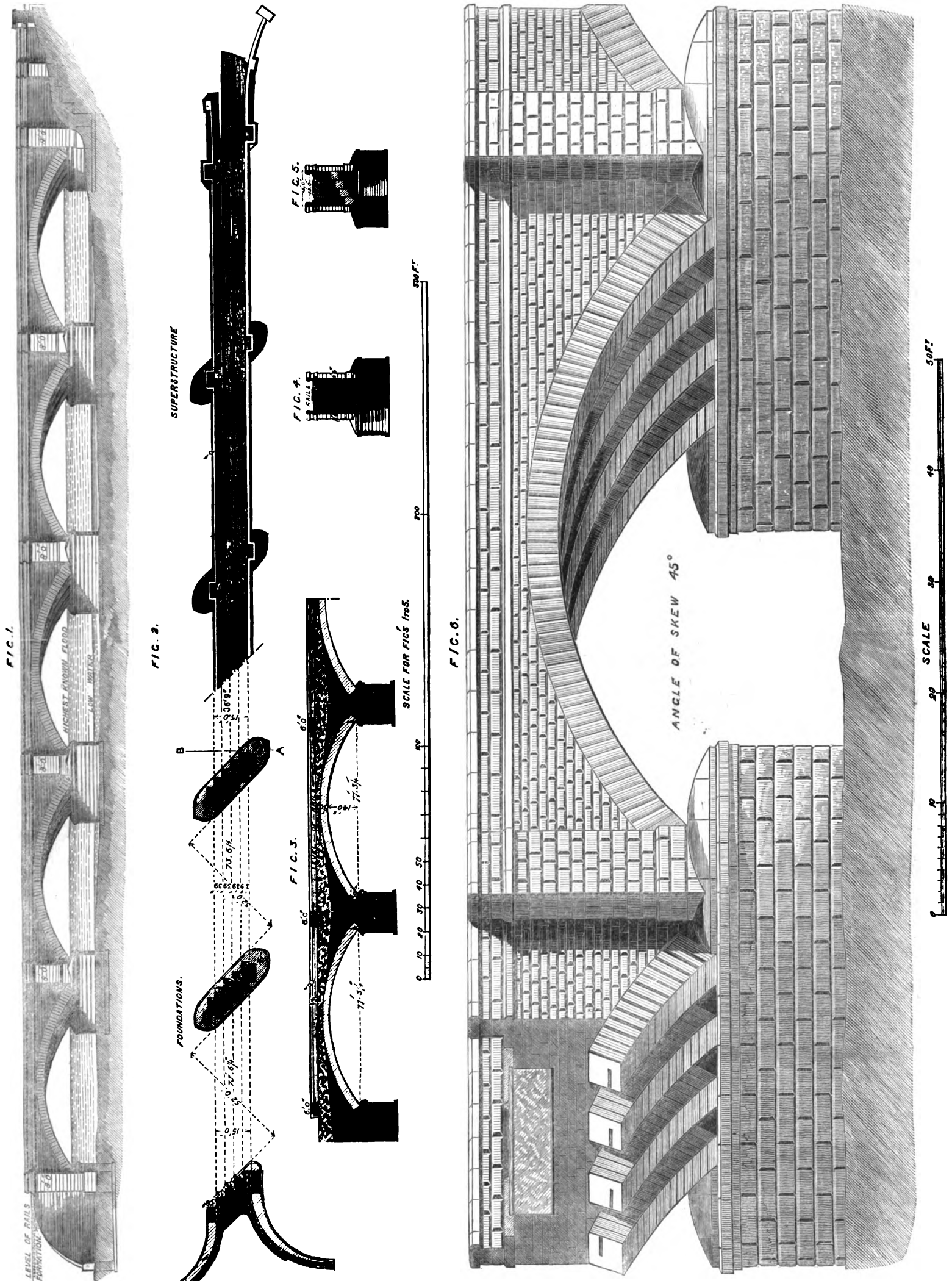
FIG. 28. PLAN OF BACKING OFF MOTION.

FIG. 26 MODE OF
BUILDING UP CUPS
HALF FULL SIZE.FIG. 27
EXTREME INCLINATIONS
UP-THREAD TO SPINDLE
IN SPINNING
FULL SIZE.FIG. 29 QUADRANT FOR REGULATING SPEED OF WINDING.
(CARRIAGE RUNNING IN SPINDLES WINDING UP THREADS.)

THE CONON VIADUCT, HIGHLAND RAILWAY.

MR. JOSEPH MITCHELL, ENGINEER.

(For Description, see Page 206 of our last number.)



LIGHTNING CONDUCTORS.

TELEGRAPHIC wires often conduct lightning into the offices. This causes much damage to the apparatus, and would not be without danger to the operators themselves, if lightning conductors were not introduced, which, under ordinary circumstances, carry off no portion of the current, but which diverge the electricity of the lightning, and conduct it to earth.

From some experiments of M. Guillemin's in France, the lightning conductor called "*à lame de papier*" is that which best preserves the officials and the apparatus from the destructive effects of atmospheric electricity. The administration of electric telegraphs in France adopts these for all offices without exception, and it is also the cheapest form of any lightning conductor.

The paper lightning conductor is composed of two plates of brass, with well planed surfaces of from 25 to 30 square centimetres, placed one over the other, and separated by a sheet of paper, one plate communicating with the line and the other with the earth. When a rather high tension is produced on the line, sparks pass between the two plates, perforate the paper, and the electricity of high tension passes to earth with great facility.

Paper, however, is an hygrometrical substance; when damp it causes a perceptible portion of the battery current, intended to work the instrument, to pass to earth. It even appears that the electrical spark carbonises the paper, when it passes between the edges of the metallic plates. The carbon resulting from imperfect combustion would, if the fact be well authenticated, have the inconvenience of putting the line to earth.

It has been proposed to replace the paper by a very thin sheet of mica. Mica insulates better; it is not hygrometrical; it cannot be carbonised, being a mineral; and, lastly, its easy cleavage enables it to be obtained as thin as a sheet of paper.

The administration intend placing a certain number of these lightning conductors with sheets of mica in the localities most subject to lightning. Experience will prove whether M. Guillemin's modification will give the good results expected.

On the 27th July a most violent thunder-storm passed over Valognes and the environs, leaving several traces of its passage. The fluid struck the telegraph wires, shattered some poles on the coast of Carteret, and on the railway; several posts, which partially conducted the fluid, were pierced and split, and many insulators were pulverised. The lightning then entered the office at Valognes, burnt all the lightning conductors, melting and volatilising some of them, and striking amongst the different line wires surrounded and struck the clerk in charge to the earth, but without hurting him. At St. Saviour's a clock was displaced by the electric fluid, thrown on a table and shattered, the current leaving by a window, shattering a square of glass. The station at Couville has also suffered from an electrical discharge.

The above is from the *Bulletin Hebdomadaire*, of the Association Scientifique de France, a very useful little publication. Lightning has committed much damage in England this year, but as a rule we suffer much less than our Continental neighbours. In fact, except at cable ends, English telegraphic companies rarely use lightning protectors. It is considered that they introduce more evils than they are supposed to remedy, and their use is not economical. Scarcely one per cent. of the instruments employed are damaged by lightning, and the cost of protecting the 99 is infinitely greater than the repair of the one injured. No authenticated case has ever been adduced of an operator being injured by lightning in England. The fall of the operator at Valognes was probably due to fright.

The principal effect experienced is due to induction. The approach of electrified clouds produces a separation of electricities in the wires, and their sudden discharge produces equally sudden recombination of those separated electricities which leads to powerful currents that demagnetise and frequently reverses the polarity of the needles of the speaking-instruments, disturbs the working of the Morse printers, and rings the bells and deranges the signals of railway electric signalling apparatus, in some cases even signalling false signals, and thereby incurring great danger. These powerful currents are sometimes seen flying about the face of the instruments as sparks, but they rarely use the coils, or effect damage. This is almost invariably the effect of the direct passage of lightning itself. Lightning protectors afford no protection from these induced currents, and therefore they are found practically useless to prevent demagnetization. The safest protector is to place the instrument on short circuit during a

storm, and this is what every intelligent telegraphist does. Many instruments are supplied with small commutators to accomplish this readily and easily, by the simple insertion of a plug in a hole. If the two ends of the fine wire of the coil of an electro-magnet or a galvanometer be covered with a double layer of silk and well saturated with paraffin, they may be twisted together with great advantage. Currents of high tension will fly across the thin bridge of silk and paraffin rather than follow the long path of the coil. Many instruments have been saved by this means, and some electricians invariably adopt this plan in their apparatus. Paper soaked in paraffin, in place of M. Guillemin's mica, is an excellent contrivance, and is much used between two plates. The French "*paratonnerre*," as adopted by the administration, is very simple and very cheap; and if they were to use paraffin, they would remedy the defects of the paper; but the value of paraffin does not appear to have made itself evident to our French friends yet. In England we use it to saturate our insulators, to improve the insulation of our silk-covered wires, to form condensers, to insulate the cells of tension batteries, and numerous other purposes where insulation, cleanliness, and perfect action is required. Its value appears to be dawning on the American mind, and the *ne plus ultra* of insulation is supposed to be attained by their last insulator, the Brooks's, which is saturated with this wonderful production.

The forms of lightning protectors are as numerous as the electricians who use them, but perhaps the most perfect form is the *vacuum* protector of Mr. Varley. Platinum wires, one attached to the line, and one to the earth, are separately sealed in an exhausted glass bulb. Rarefied air acts almost as a conductor to high-tension electricity. It does not interfere with the working currents. When lightning enters the wire, it generally destroys the bulb of glass, but saves the apparatus. The Electric Telegraph Company fix them at the ends of all their cables, and according to Mr. Culley they act perfectly. Several cases have occurred of stations being set on fire by the lightning fusing the gas pipes to which the wires are sometimes attached for earth purposes, and thus lighting the gas. Great care therefore is required to make use of water-pipes in preference to gas-pipes for this purpose.

Franklin was the first to establish the identity of the lightning of the heavens with the spark of the machine. The production of electricity in either case is due to the same cause. The motion of the particles of the air, the friction of the clouds, the variations of the temperature of the atmosphere, all lend a helping hand to produce that separation of the two electricities, which in their subsequent union produce thunder and lightning. Lightning is of three kinds, *forked*, *sheet*, and *ball*. Forked lightning is the spark that accompanies the discharge of a charge-cloud either into the earth or into another cloud. Sheet lightning is the mere reflection of this discharge, which is frequently very beautiful in summer on the sea-coast, lighting up the horizon with brilliant flashes of light—the reflection of some distant storm. Ball lightning is very rare, and more meteor-like than electrical. It is thus described by Ferguson:—"After a violent explosion of lightning, a ball is seen to proceed from the region of the explosion, and to make its way to the earth in a curved line, like a bomb. When it reaches the ground, it either splits up at once and disappears, or it rebounds like an elastic ball several times before doing so." It is said to last for several seconds, and is not, like forked lightning, momentary. It does not appear to be electricity, but some physical result of electric discharge. The atmosphere is always electrical, whether cloudy or clear. In mist the tension is greater than in the bright sunshine. The higher we ascend, the greater is the tension. It is greatest in winter, least in summer, and yet during the latter period we chiefly suffer from storms, though in the former we get auroræ borealis. We have much to learn of its pathology yet, and glad we are to find that the British Association and the Kew meteorologists maintain such a constant watch over its doings. A very interesting paper was read, at Dundee, by Professor Everett, of Glasgow, upon the indications of Thomson's self-registering electrometer at Kew, and Windsor, North America, which electrometer is now in use at many stations. There is a kind of tide in the electricity of the atmosphere. It rises and falls, and changes its nature regularly and irregularly, and its maxima and minima are indelibly imprinted by Thomson's beautiful apparatus. We shall probably, in course of time, know more about it, but at present we are very ignorant of the electricity of the atmosphere.

MESSRS. PENN'S FACTORY.

VISIT OF THE SOCIETY OF ENGINEERS TO THE WORKS AT GREENWICH.

THERE are few engineering firms, if any, who have a more widely spread reputation than Messrs. John Penn and Son. In ironclads, in frigates, in large ocean and smaller river steamers, the engines constructed by them are at work in all parts of the world, and the excellence of their design and beauty of their finish have done much to establish the character for the highest class of engineering workmanship which this country possesses. Messrs. Penn's works at Greenwich originated in a wheelwright's shop, established about fifty-five years ago by the father of the present John Penn, who, we may remark here, is really the "Son" in the firm. This wheelwright's shop stood upon a piece of the ground occupied by the present factory, but no part of it now remains, the last portion of the old works having been pulled down as lately as five or six years ago to make room for new shops. The present works at Greenwich stand upon seven acres of land, and when in full swing give employment to about 1000 men. They are capable of turning out engines to the extent of 8000 nominal horse power annually. Besides their Greenwich factory, Messrs. Penn have boiler works at Deptford Pier, these occupying about two acres of ground, and giving employment to 600 hands, when in full work.

On Friday last Messrs. Penn's works were visited by a large party of the members and associates of the Society of Engineers, and in the absence of Mr. Penn, the visitors were received by Mr. English, Mr. B. B. Knight, and Mr. B. Gridley, who conducted them over the works and courteously afforded them all the required information.

The first department visited by the party was the large building which forms the fitting, erecting, and heavy machine shops. This building has four bays, two of which are devoted to the heavy tools, whilst in the others the fitting up and erection of the engines is carried on. All the bays are provided with overhead traversing-crane, one of these cranes in one of the bays being worked by a quick running band, on the excellent system introduced by Mr. Ramsbottom, and now used at many large works. At Messrs. Penn's, however, the band or cord, instead of being made of cotton and being run at a speed of 5000 ft. per minute, as is the case at Crewe, is made of grained hide, and is run at the much lower speed of 1500 ft. per minute, the strain upon it being greater than upon that used by Mr. Ramsbottom. Both the longitudinal and lateral traversing motions, as well as the hoisting motions of the crane, are worked by the rope, and the details are very neatly arranged, the various motions being thrown into and out of gear by means of hand-ropes, which are lettered to correspond with directing arrows painted on a board fixed to the underside of one of the crane-girders. Thus, by pulling the rope lettered A, the crane is made to move in the direction of the arrow marked A, and so on. Seven of the other travelling-crane are about to be fitted up in the same way as the one just mentioned.

On entering the part of the building devoted to the erection of machinery, one of the first things noticed was a set of nearly completed engines for driving twin screws. They are direct-acting engines, the cylinders being placed horizontally next the sides of the vessel, and the condensers being situated between the screw-shafts. The whole arrangement is very simple, and all the parts are thoroughly accessible. Near these engines were some engines for twin-screw launches, these being exactly similar to those which we illustrated and described on pages 22 and 23 of the second volume of this journal. These engines consist each of two pairs of engines, bolted vertically, one pair on each side of the firebox casing of a boiler of the ordinary locomotive pattern, and they were much admired by the visitors on Friday, for the lightness and elegance of their design. The cylinders are five inches in diameter, with six inch stroke, and the piston-rods, connecting rods, crank-shafts, and screw-shafts are made of steel. The boilers, also, are made entirely of steel, the material being very carefully chosen, as some of the plates are flanged in a way which tests their quality severely. The boilers—which are tested to 180 lb. per square inch—are worked at from 60 lb. to 80 lb., and the engines are driven at from 300 to 350 revolutions per minute, at which speed they give out from 34 to 38 indicated horse power, an excellent result, when it is considered that the total weight of the set of engines, boiler, water, and machinery, including engine beams and wood chocks, is only 8 tons 6 cwt. The engines drive four-bladed screws 2 ft. 6 in. in diameter, with 4 ft. pitch, and the speed obtained is from 7½ to 7½ knots, the launches to which these engines are fitted being 42 ft. long, 11 ft. beam, and of very bluff build. Messrs. Penn have now their twenty-seventh engine of the class we have described in hand.

Near the engines for the twin-screw launches were many details of the engines of 1000 horse power, nominal, for H.M.S. Inconstant. These engines are, excepting those of the Hercules, which are nearly completed, the largest at present in hand at Messrs. Penn's. They are trunk engines, with cylinders 112 in. in diameter, with 4 ft. stroke, and are to be fitted with surface-condensers.

The most prominent object, however, in this portion of the works, was the engines of H.M.S. Hercules, which, as we have already stated, are almost finished. Although rated at only 1200 horse power, nominal, they have larger cylinders than any engines previously made at Greenwich, the diameter being 127 in., and the stroke 4 ft. 6 in.; these dimensions being both greater than the corresponding ones of the Warrior's engines, although these latter are rated at 50 horse higher nominal power. The engines of the Hercules are similar in their general design to the trunk engines usually constructed by Messrs. Penn; but there are some special points in their arrangement which have been necessitated by the limited space allowed for them in the vessel. It will not, however, be necessary that we should enter into detailed particulars of the engines here, and we therefore need only remark that they are in every respect a splendid specimen of workmanship, and fully calculated to maintain the high character of the factory at which they were constructed. It will be remembered by many of our readers that the crank-shaft for these engines was made by the Mersey Steel and Iron Company. It is the largest that has yet been turned out, the forging weighing 34 tons 16 cwt.

in the rough, a weight which was reduced to 30½ tons by the operations of turning, shaping, &c. The weight of this shaft will give our readers an idea of the massive character of the whole work.

Not far from the engines of the Hercules were a pair of trunk-engines constructed for the Spanish Government; but of these it will be unnecessary that we should speak further at present, and we may therefore pass on to the machinery which, as we have already mentioned, occupies two of the bays of the shop we are describing. This machinery is all driven by a pair of "grasshopper" engines, each of 12 horse power, nominal; these engines, which do their work exceedingly well, being similar to two other pairs employed in other departments of the works. The engines are fitted with a simple adjustable cut-off, regulated by one of Porter's governors.

One of the most conspicuous of the heavy tools is a fine machine for shaping heavy crank-shafts and turning the crank-journals. This machine was designed by Mr. B. Gridley, who has charge of all the machinery at Messrs. Penn's; and it was constructed at their own works. In some respects the machine resembles the lathe for boring railway tyres, constructed by Messrs. Greenwood and Batley, which we illustrated and described a few weeks ago (*vide* page 79 of the present volume); but instead of the work revolving and being acted upon by stationary tools, the work remains stationary, and the tools themselves revolve. The machine at Messrs. Penn's consists of a massive bed—somewhat of a T form in plan—on which the heaviest crank-shafts can be secured either transversely or longitudinally. This bed carries a large headstock in which an annular casting revolves, being driven by suitable gearing. This casting, which is about 6 ft. in diameter inside, is furnished with a pair of radial slides to which tool-holders are fitted, these slides being arranged so that the tools can be set either radially or parallel to the axis of the revolving casting. The exterior of the revolving casting has a V formed on it, one side of this V fitting against a correspondingly shaped surface on the inner side of the headstock, and the other side bearing against a ring which can be adjusted to take up any looseness caused by wear. The headstock has a self-acting, traversing motion along the bed-plate, in the direction of its axis, and the tool-holders have also a feed motion on the radial slides of the revolving casting. The manner in which a crank-shaft is finished by this machine is as follows:—The main body of the shaft is first turned in a lathe in the ordinary way, this being done to facilitate the setting of the work on the machine we have been describing. In this machine the throws of the cranks are planed or shaped, and the openings of the cranks cut out, the crank journals or joints being also finished. For effecting the first of those operations, the shaft is placed on the bed of the machine transversely, so that one of the throws stands vertically opposite the headstock, the centre line of the shaft being at right angles to the centre line of the latter. This being done, the tools carried by the revolving ring or casting plane the surface of the throw by taking a series of circular cuts over it.

The cutting out of the cranks, and the finishing of the crank pins is effected by placing the shaft through the hollow headstock, and adjusting it so that its centre line is parallel with, and on the same level as, the axis of the latter, and is distant from it horizontally by the amount of the throw of the crank. At the same time, the headstock is brought so that it surrounds the crank to be cut, and the tools, carried by the casting revolving within the headstock, are thus enabled both to cut the opening in the crank, and, when this has been done, to finish the crank pin. One crank having been finished in this way, the work is shifted until the other crank is brought within the headstock. It will thus be seen that the process of cutting out the cranks and finishing the crank pin is just the reverse of turning, the work remaining stationary, and the tools travelling round it. When such heavy masses as large marine-engine crank-shafts have to be dealt with, it is much more convenient to treat them in this way than to chuck them in a lathe; and in fact, in the case of the largest shafts, it would be almost impossible to finish them by the ordinary process of turning. The consequence is, that these "hollow lathes," as they are sometimes called, are being gradually introduced in most large marine-engine works, particularly on the Continent, where they are, probably, more generally known than they are in this country.

To return to Messrs. Penn's, however, close to the machine for finishing crank-shafts is a large vertical planing-machine, which, like the crank-machine, was designed by Mr. Gridley, and constructed at Messrs. Penn's own works. In this machine the tool-holder traverses on a vertical slide, which, in its turn, moves horizontally on the main bed; and the work to be planed is placed by the side of the machine, and adjusted as required. The extreme vertical traverse of the tool is 12 ft., and the horizontal traverse of the tool-slide on the bed 15 ft., it being thus possible to bring the tool to bear upon any point within a rectangle of these dimensions. The details of the machine are very neatly and simply arranged. The reversal of the motion of the tool-holder is effected by the use of plain and crossed belts, the belt gear being worked by tappets carried by the tool-holder acting upon adjustable stops in the usual way; but instead of these stops being fixed to the bar on which they are placed, they merely bear against spiral springs attached to the bar, and the tool-holder thus continues to traverse for a short distance in each direction after the tappets strike the stops; the bar by which the belts are shifted, not moving until the spring against which the stop which is struck bears, is compressed to some extent. This arrangement gives a very decisive movement to the belt gear, and at the same time does away with much of the jar which takes place at the end of each stroke of many planing-machines.

Amongst the other tools contained in the same shop as those we have noticed, are some fine boring-machines for heavy work. One of these was made by Whitworth, and another was designed and constructed at Greenwich. In this latter machine, which is capable of boring cylinders of the largest size, the boring-bar is driven by a worm gearing into a large worm-wheel carried by the bar. In moulding this worm-wheel, the teeth were cut out of the loam by a revolving worm-cutter, and the result is that the fit between the driving worm and wheel is practically perfect, and an extremely steady motion is given to the boring-bar. The same system has been adopted in making the worm wheels used in the foundry and other cranes, which we shall describe

presently. The boring-machine made by Messrs. Whitworth and Co. has a large rectangular table, on which the work is placed, this table being furnished with two boring-heads, the boring-bars of which can be worked at right angles to each other. The heads can be shifted into various positions, and the arrangement is a very convenient one for heavy work. There is another smaller boring-machine constructed on the same general plan. The remainder of the tools in the heavy machine-shop will not require special notice; but we may mention that, before leaving this shop, the visitors were shown the screw-shaft of the Hercules, and the boss of the screw for the same vessel. This boss, which is of gun-metal, weighs 8 tons, its value being thus worth—speaking roughly—about 800*l*.

From the fitting and machine shops the visitors, last Friday, were conducted to the foundry, a roomy building, L-shaped in plan, and well fitted up with the necessary plant. The iron is melted in four cupolas, capable of running down 10 tons of metal per hour. Each cupola has four tuyeres, each 7 in. in diameter, and the pipes belonging to these are led down to the nozzles from the loading stage—instead of up from the ground level, as usual—the lower part of each cupola being thus left clear. The pressure of blast used is 9 in. of water. The materials are raised to the loading stage by a chain hoist worked from shafting driven by the engine in the large machine shop, the same shafting also giving motion to the cranes with which the foundry is provided. These cranes are five in number, two of them being capable of lifting 40 tons, and the others 25 tons each. They all have plate-iron jibs and posts, and were all designed and constructed at Messrs. Penn's own works. In all the cranes both the hoisting gear and that for giving the traversing motion of the chain carriage along the jib is worked from the shafting, the hoisting barrel being driven by a worm wheel and worm, so that the load cannot run down in case of a strap breaking. The lowering of a load is effected by driving the gearing by a crossed belt, and the plan has the advantage of giving a very steady motion and of keeping the load at all times under perfect control. The handles by which the hoisting and traversing motions of each crane are governed are placed by the side of the adjacent wall, and are conveniently arranged.

The high finish of the castings turned out at Messrs. Penn's works is so well known that it is scarcely necessary to allude to it here; but we may mention that the beautiful cylinder casting exhibited by the firm at the International Exhibition of 1862, and which attracted so much attention from its sharpness and excellent surface, was by no means an exceptional example, as a visit to the foundry at Greenwich will immediately prove. On Friday last no metal was being run, but a good deal of moulding was going on, and a large casting—one of the surface condensers for the Inconstant—was just being removed from the foundry.

Besides the cupolas, the foundry contains two air-furnaces for melting gun-metal, one of these being capable of containing a 7-ton and the other a 15-ton charge. In these furnaces the fire-grate is arranged at one end, and the metal to be melted is placed upon an inclined bed near the other end, where it is fully exposed to the flame and heated gases from the fire, which are reverberated from the roof of the furnace. The metal, as it melts, runs down into the well or bed of the furnace immediately behind the bridge, from which well it is run off as required. Each furnace is provided at the firegrate end with openings, through which air can be admitted above the fire. These furnaces are employed for making the castings of screw propellers and other heavy work, the light brass work being cast in a small separate brass foundry, about which nothing special need be said.

Besides the shop already described, containing the heavy tools, there is at Messrs. Penn's a two-storied shop, in which are placed the smaller lathes, shaping and drilling machines, and other light machinery. This machinery is driven by a pair of grasshopper engines, similar to those in the large machine-shop. In this pair of engines, however, the piston-rod stuffing-boxes, instead of being packed in the usual way, are each fitted with a deep bush, which surrounds the piston-rod. The bore of each bush has a number of grooves turned in it, these grooves acting like those in the solid grooved pistons, which have, to some extent, been used for steam-engines and pumps. Each bush has a collar formed on it at the lower end, this collar resting upon an india-rubber ring placed in the stuffing-box, whilst another similar ring is placed above the collar, and, being pressed upon by the gland, keeps the whole in place. The bush does not fit the gland closely, and it is thus enabled, to some extent, to adjust itself to the piston-rod, and to follow any irregularity in the working of the latter which may be caused by inaccuracy in the parallel motion. These grooved-bush packings act exceedingly well, and are found to be very durable.

Amongst the noticeable tools in this small machine-shop is a shaping-machine, which has had an arrangement added to it to fit it for shaping expansion links. This contrivance consists of a radius-bar of adjustable length, one end of which fits upon a pin below the floor level. The radius-rod vibrates on this pin in a vertical plane parallel to the face of the machine, and it carries at its upper end a guide, through which the cutting-tool works. The reciprocating arm of the machine is fitted at its end with a slide, in which the tool-holder can move vertically, and thus, as the saddle is traversed along the machine, the tool is constrained by the action of the radius-bar to move in an arc of a circle. The links to be shaped are fixed upon the pair of tables on the front of the machine in the usual way. The arrangement is a very neat one, as the radius-bar, standing vertically, takes up but little room, and is out of the way.

Another neat tool worth notice is a small machine for drilling the centres in bolts, pins, and similar articles, previous to their being put in a lathe. This machine, which was designed by Mr. Gridley, consists of a bed on which is a small lathe headstock carrying a drill-spindle working horizontally. On the bed of the machine is placed a saddle having a transverse slide on which a pair of blocks can be made to approach or recede from each other by a right and left handed screw. The opposing faces of these blocks have each a > cut in them, and it is by these >s that the article to be centred is held; the >s being so arranged that their points are on a level with the centre of the drill-spindle, and the blocks and right and left handed screw being also arranged so that the former, when screwed together, meet on the centre line of the machine. When a bolt has to be centred,

it is thus only necessary to place it between the >s, and to screw the blocks together when the centre of the bolt is brought immediately opposite the centre of the drill, and the hole can be drilled by shifting the saddle toward the latter. The machine enables small articles to be centred very quickly and accurately.

The forge at Messrs. Penn's is one of the best shops of the kind we have seen. It is spacious, light, and exceedingly well ventilated. At one corner, below the floor level, are placed the three Cornish boilers by which steam is supplied to the engine already mentioned, and close by is one of Ryder's swaging machines, which is employed for turning out a great variety of work. In this machine a series of swages or dies are worked by eccentrics on a shaft revolving at about 300 revolutions per minute, and the article to be forged is subjected to the blows of several swages successively, according to the form required. At the time of our visit the machine was being used for forging the eye-bolts to which boiler stays are attached; it turns out good work, and performs it quickly.

Down one side of the forge are arranged a number of "olivers" for bolt-making, &c. In the construction of these, light iron frames and spiral steel springs have been substituted for the clumsy wooden frames and ash springs usually employed, and some of the "olivers" are provided with two hammers, each striking on a corresponding swage on the anvil. This plan saves the time lost in changing swages, when two of different forms are required for finishing a bolt. The forge is also furnished with four small steam-hammers for general work, one of these being on Mr. Naylor's plan, and the others having been made by Messrs. Glen and Ross. These latter hammers are all fitted with a simple self-acting valve gear, which was designed by Mr. Cohen, the foreman of the smiths at Messrs. Penn's, and which appears to answer its purpose exceedingly well.

The work turned out in the forge above noticed is only of a light or, at all events, moderately heavy character, heavy shafts and similar articles being forged in another building, open at the sides, containing the heavy steam-hammer and the necessary furnaces for working up the scrap. At present, however, this large forge is not in use, Messrs. Penn not having sufficient heavy work in hand to keep it fully going, and therefore preferring to get their heavy forgings from other firms, who make such things their *specialité*.

Near the large forge is a shop well supplied with various kinds of wood-working machinery by the best makers, the plant including a planing-machine by Messrs. Samuel Worsam and Company, a band saw by Messrs. Greenwood and Batley, circular saws, and other tools. In this shop the wood is cut up for the use of the pattern makers, and for other purposes. Not far from the shop containing the wood-working machinery is a department of the works which, although not exactly of an engineering character, is yet well worthy of notice here. We mean the stables, harness-rooms, &c. Mr. Penn takes great pride in his horses, and he has eighteen which he employs for hauling heavy loads, and which are of themselves almost worth a trip to Greenwich to see. It is, we believe, a standing joke that these horses, like Mr. Penn's engines, work up to five times their nominal power and upwards. The stables and other offices are all fitted up in the best possible style, and attached to them is a shoeing forge, the smith and hammerman in which are watched and sometimes imitated by an attentive monkey! Even in the stables machinery has been introduced, the hay, corn, &c., being raised to the lofts by a hoist worked by one of Messrs. Clayton, Shuttleworth and Co.'s two-horse horizontal engines, this engine being also employed to work the machines for cutting chaff, &c. The steam for working this engine is conducted from the main boilers through pipes laid underground for a considerable distance.

Before leaving the Greenwich works on Friday last, the visitors were shown into the small shop, where the models of engines are constructed, and where small tools are made and repaired. In this shop are generally kept the models themselves, but at present these are almost all at Paris, where they have attracted much attention from the beauty of their finish and the accuracy with which they represent the actual engines. The models made at Messrs. Penn's are not "dummy" models; in them all the internal parts are as carefully fitted up as those which are immediately visible, and the consequence is that their construction involves the expenditure of an immense amount of labour and skill. The shop in which they are constructed is provided with a number of ingenious tools for light work, which will well repay examination.

We have said in the early part of this notice that, in addition to their factory at Greenwich, Messrs. Penn have extensive boiler works at Deptford Pier. Of these works, however, we shall not give any description on the present occasion; but we may remark that they are very completely provided with all necessary plant, amongst which some machines for planing the edges of plates are especially noticeable.

MONT CENIS RAILWAY.

TO THE EDITOR OF ENGINEERING.

SIR,—Referring to your remarks in last week's journal, wherein you say "we have expressed our belief that the Mont Cenis engines will generally be worked up 1 in 12 by the simple adhesions of their own driving-wheels," I beg to send you the following quotation as to a mountain line in California.

They (the articles wanted) "are for a locomotive of 16 tons weight, with engine, tank, and wood, upon light driving-wheels, all connected to each other, cylinders 8 in. diameter by 15 in. stroke, gearing, at present 3 to 1, upon the forward axle, wheels 3 ft. diameter—tire surface, including everything, 275 square feet—built to run upon a coal road, rails 40 to 45 lb. to the yard, on wood sleepers, with an inclination of 280 ft. to the mile at the heaviest point. At present the road is about 4 miles in length, but she has no difficulty in pushing up 24 cars of 3800 lb. each, up a grade of 150 to 200 ft. to the mile, and round some very sharp curves." I am satisfied this style of engine is well suited for our mountain roads.

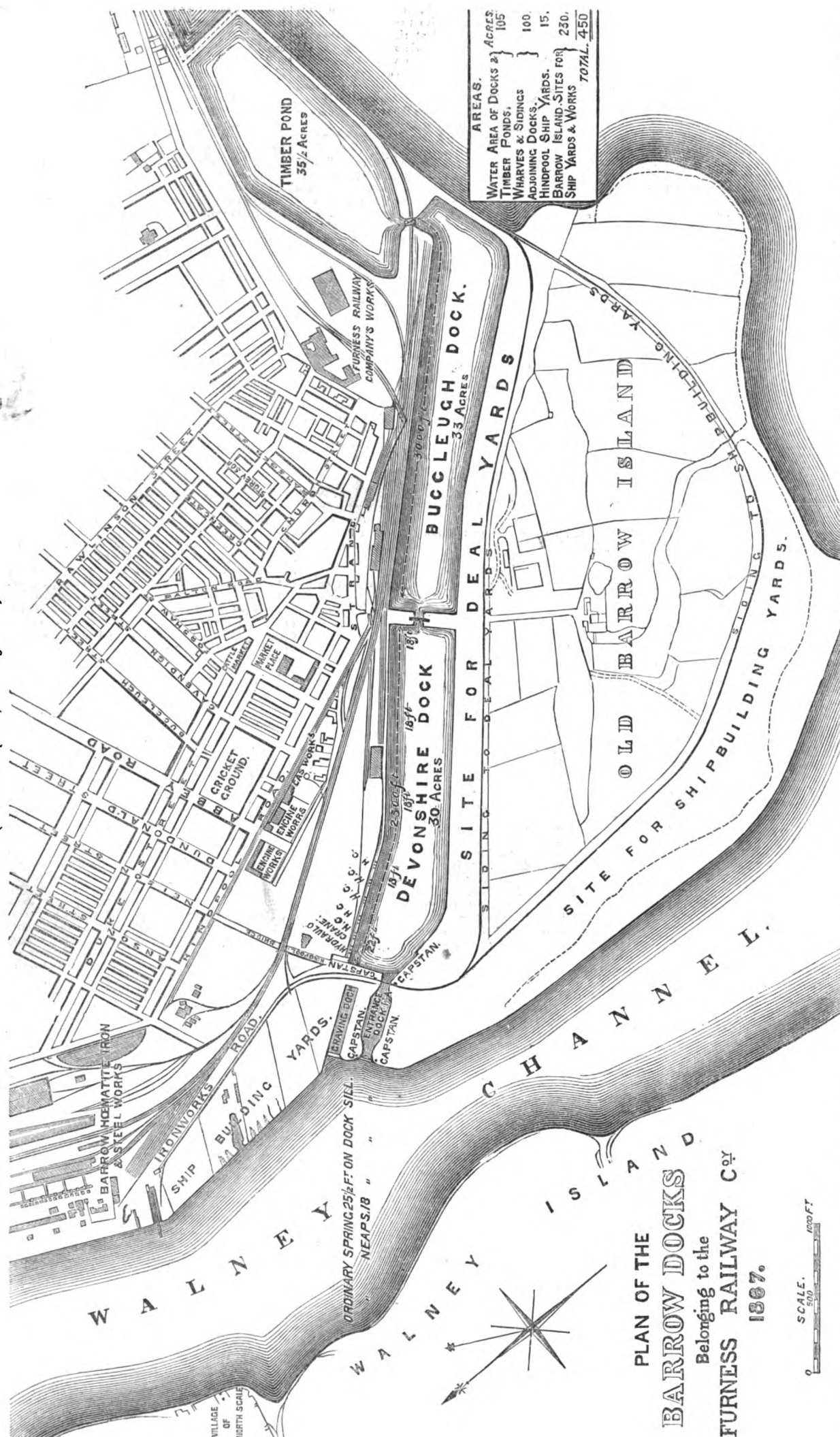
R. M.

FROM THE NORTH.—Messrs. C. Mitchell and Co., of Low Walker, have launched a steamer of 2500 tons burthen, with engines of 160 horse power, by Messrs. Penn and Co., of London, for the Russian Steam Navigation Company. This steamer is intended for the Black Sea trade.

BARROW DOCKS, BELONGING TO THE FURNESS RAILWAY COMPANY.

MESSRS. J. R. MCLEAN AND F. C. STILEMAN, ENGINEERS.

(For Description, see Page 262.)



PLAN OF THE BARROW DOCKS Belonging to the FURNESS RAILWAY COY 1867.

SCALE.
0 500 1000 FT.

THE MERSEY IRON AND STEEL WORKS.—In our notice, last week, of the various Bessemer steel works in the kingdom, we inadvertently omitted the Mersey Iron and Steel Works, at which there are two 6-ton converters, which have been at work making Bessemer steel since October, 1865.

SHEFFIELD.—There is not much improvement to report in the state of trade at Sheffield. There is a pretty good demand, however, for steel for manufacturing purposes. The demand for railway materials has not been very brisk, but there has been somewhat more doing in armour plates.

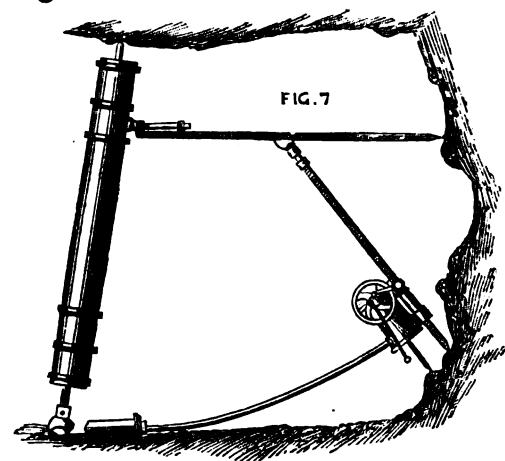
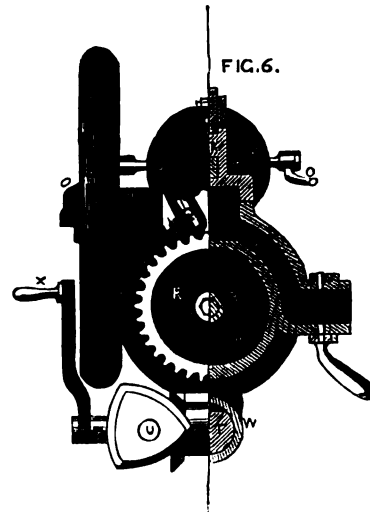
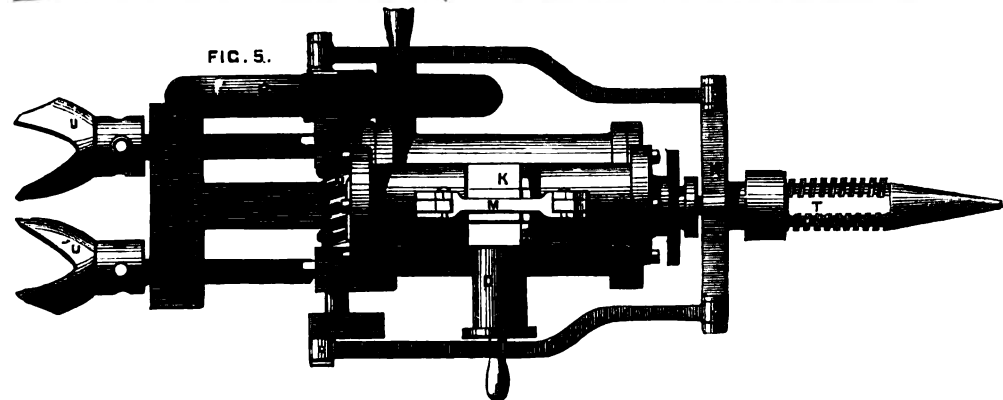
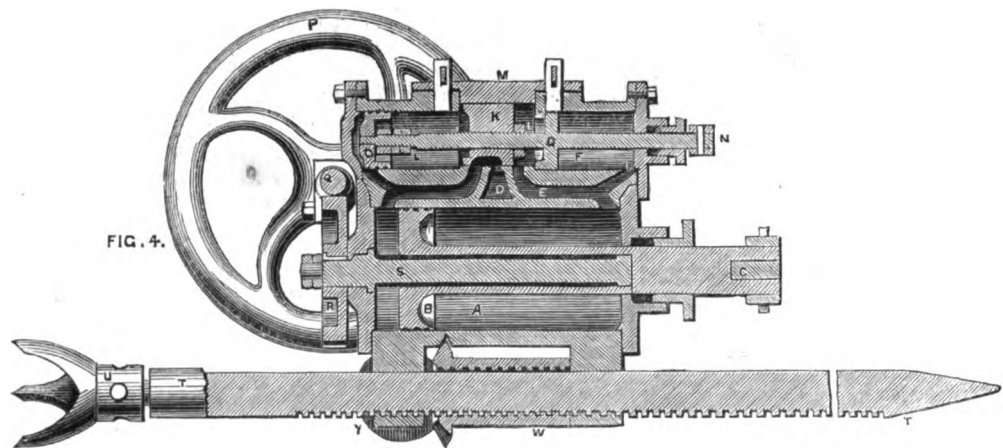
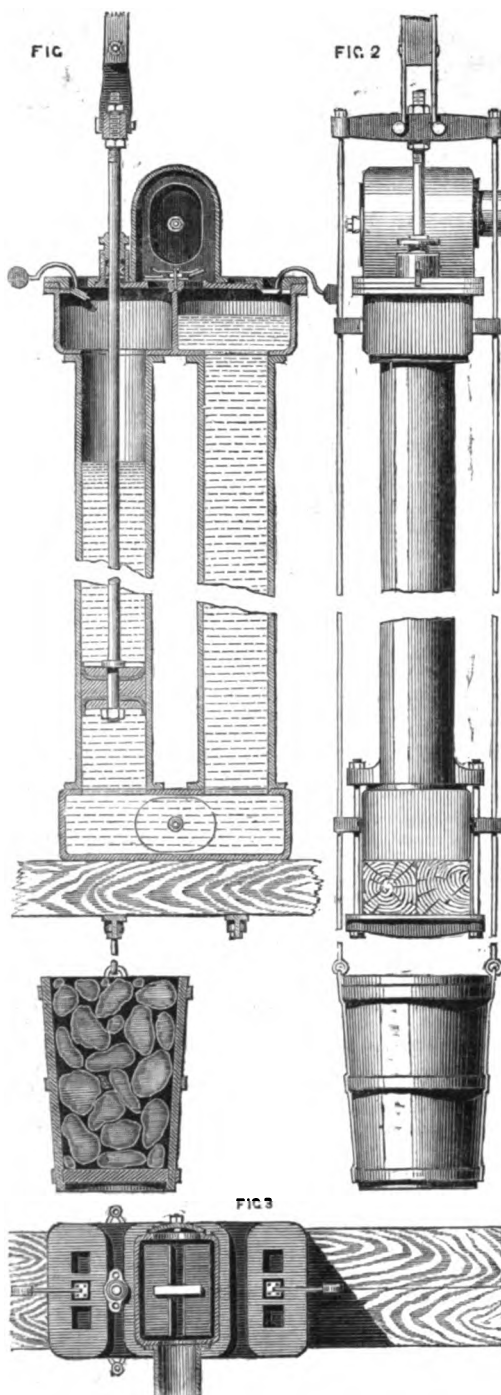
THE CLEVELAND IRON TRADE.—The Cleveland pig-iron trade is considered to be gradually passing into a healthier stage. The demand is now rapidly approaching to a level with the supply, stocks in makers' hands and in the railway warrant stores having increased but very little during the last two months. The demand from Scotland and South Wales continues brisk, but from the Continent there has recently been a falling off. In manufactured iron a good deal more is being done, but complaints are made that the prices paid are comparatively unremunerative.

MESSRS. SHEPHERD, HILL AND CO., LEEDS.—A recent visit to the works of these makers of engineers' tools (to whom a gold medal was awarded at the Paris Exhibition) showed us that they were fully and probably prosperously employed in these slack times. They are filling extensive orders for Woolwich Arsenal, the East Indian Railway, &c.

A GOLDEN MARK.—A correspondent of one of the papers has made a calculation showing that Colonel Pearson's mare, Achievement, has won her weight in gold, taking her winnings upon various race-courses within the last few years.

COAL AND IRON IN NORTH AMERICA.—A St. Louis letter states that General Palmer, treasurer of the Union Pacific Railway of Kansas, and Dr. L. E. Conte, geologist of the surveying party, have been engaged for a month past in investigating the coal-fields of the Raton Mountains in Colorado and New Mexico on the proposed line of that road. They report many large deposits of valuable coal, and one vein fifty miles north of Fort Union is 10 ft. thick and more than fifty miles square in extent. The coal is considered to be equal to the best Pittsburgh coal. Iron ore has also been discovered in the same locality.

BERGSTREM'S BORING-MACHINE.



BERGSTREM'S BORING-MACHINE.*

By C. LE NEVE FOSTER, B.A., D.Sc., F.G.S.

Description of the Machine.—Bergström's boring-machine, which is now being used at the Perseberg mines, near the town of Philipstad, in Sweden, is a modification of that constructed by Schumann, of Freiberg. A short description of the machine is given in the *Berg-und Hüttenmännische Zeitung* (1866), which I will now employ; but the main facts of the paper have been obtained by personal observations and inquiries at the mine.

The machine consists of a cast-iron cylinder, A (Fig. 4), $4\frac{1}{2}$ in. in diameter, in which the piston, B, and at the same time the borer fixed in the socket, C, is moved by compressed air or steam. The length of the stroke is 7 in. The compressed air enters by a pipe at D, and then passes through one of the ports, E and E, into the cylinder, and moves the piston backwards and forwards. F and F are two single-acting cylinders, in which the pistons, G and G, and their common piston-rod, H, are moved by air or steam, entering by the openings at I and I. K is the slide valve, which is pushed backwards and forwards by bosses on the piston-rod, H, in order to make the air act sometimes on one side of the piston and sometimes on the other. By means of the nuts, L and L the position of the slide valve on the valve face is determined, and consequently at the same time the entry of the air. M is a guide for the slide valve. On the valve-rod the cross-head, N, is keyed, which, by means of two connecting-rods, O and O, sets in motion the fly-wheel, P, its axle, and the worm, Q, which has been formed on it. The screw takes into the worm-wheel, R, which thus causes

the spindle, S, to rotate. The spindle, S, has on each side a groove, in which feathers, dovetailed into the hollow piston-rod, C, can readily move, and thus when the spindle turns it causes the rotation of the piston, and consequently also of the borer.

The machine hangs from, or may be supported by, a bar, T, having a thread cut on it. In order to prevent the machine from turning on the bar, T, the thread is cut away, as shown on the cross section and plan. By means of the screws, U and U, the rod is firmly forced against the rock. The advance of the machine is done by hand, by working a winch handle, X, which actuates a mitre wheel, Y, which gears into another mitre wheel on the nut, W. This nut, W, is held between two lugs cast on the cylinder, and therefore as the nut is caused to rotate the machine advances or retires. The machine gives 200 to 300 and even 350 blows per minute, and the borer makes one entire turn for 22 blows. The machine weighs about 122 lb. avoirdupois; it costs about 22*l.* 10*s.*

Strut.—In order to furnish a *point d'appui* for the screws, U, a wooden strut, provided with an iron at its upper end, and at its lower with an adjustable screw and tripod, is firmly fixed across the level.

It will now be readily understood that the machine can be fixed in any position, and consequently holes can be bored in all directions. It takes two men to put up the machine, and one to attend to it. The other man can be boring by hand in the mean time.

Air-compressor.—At the Perseberg mines the machine is worked by compressed air. The air-compressor (see Figs. 1, 2, and 3) was designed by Professor Angström. It consists of two vertical iron barrels $15\frac{1}{4}$ in. in diameter, and

about 8 ft. high, communicating with one another at the bottom by a chamber.

The upper end of each barrel is provided with a valve-box having two valves, one opening inwards, for the admission of air, and the other outwards into the delivery-box, for the eduction of air. In one barrel a piston is made to work up and down, and in order to deliver every particle of air at each stroke, and to keep the barrels cool, a quantity of water is placed inside the pump, which at each stroke entirely fills up the valve-box, and thus expels the whole of the air from the pump. The other barrel has no piston working in it, but is also filled with water, which is caused to rise and fall as the piston goes down and up. This water also forces out all the air from the barrel and valve-box at each stroke. The piston-rod is connected to the main rod of the pumping-engine, and is provided with a cross head, from which a weight is suspended by rods. The stroke is 7 ft. Four strokes per minute furnish enough air for one boring-machine. The air must be compressed to 15 lb. or 20 lb. per square in., which corresponds to an excess pressure of 1 or $1\frac{1}{2}$ atmospheres. If such a pressure cannot be had no good results are obtained.

This air-compressor costs 80*l.*, and is specially constructed for places where the power is derived from the main rod of the pumps. It is considered that 5 or 6 horse-power would be required to drive an air-compressor. In the Perseberg adit the air-compressor is from 60 to 70 fathoms from the end; there is no regulator.

Pipes.—The air is conducted from the compressor along the level by cast-iron flange-pipes, 4 in. in diameter and 9 ft. long, with a small spigot and socket, the joints being made with tar, mixed with finely powdered brick and lime.

* Paper read before the British Association at Dundee.

The pipes cost 2s. 3d. per foot. These pipes conduct the air very nearly to the end, and the air is finally brought into the machine by some 30 ft. of india-rubber pipe, 3 in. in diameter and $\frac{3}{8}$ in. thick. It costs 2s. 3d. per foot.

Nature of the Work.—At the Perseberg mines they began driving their Oscar adit in 1856. It is intended for an exploring cross-cut, as well as for unwatering. They drove a considerable distance by hand; but in 1863 the rock became so excessively hard that no man could work in the end. In 1864 they began with one of Schumann's machines, and since that time have employed machine power. Bergström's machine has now been used about two years by them. They began the adit in *hällfint*, a rock which is considered by Swedish geologists to be a compact variety of gneiss; but in 1863 they came to that mixture of garnet, hornblende, angite, and epidote, which is excessively hard and tough. This rock has continued almost without intermission up to the present time.

The adit is carried 8 ft. high by 8 ft. wide, and they are paying 10l. per fathom for it. This includes small repairs; in fact, all cost, excepting very large repairs and the interest on the original outlay for machinery.

Five men are employed altogether, viz. two men by day for twelve hours and two by night for twelve hours, and one smith to sharpen the borers and attend to small repairs.

From March, 1865, to March, 1866, they drove at the rate of 4 in. for each working day, or about 9 ft. per month. From March, 1866, to March, 1867, they have driven 6 in. of level per day. In the former period they had to bore 44 ft. of holes per foot of adit, driven in the latter only 30 ft. 6 in. for the same distance; and as the rock has been pretty uniform, this proves that the workmen can do more work when they get thoroughly used to the machine.

In ordinary rocks, i.e. when the rock is not excessively hard, Bergmästare Sjögren calculates that they can drive at the rate of 1 ft. per day with one machine, and that on the whole, with machine labour, one can drive twice as fast as by hand, with an economy of 20 to 25 per cent. in money. In the Oscar adit, nitroglycerine is the blasting material employed, as it is considered superior to powder; but even if powder were used, Bergmästare Sjögren feels sure that great economy in time and money would be the result.

I was informed at the mines that at first it was somewhat difficult to teach the men to use the machine. In the first year they were paid by the day, in the second by the number of feet of holes they bored, and now they are paid per foot of adit driven. In the adit they fire all the holes bored in one shift at once—perhaps eight holes of about 2 ft. deep by $1\frac{1}{2}$ in. diameter. Ten to twelve borers are blunted in a 2 ft. hole, but it appears that by hand they blunt five times as many borers as they do by machine-work.

For each machine in actual use a second one must be kept in reserve, so that operations may not be suspended should any repairs be necessary.

One of Bergström's machines is at work at Langbanshyttan, some six miles from Perseberg. A cross-cut is being driven in dolomite. It is carried 8 ft. high by 8 ft. wide, at the price of 6l. per fathom, and it is driven at the rate of 1 ft. per day. Unluckily, the machine was not at work on the day I visited the mine; but it has been ascertained, during the short time the machine has been at work, that there is decided economy in time, though not much in money.

Both at Perseberg, then, and at Langbanshyttan, machine labour is more advantageous than hand labour. It is true that in both places the work is straightforward—straight cross-cuts; but there are many cases in our mines where similar work has to be performed, and by-and-by the same machine will be employed in Sweden for sinking shafts. The advantages of Bergström's machine are its lightness, simplicity, and cheapness. It is true that the feed is not automatic; but where a man must always be on the spot, he may just as well feed the machine forward by hand as the hole is deepened. By omitting the part necessary for an automatic feed, the machine is rendered less complicated.

In conclusion, I must express my great obligations to Bergmästare Sjögren, of Philipstad, the Messrs. Bergström, of Perseberg, and Mr. Ekman, of Langbanshyttan, for their kind attention to me whilst endeavouring to learn all I could about the perforator; and I have especially to thank Mr. Sjögren for many of the details in this account of Bergström's machine.

VALUABLE INFORMATION.—We learn from *The Engineer*, and we print *verbatim*, vide page 225 of the last number, that "The languages of a people so low in the scale of humanity as the Australians, incapable of reckoning beyond quality, is found to be not only skilfully but even completely constructed." And again, "It is estimated that about 165 millions of human beings travel by rail in the United Kingdom of Great Britain and Ireland in the course of a year." Inasmuch as there are not one-fifth this number of "human beings" in the United Kingdom, how is it that so many travel by rail? A single human being may be properly counted as a passenger every time he rides upon a railway, but a hundred rides will not make a hundred human beings of him.

THE LAIRDS.—Messrs. Laird, of Birkenhead, have now on hand the iron-clad turret-ship Captain, 4272 tons and 900 horse power; a composite gunboat for her Majesty's Government; two iron-clad turret monitors, of about 1600 tons burthen and 140 horse power; an iron-clad ram, of 1320 tons and 350 horse power; and two paddle-wheel steamers of about 600 tons; while a small fleet of twelve iron screw launches has just been completed.

THE BARROW DOCKS.

BARROW-IN-FURNESS is now a town of 20,000 inhabitants. Its situation on the seacoast, opposite to the Isle of Man, and only 46 miles distant from Douglas, 115 miles from Belfast, and 127 miles from Dublin, make it a place which may justly aspire to a future important general traffic, while its position in the centre of the hematite ore district, and its railway connexion with the Cleveland district (121 miles to Middlesboro') and with the Durham coal-fields (123 miles), give to this place an extraordinary facility for the exchange of minerals and other raw materials with these localities. The shortest road from Barrow to Hull, by Skipton and Leeds, is 147 miles; and at about half that distance, in another direction, lies the Lancashire coal-field, with its important ironworks at Kirkless Hall, drawing its supply of ore from the Barrow district, and sending coal to Barrow in return. By its geographical position, Barrow-in-Furness appears destined to become one of the most important sea-ports of the future, and the provision of the best dock accommodation required for a first-class mercantile harbour has therefore been felt as a necessity for some time past, a necessity for fulfilling which nature has supplied many advantages. The site of the town is separated by a channel from a small island, called Old Barrow Island, which forms the extreme point of the coast against the Walney Channel at its narrowest part, opposite the church on the Isle of Walney. This channel between the town of Barrow and Old Barrow Island affords a dock accommodation of 105 acres in area, and it has been made use of for the construction of the new docks made by the Furness Railway Company, and opened yesterday. We have given an engraving, on page 260, of the general plan of the new docks, the first of which, called Devonshire Dock, with an area of 30 acres and a stone quay of 2500 ft. in length, is the only one now completed, while the second basin, Buccleuch Dock, has been finished only as far as the stone quay on one side is concerned, and has been used for the accommodation of traffic while the Devonshire dock was in course of construction. The engineers of the Barrow docks are Messrs. McClean and Stileman, of 23, Great George-street, Westminster, the contractors are Messrs. Brassey and Field, the contract having been let in the year 1864. The docks comprise $1\frac{1}{2}$ miles in length of stone quays, and wharves of an area of 100 acres in extent. The Devonshire Dock has its entrance from Piel harbour, near the south end of Walney Island; but it is proposed at some future time to make a second entrance at the north of Walney. The present entrance at Piel harbour has five fathoms of water, and a low-water railway pier was erected by the Furness Railway Company at that place some time ago. The entrance of the Devonshire Dock is 60 ft. wide; the water level maintained in the dock is 25 ft. above the dock sill, the tide outside varying from $2\frac{1}{2}$ ft., spring tide to 18 ft. neap tide. The outer or entrance dock is closed by gates in the usual way, while the entrance of the dock itself is closed by a caisson placed across the entrance, and held by a groove in the masonry on both sides. The caisson, when filled with water to the higher water level, remains standing upon the dock sill, and closes the passage; but when water is allowed to escape from the caisson, so as to fall to the lower level, the caisson floats, and can be drawn to one side so as to clear the passage. There is therefore no pump nor other machinery required for working the caisson. The road passage across the dock entrance is maintained by an iron drawbridge worked by hydraulic machinery. This, as well as a large number of fine hydraulic cranes and capstans, is the construction and make of the Elswick Works, Sir W. G. Armstrong and Company. The whole hydraulic machinery is worked by a pair of horizontal engines of sixty horse power. The pumps are placed behind the steam cylinders, between the latter and the fly-wheel shaft, and are worked direct from the piston-rods of the steam cylinders. They work an accumulator in the usual way. A large warehouse four stories high, with a total floor area of 17,000 square yards, stands upon the quay of the Devonshire Dock. It really consists of two separate warehouses, having a covered passage of about 50 ft. in width between them. Hydraulic lifts and cranes are about to be erected in this warehouse, so as to make it ready for service very shortly. Outside of this are some of Chaplin's patent steam cranes, employed during the construction of these docks, and at present in full work. The sub-contractors for the dock-gates, caissons, and some other fittings are Messrs. Ennerson and Murgatroyd. The whole area of Old Barrow Island is the property of the Furness Railway Company, and is intended for private shipbuilding

yards, timber yards, and other works for which this locality is suited. There are railway sidings constructed to all parts of the grounds, the total extent of which is 230 acres. Railway sidings are also laid on the quays, so as to bring the wagons alongside the ships. On Hawes Point, the S.E. point of Walney Island, is a stone lighthouse, exhibiting a brilliant revolving light at 70 ft. above the level of high water. The light revolves and appears full at intervals of one minute. It may be seen from all points seaward between N.N.W. and E., and in clear weather between four and five leagues off. The depth of water over Piel bar at half tide is 20 ft. The present shipping trade at Barrow is principally in ironstone, coal, pig iron, and timber, but it is expected to gain both in extent and in variety with the improved dock accommodation now provided at that port.

THE PRESENT STATE OF THE MANUFACTURE OF IRON IN BRITAIN.*

By MR. I. LOWTHIAN BELL.

MR. BELL began by observing that the object of such exhibitions as that which now occupies so large a share of public attention at Paris being to compare the results of human industry, it is not surprising that we have been favoured with many expressions of opinion on the relative merits of manufacturing science, as manifested in individuals as well as in nations. These opinions are necessarily founded upon the information conveyed by the specimens of workmanship exposed for inspection, and therein, it is to be feared, is involved more or less of a serious fallacy. No one of any practical experience attaches the slightest difficulty or skill to a manufacturing chemist being able to exhibit any of his usual products in a state of great purity, provided he pays a little additional care in their preparation, and is regardless of the expense incurred in this exceptional mode of treatment. In like manner the ironmaster, by selecting very pure ore and pure coke, may run from his furnaces an unusually fine specimen of pig iron, which being puddled by his best men, hammered and rolled any number of times, gives, as it cannot fail to do, a sample of iron of great excellence. If the question were asked, do the articles we have the opportunity of examining upon such occasions convey in every case a correct idea of the average quality of the goods manufactured by, and sold at the current rates of, the exhibitor, it is much to be apprehended that such would not be found to be the fact. The Industrial Exhibition at Paris has afforded an occasion for the ironmasters, engineers, and practical chemists of the United Kingdom being told, on the authority of very influential names, and of very intimate acquaintance with the subject, that while foreign nations have in recent times been making wonderful advances in manufacturing science, little progress has been effected in this country. It will probably be beyond the power of any one individual to speak with a proper degree of confidence, from personal knowledge, on all the questions embraced in the general charge against our national industry. This paper will be confined to an attempt to institute a comparison between our position and that of our neighbours in the treatment of the ores of iron and their products. This subject is selected because it is one to which the most pointed allusion has been made, and because in it any deficiency on our part would be the least excusable, seeing that nature has provided us with advantages which ought to afford the means of our competing with those nations who, by their superior intelligence and energy, are said to threaten us most. If cost of production has to form no element in the calculation, it is clear results might be obtained which would lead to very erroneous conclusions in any comparative estimate. It is equally evident that any inherent excellence in his ores of iron would confer upon the smelter the power of producing a superior quality of metal, in doing which, little, if anything, may be due to skill in manipulation. These circumstances are referred to merely to remind you of the difficulty in pronouncing, with certainty, upon a question where, in drawing a parallel, so many allowances have to be made. For the present, however, these disturbing influences will be disregarded, and attention only directed to the information conveyed by the numerous specimens of the metal to be seen at the Champ de Mars, and which by many have been assumed to proclaim our inferiority as manufacturers of iron. No one who gives himself the trouble to study this department of the International Exhibition at Paris can be otherwise than impressed with the pains the French makers have taken, not only to afford proofs of the quality of their produce by ingenious devices in showing fracture and tests resistance, but also by a great number of sections of iron which, from thinness and distribution of material, or great length, or with all these conditions combined, prove at once the chemical excellence of the metal, and the perfection of the machinery used in its mechanical preparation. After giving the most ample margin to the French, who in their own country would wish to do it all honour, and probably would possess some superior facilities in securing the necessary space for the display of their manufactures, an Englishman cannot but feel disappointed at the attempts, as exhibitors, made by some of our ironmasters, who have aspired to represent

* Paper read before the British Association, at Dundee.

their own nation; indeed, nothing can excuse the careless indifference of one or two who have intruded slovenly heaps of raw materials, intermingled with pieces of rusty iron, upon an occasion which may be looked upon as a state ceremonial of industry. The practical man, however, notwithstanding these disadvantages, has there material and opportunity enough to enable him to pronounce an opinion with sufficient precision on the question of quality of the samples submitted for examination. I have myself carefully and repeatedly studied all the great divisions of this important branch of metallurgical industry at Paris. I have done so alone and in company with English and French engineers, iron shipbuilders, and ironmasters, both British and foreign, including men of the greatest experience and knowledge of the subject, and supported by their concurrent testimony, I unhesitatingly advance the opinion that no evidence whatever is to be found there that this country occupies a position less conspicuous for excellence of its produce than that of other nations. Of course it is not pretended that in such a competition the 4,500,000 tons of British-made iron have to be brought into comparison with those 800,000 tons or 400,000 tons of the metal which it requires the collective power of every European nation to smelt from the purest and rarest known ores and charcoal, and which cannot be made or sold at much under double the price of our most esteemed brands. It is of importance, in an inquiry like the present, to bestow especial attention to what may be considered the purely mechanical treatment of iron, to that treatment by which it is obtained in the various forms known in commerce. Those sections of bars which present mechanical difficulties in rolling have those difficulties greatly increased by the presence of certain chemically combined impurities. A good skin, as it is called, and unbroken edges, particularly in some forms, may be accepted as a fair indication of quality of iron as well as of excellence of machinery employed. Judged by this standard, the French, as well as some other nations, have every reason to congratulate themselves on the state of iron manufacturing science in their respective countries, as evinced by some of the really marvellous pieces of iron they exhibit. One firm, for example, has sent solid rolled bars of double T iron 27 in., and others 83 in. deep by 30 ft. and 40 ft. long, each bar in both cases weighing 46 cwt.; but the greatest *chef-d'œuvre* in this way is a girder of the same form as the preceding, from the works of Chatillon and Commentry, 43 in. deep, with flanges 11½ in. wide and a web of 1½ in. in thickness. This last achievement has not so far met with any practical application, but it is of value in showing engineers what can be done, and that when occasion requires it they have it within their power to obtain perfectly solid masses of wrought iron of these large dimensions; at the same time, it may be questioned whether, looking at the lengths which generally accompany the use of iron of such sectional strength, it will not be found more economical to construct the girder by rivetting plates or bars and angle iron together. It should be stated that the Butterley Iron Company have for some time past rolled iron of this description, in a somewhat different way, which they charge 40s. a ton less than the general quotations. Plates of iron, too, are exhibited, rolled so as to require no shearing along the sides, as has hitherto been practised. In many instances, such, for example, as in the construction of tanks, bridges, and other articles, where a slight deviation from perfect soundness on the edge is immaterial, this mode of manufacture offers advantages by reason of the economy it effects. Against these proofs of efficiency of mill machinery and skill in its use may be placed the armour plate, weighing 11½ tons, from the works of Messrs. Brown and Company, of Sheffield, who have rolled plates of this kind weighing 25 tons each. There are, it is true, pieces of forged iron in the Exhibition heavier than even this, but the difficulty our manufacturers had to encounter in transshipment would offer impediments in carriage not experienced by Continental nations in sending objects to Paris, where size alone formed the test of merit. Any one having any recollection of the state of metallurgical science in the time of the 1851 Exhibition in London will detect, in the means afforded him at the Champ de Mars, a wonderful change in the manufacture of steel. This is apparent in the number and dimensions of the objects now produced in that material. More recently even than sixteen years ago the use of steel might also be said to have been confined to small articles of cutlery; to-day railway wheels, axles, heavy working parts of steam-engines, and even railway bars, absorb immense quantities of this form of iron. The manufacturers of other nations, in this substance, as in iron, maintain their superiority as exhibitors, and probably at the head of all will be placed the name of Krupp, of Essen, from whose establishment has proceeded, among other admirable specimens of workmanship, the gigantic mass of cast steel in the shape of a piece of ordnance weighing upwards of 50 tons. We shall endeavour to discover presently to whose energy and inventive genius the credit is most due of having led the way in dealing with iron and steel of such extraordinary dimensions as are to met with in our own days, and at the same time seek to establish what is the true position of different nations which have laboured in raising this remarkable branch of industry to its present colossal proportions. In attempting this, the only mode of procedure is by reference to the history of the past, which shall be done in terms as brief as is consistent with clearness; at the same time it is

obvious that in a manufacture involving both mechanical and chemical appliances, upon this occasion as well as hereafter, we shall be compelled to exceed those limits which ought to be observed in any section set apart for discussing a particular science. Some indulgence also must be extended to any minor inaccuracies in any endeavour to trace the progress of an art which owes improvements in its details to different individuals, whose position in questions of priority it is sometimes so difficult to determine. It is not so very long ago that the attention of the Government of this country was called to the fact that the iron furnaces of that day threatened to place the kingdom in a position of considerable difficulty from the rapid manner in which they were consuming the forests of certain districts, and indeed for a time, under the pressure of circumstances which arose, the make of iron, insignificant as it was, suffered considerable diminution. From this state of things the nation was relieved by the Darbys, in the midland counties, succeeding during the last century, in applying, upon a practical scale, Dud Dudley's discovery of the capabilities of mineral fuel being employed as a substitute for charcoal in the blast furnace. It is quite impossible to overrate the importance of this event in the history of the iron trade, because even in localities where timber is of little value the rapid manner in which even a limited make consumes the forests near the smelting establishment causes charcoal quickly to rise in price, owing to the increasing cost of carriage. This is easily perceived when it is remembered that in Styria and Carinthia something like 25 square miles of wood are stated as being required to supply the wants of each furnace, and that, in consequence, the best charcoal, owing to the distance it has to be conveyed, often costs close on 50s. to 60s. per ton before it reaches the ironworks. Simple as this substitution of pit coal for charred wood appears, it was a long time before the difficulties attending its introduction were overcome, and the prejudice against its use set aside—Dudley himself being in his grave long before the accomplishment of either. This cardinal improvement in iron-smelting brings us, without further change, down to about the beginning of the present century, when our blast furnaces were running thirty or forty tons a week, and that portion of their produce, which had to be converted into bar iron, was obtained in this condition by means of the old "hearth," a most laborious, costly, and wasteful mode of treatment. In it charcoal was frequently the fuel still employed, and the small tilt hammer the only means possessed for reducing the malleable product to the state of the bar. This was our position when our countryman Cort effected an entire revolution in the character of the operations carried on in our forges by the invention of the rolling-mill and the puddling furnace. The latter contrivance was subsequently greatly improved by Rogers, abandoning the old sand bottoms used by its original designer, and by substituting iron plates protected by iron slag. Fostered by the discoveries of Dudley and of Cort, the use of iron extended in every direction, rendering every subsequent improvement of increased importance, by reason of the enlarged field provided for its exercise. It was thus a fortunate circumstance that the labours of James Watt, in connexion with the steam-engine, placed in the hands of the iron manufacturer the means of driving his new machinery, for which the water-wheels of our old forges in many instances were totally inadequate. If the other changes which have been introduced in later times into our iron processes are to be considered as modifications and improvements only of what Dudley and Cort effected many years ago, that of Neilson, in applying heated air to the blast furnace, has been followed by results of such magnitude as to rank in importance with discoveries of the highest order. The effect Neilson's idea has had in reducing the consumption of fuel and the expense generally in smelting the ores of iron is too familiar to all to require repetition here. It would appear, however, that it is only to those greater and more sudden changes that the world at large seems to attach any significance; for, judging by recent criticism on the progress of metallurgical science in this country, the fact apparently has been overlooked that the ironmasters of Durham and North Yorkshire, within the last four years, have introduced great alterations in the character of their furnaces, and have succeeded in raising the temperature of the blast they employ to a point never contemplated by Neilson himself. These progressive changes have enabled their projectors to effect a saving in coal, and an increase in produce, greater than the difference between those cold and hot blast furnaces still in common use. Our rolling-mill engineers had kept pace with the constantly increasing requirements for malleable iron, until about a dozen years ago, when the example of the Emperor of the French created a demand for an article beyond the powers of any rolls then in existence. Possibly they were never applied to, owing to the belief then prevailing that hammered slabs of metal alone would satisfy the necessary conditions attending the protection of ships of war, by means of the so-called armour plating—at all events it was by means of the steam-hammer, a French idea, it is said, originally, but indebted for its practical introduction here to Nasmyth, that we in this country, in the year 1855, manufactured the iron for two floating batteries. To Mr. G. G. Sanderson, of the Park Gate Works, we owe the idea that rolled plates, by reason of their toughness, would be found superior in resisting shot to those of hammered iron, and to him and to the owners of that establishment is due the merit of having in the same year provided a mill,

and rolled the plating for a third floating battery, built by Messrs. Palmer, on the Tyne. The correctness of Mr. Sanderson's views have been justified by subsequent experiments. Sir William Armstrong's ingenious method of building up wrought iron so as to produce ordnance, having incredible powers of penetration, has called for greatly increased thickness in armour-plating. Manufacturers of this description of iron, however, by increasing the powers of their heating furnaces, mills, and other appliances, are now able to supply our naval yards and military establishments with material still more invulnerable than that formerly deemed sufficient as a means of defence. It is this character of machinery which has enabled mill-owners here and abroad to handle such huge masses of wrought iron as have excited the admiration of all who interest themselves in such matters, and it is by means of the so-called universal mill, designed by Mr. Arrowsmith, that our friends in France are rolling their smooth-edged plates. This hasty sketch, it is hoped, an impartial account of what has been done in this country towards advancing the manufacture of iron to its present position. As soon as the occasion arose, other nations profited by the wisdom our more matured experience had acquired, and every improvement in machinery or in process found immediate imitators in each locality where the "forge Anglaise" had to be constructed.

(To be continued.)

NEGATIVE SLIP.

TO THE EDITOR OF ENGINEERING.

SIR,—I only know of one phenomenon to which the term, "negative slip," is applied, and that consists in the vessel, during each revolution of the screw, advancing a greater distance than that represented by the pitch of the screw. If you mean the same thing when you refer to "negative slip" in your review of Mr. Bourne's work on the screw propeller, I beg to observe that there is no difficulty in ascertaining the immediate cause of it.

Let a vessel of any desired size, and of fair sailing qualities, be selected, and four two-bladed screws (which I will call A, B, C, and D, respectively) be made, so that each of them can be mounted on the same screw-shaft. Let the diameter of A, B, and C be the same, and about equal to the mean draught of the vessel; for argument's sake, I will call it 16 ft. Let the pitch and the length of each blade in the direction of the axis be respectively 20 ft. and 3 ft. 9 in. for A, 12 ft. and 2 ft. 3 in. for B, and 8 ft. and 1 ft. 6 in. for C (pitchs respectively = 1½, ¾, and ½ diameter; length of each blade = ¼ pitch). Further, let D have a diameter of 12 ft. only, a pitch of 16 ft., and a length of 3 ft. Then, if the trials be made with the same draught and trim of vessel, when the sea is calm, and there is no wind nor current, it will be found that the slip of A and D is positive, and that of B and C negative, the negative slip of C being greater than that of B. And the results will be precisely the same for the same number of revolutions of the screw, and nearly the same for all velocities of it, however often and in whatever rotation the experiment may be repeated. Of course the screws A and C alone would suffice for this test, in which case the cost of the experiment would be reduced to one-half.

Should the same screws be applied to a vessel of larger size (requiring a greater force to propel it at a given speed), then the positive slip would become greater, and the negative slip less; or the latter might, possibly, disappear altogether and turn positive. On the other hand, if the screws were fitted to a vessel of smaller size (requiring a less force to propel it at a given speed), the negative slip would be increased, and the positive slip decreased. The negative slip of the screws B and C, would likewise be augmented by increasing the length of their blades.

I speak confidently upon this subject, because I am making statements in accordance with facts, which were experimentally established some twenty years ago, and have been frequently corroborated since, but which have been deliberately ignored.

That the advance of the vessel can and does exceed the pitch of the screw under the circumstances which I have pointed out proves, not that the phenomenon is mysterious, paradoxical, anomalous, and what not; but that the laws which govern the action of the screw, whether the latter be considered simply in the character of an inclined plane, or in its capacity of a propeller, are totally different from what they are supposed to be.

The term, negative slip, as generally understood, is intended to represent the case of a screw-propeller actually outstripping the vessel, in the direction of its course. It is always plainly described as implying an excess of velocity of the screw over that of the vessel. This is, in fact, its distinctive feature, that to which it owes the peculiar prominence which it has attained. As soon as this definition—which, by-the-by, no one who has the least notion of what a screw-propeller is, can seriously accept for a moment—is either modified or abandoned, the exceptional character of the phenomenon instantly vanishes. As soon as "negative slip," literally understood as I have described it, ceases to be an expression relating to an occurrence which can be strictly proved to be actually taking place, it loses all the significance with which it has been invested, and can be no further a subject for serious discussion.

As the screws which would be required for such an experiment as I have suggested, even if they had to be made on purpose, would not be lost, and as it is, moreover, quite possible that suitable "second-hand" screw-propellers could be found, some of our marine engine-makers may perhaps be induced to incur the comparatively trifling expense which a test of this kind would involve.

I am, Sir,

Your obedient Servant,

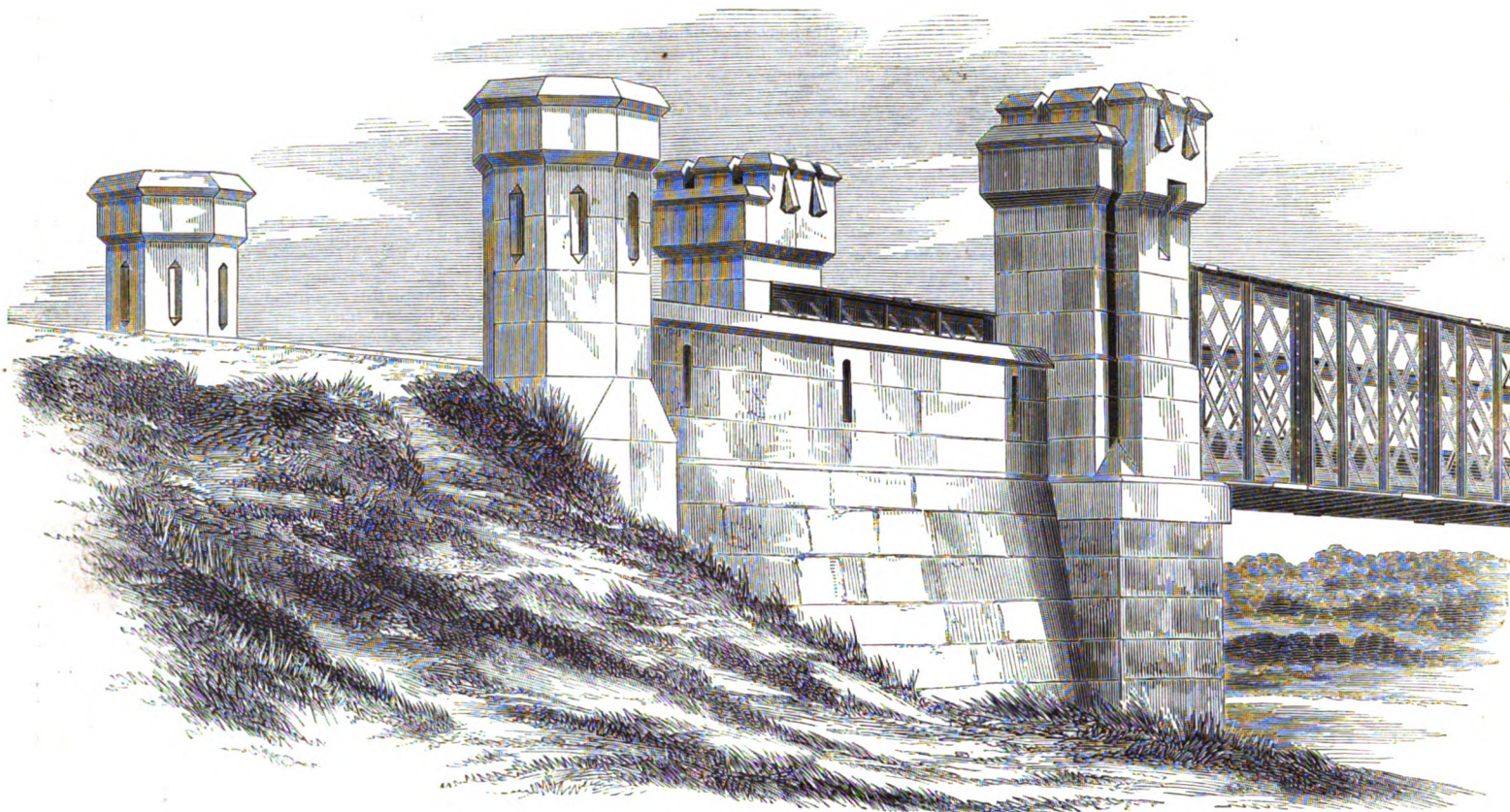
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September 14, 1867.

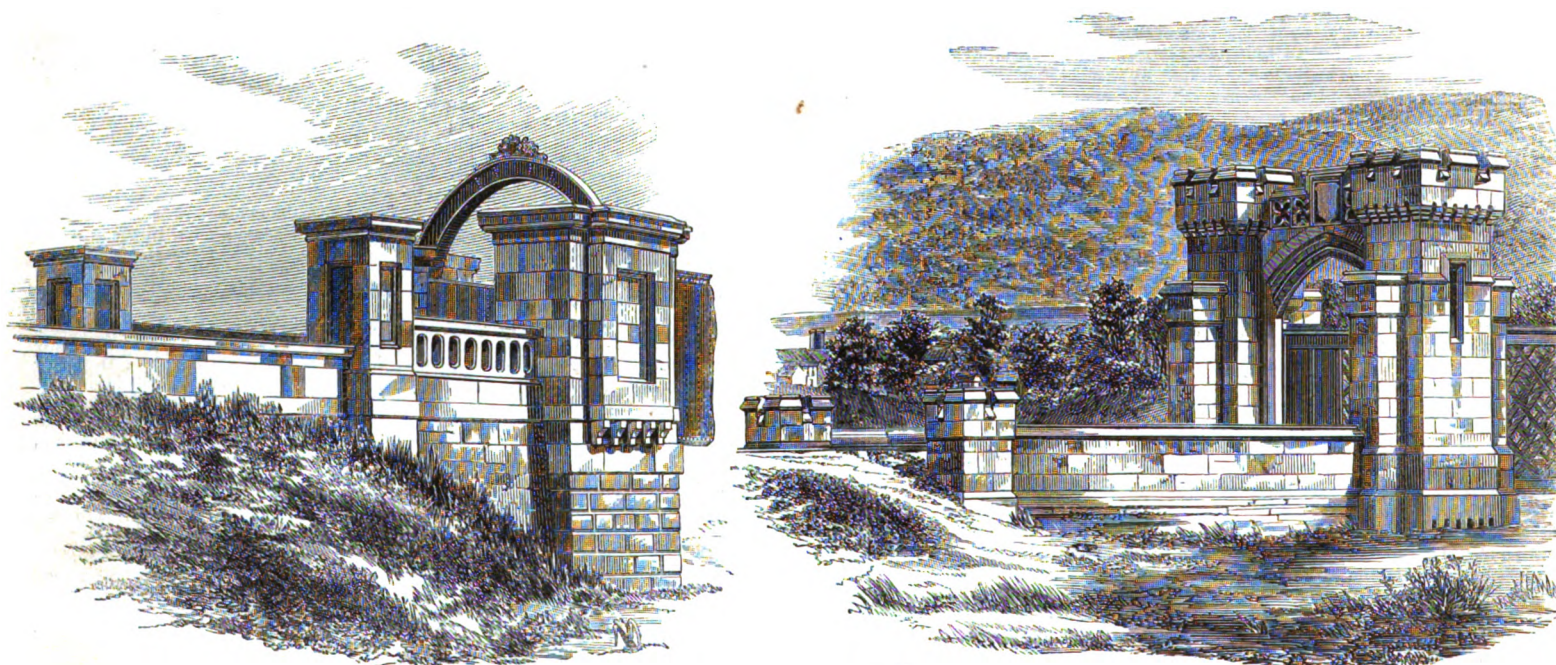
THE OAKS COLLIERY.—Very little progress in opening this colliery has been made since last week, and no bodies have been recovered.

EXAMPLES OF BRIDGE ABUTMENTS: HIGHLAND RAILWAY.

MR. JOSEPH MITCHELL, ENGINEER.



ABUTMENT OF DULNAIN VIADUCT, STRATHISPEY.



ABUTMENT OF FINDHORN VIADUCT.

ABUTMENT OF TILT VIADUCT, BLAIR-ATHOLE.

We give, above and on page 257, engravings showing some of the works on the Highland Railway, referred to in the excellent paper read before the British Association, at Dundee, by Mr. Joseph Mitchell, and published by us in our last number. The bridges and viaducts on the Highland Railway are not remarkable for the size of their spans, or for any great engineering difficulties which have arisen during their construction; but they are remarkable for the architectural skill and taste with which their details have been designed, and which render them well worthy of special notice. The various works were so fully described in Mr. Mitchell's paper that it will be unnecessary that we should say more concerning them here, and we need, therefore, only mention that we shall publish further engravings of them on an early occasion.

SMOKING LOCOMOTIVES.—Do the Great Northern engines smoke worse than those on other lines? We only know that they do smoke fearfully, and they throw a good deal of fire as well. Why is not all this, as it may be, prevented.

RAISING OF THE STEAMSHIP DRUID.—This fine ship, which sank in the river off the Tunnel Pier about a fortnight back, was successfully raised last Friday. During the previous week preparations had been made for pumping her out, and to this end the combings of the hatchway had been raised, and a couple of centrifugal pumps placed, one in the fore hold and one in the engine-room, each being driven by a portable engine. Some powerful hand pumps had also been placed aft, and all being in readiness, the attempt to raise the vessel was made yesterday week. It was soon found, however, that sufficient pumping power had not been provided, and application was then made to Mr. Roberts, of Millwall, for one of his steam pumps, having two 11½ in. cylinders. This, with one of his boilers, was taken up and got on board, and in half an hour was connected and at work. About a foot of water having been pumped out, further proceedings were postponed until Friday morning, when, as soon as the tide left, pumping began. It soon became evident that all was going on favourably, and Mr. Roberts's pump attracted particular attention, from the large quantity of grain it brought

up. When, therefore, it became necessary to put on a greater length of suction pipe, it was forced down into the cargo (oats) without a strainer, and upon the pump being again started it raised up the grain so fast that the men were brought up from filling baskets in the hold to clear it off the deck, and after a time men had to be sent down to shovel the oats down to the suction pipe. In this manner the grain in the way of the hatchway was pumped out to the depth of 12 ft., the length of suction pipe at starting being 8 ft., and at finish 15 ft., it then being within a foot of the bottom. About three-quarters of an hour after pumping commenced, the ship began to get lively, and shortly afterwards it was afloat, and as the tide rose was towed in shore, where, temporary patches being put on, she now remains to complete the discharging of her cargo.

THE MINERAL WEALTH OF JAPAN.—Mr. Gower, the British Consul at Hakodadi, refers in his report this year to the minerals which abound in the island of Yesso. It appears that there is an abundant supply of good coal, and copper and iron are also found in different forms. There are also good lead mines.

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.

The price of ENGINEERING to annual subscribers, receiving stamped copies at places three miles away from the General Post Office, is 11. 1s. 8d. If credit be given, the charge is 2s. 6d. extra, subscriptions being payable in advance.

Cheques and money orders to be made payable only to Mr. Charles Gilbert.

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Subscriptions for the ANNALES DU GENIE CIVIL are received by Mr. Charles Gilbert, the Publisher of ENGINEERING, of whom also the NOUVEAU PORTEFEUILLE DE L'INGENIEUR DES CHEMINS DE FER may be obtained, price 9l.

NOTICE.

The publisher of The Engineer, in a public announcement in that paper, untruly states that its circulation is larger than that of ENGINEERING, whereas the contrary is the case. He can know nothing of the circulation of this paper; but Mr. Colburn, as the former Editor-in-Chief of The Engineer, knows that its circulation in 1858 was but 2850, and that down to the end of 1864 it had never exceeded 5000. Even this increase, under his management, was an unusual one. That its circulation, so far from increasing since that time, has declined there is abundant reason for believing. Competing as it has done with this Journal, which has enjoyed the advantages of superior capital, superior and exclusive sources of information, and a status in the profession which The Engineer, even when under its former management, never possessed, its circulation could hardly fail to diminish, or at best to remain stationary. But we have abundant evidence in our office, much of which we are permitted to show to advertisers and others, that ENGINEERING, measured not alone by the numerical test of circulation, has largely displaced the journal formerly conducted by Mr. Colburn. It is but justice to our advertising friends that they should be made aware of this fact, and the written proofs, containing many names of the highest eminence, but of which we can make no public use, are in many, although not in all, cases open to their private inspection in our publishing office.

The circulation of ENGINEERING is now double that enjoyed by The Engineer in its best days, and probably three times its circulation at the present moment, and the singular and exceptional value of the former to advertisers may be judged from the following extract of a letter from one of the largest and most successful advertising firms in the kingdom—a letter which is open to the inspection of any one who desires to see it: "We are happy to inform you that we have just received an order from the Costa Rica Government for goods to the value of £—, —, and in their order their agents expressly refer to our advertisement in ENGINEERING. We may also state that the India Office last year gave us orders to the value of £—, —, and their inspecting engineer, an officer in the Royal Engineers, expressly told us our advertisement in ENGINEERING first brought their attention to us. We might mention many instances, and we may state as a fact that we have traced more orders to our advertisement in ENGINEERING than to all the other papers put together."

ENGINEERING.

FRIDAY, SEPTEMBER 20, 1867.

• THE PROFESSION.

THE true engineer is so imbued with the faith in the greatness and abstract goodness of his profession, that he can hardly believe there can be too many engineers. The essence of all engineering is *thought*, and that of the most valuable kind, not only when regarded in its material aspect, but valuable also when considered in relation to its beneficent and Christianising tendencies. Half the world, possibly nine-tenths, still believe, and will always believe, in mental ap-

prenticeship, and in the routine of mental impartation; in other words, that a youngster of average dullness can, by pupilage, become a good routine engineer, and thus gain a living for himself, as the be-all and the end-all of his profession. As well might we apprentice a youth to Tennyson that he might become a poet, or to Gustave Doré that he might become a painter of the grand and the terrible. Engineering has its thousand formulæ, and these any studious mind, of a practical turn, may master; but the mastery of all of them will not make the engineer, in the higher sense of the term. With their knowledge alone he may become a private, or even a non-commissioned officer, but never a captain, still less a general, in the great army of engineers. True, as in all other armies, engineering must have its rank and file, and there will be men who can only know and can only do what they are told, and whose whole idea of duty lies in obedience to command, and we would speak with all respect of these men. The engineer whose own mind is all alive with origination and expedients, and who can gain a given end by a dozen different roads, must always respect his faithful assistant, who, with an undying devotion to duty, will scrupulously carry out his orders, working day by day, and, if need be, night after night, copying, filling in details, tracing, taking out quantities, measuring up work, calculating strains and resistances, performing, in short, all the routine of design, and that contentedly at from 30s. to three guineas a week, and who, even with a wife and a little constellation of children, subsists honestly and decently upon his salary, and has generally, if not always, something between him and want. How much the great engineers owe to the conscientious care, the persistent industry, and critical and accurate habits of thought of their assistants can never be fully known; but those who are deep in the experience of our profession know how truly this assistance is indispensable to the success of every great master of our art. To him such assistants—and there are many yet, after all that is said and all that must be admitted of professional degeneration—are what brave and faithful soldiers of the line are to the great general, the victories of whose army are individualised in his own name. None who realise the triumphs of British engineering should forget how much of the brunt and hard drudgery that won them has been borne by the engineering assistants of this kingdom; many of them noble fellows, recruited both from this side and the other side of the border, and from the sister isle. It is these poor fellows, just now, who, while their "governors" are racking their wits to discern the direction of future investment, when new companies will float, and what new phase of engineering will pay, are wondering whether the clouds will ever lift, and whether the great offices in Westminster will ever again be alive with the cheery hum of paying work. The assistant has his own thoughts, and he knows full well that all our modern periodical accessions of national prosperity have been based upon the development of some great material discovery, and that we are not just now in want of new railways, new harbours, new steamships, nor monumental engineering of the grander sort. Even the bolder and original flights of engineering have become tame. There are plenty now who can float a railway over a fathomless bog, or tunnel two miles under a lake, or span a chasm half a mile wide at a single leap, or unwater a mine drowned to its uttermost depths, or take a railway and its rolling stock up an Alpine steep, or put in a pier in a hundred feet of water and mud, or stop a rushing torrent where a sluice has burst in treacherous ground, or perform any one of the hundred miracles which have given such lustre to our profession. We would be glad indeed could we foresee the direction and results of the next great campaign of engineering in the unknown. For the sake of the thousands of our rank and file, who have chosen our profession for life, and who have before now taken its overwork in honest earnestness, incurring all the risks of premature decay, of breaking down long before the allotted time of nature, we would, if we could, point out the precise direction from which they may expect fresh and profitable employment; for the heart always jumps with the nimble and prosperous hand. We can only say, broadly, that great future prosperity must be looked for in fresh discovery and invention, and in this British genius has been too long fertile to allow us to doubt that new and still unexpected sources of wealth will be found. As it has been before, so it will be in time to come, that the improbable and unlikely of to-day, or rather that which but few far-reaching minds can recognise as likely or probable, will nevertheless give the greatest return in general prosperity.

THE SMOKE NUISANCE.

THE high priests of science have been discoursing learnedly at Dundee, before the British Association, and coal has come in for its share of discussion. Ever since the note of alarm over our diminishing coal-beds was struck by Sir William Armstrong, at Newcastle, a few years ago, the last reverberation of which has not yet died out, our *savans* have been investigating the question of coal supply, and our legislature likewise has had a hand in it. In the Sanitary Act of 1866, smoke-consuming clauses were provided, by which local authorities were empowered to take measures to suppress the nuisance of smoke. The act had its origin from a double motive—the desire to purify the atmosphere of towns, and the desire to diminish the waste of fuel, it having been logically argued that smoke being unconsumed fuel, its prevention or consumption would lead to the economy of fuel. Professor Rankine, at Dundee, has told us that we lose from 20 to 40 per cent. of coal in applying it for the generation of steam. Twelve months were allowed to transpire before the law was to come into operation, which took place last month, so as to give time to manufacturers to adapt their furnaces to fulfil the provisions of the law. The time thus allowed was ample, and in many towns the local authorities, with a view to give practical effect to the law, have appointed smoke-suppression committees and salaried inspectors. It is almost a satire on the science of the age that smoke continues to roll lugubriously from our manufacturing chimneys; that our railway locomotives are annually distressing the country with a heavier discharge of smoke from their funnels, until railway trains have come to resemble runaway limekilns, defacing the beauty of the fields, blackening the carriages, and griming the passengers with dust and smoke. This wasteful nuisance is perpetrated in the name of "economy," but it is fast becoming intolerable, and who that has entered a principal station does not know the deafening roar of the steam-jets, or "jimmies" in the funnels, turned on to diminish or "paint" the smoke, whilst they cause a dangerous and wasteful generation of steam, which necessarily blows off and adds to the din. In like manner, our steamers delight to blow a cloud athwart the sky, trailing the black vapour in their wake for miles. The same freak is performed daily at London-bridge, where the steam-ships on the eastern side, taking the benefit of an old Act, pour out volumes of smoke like so many marine volcanoes, often to the great discomfort of persons traversing the bridge. A smokeless London, or a smokeless Manchester, or Bradford, or Halifax, is a dream which we should like to see realised, as in fact it can be, and we wish that the British Association had turned its attention to such a problem. But it has been busy with many other things—the topography of Jerusalem, the disease among the grouse, the geography of Central Africa, the antiquity of man, the origin of civilisation, pic-nics, and the utilisation of male convicts.

Since Charles Wye Williams prosecuted and published his investigations into the combustion of coal, and gave us the benefit of his practical knowledge, there is no excuse for not knowing what is required to be done to prevent smoke. That great and persistent apostle's first, second, and third rules were mix, mix, mix the air and the combustible gases: thus only will you effect complete combustion. Everything depends upon a thorough and timeous mixture. Simple though this dictum is, we are far from realising the force of it in our usual practice. Generally speaking, we do not mix the air and the gases, and when we do we don't do it at the right place. The mixture must be done in the furnace, immediately over the fire. Mr. Williams, moreover, has clearly shown that a supply of air specially to burn the smoke-making gases, must be introduced from above the fire—that is to say, not through the grate—for we cannot hope to avoid smoke by depending on the admission of air through the fuel on the grate in the green state of the fire. If it be asked where and how the additional supply of air ought to be admitted, theory and practice alike concur in the answer that the proper point for its admission is in front of the fire, at the doorway, where the supply can be conveniently controlled. To accomplish the two ends—the avoidance of smoke with the economy of fuel—the aim of the fireman must ever be to maintain a uniform and active rate of combustion; admit as much air during the critical periods as is sufficient for the complete combustion of the gases, and no more; and to do this he must not place much reliance on his dampers; these are to be kept open as far as necessary to maintain the requisite draught and no further; and he must finally depend, in regulating the supply of

steam, on his management of the fires. It is not forgotten that the conditions imply more energy, more intelligence, more skill and perseverance, than firemen ordinarily possess; altogether more than they are usually expected to possess and their duties to demand. But the present purpose is not to bring down the art to the level of "the meanest capacity," but to indicate the conditions that it is necessary and sufficient to fulfil, in order that the smoke nuisance may cease.

As coke and anthracite coal give no smoke during combustion, although composed of the very matter of smoke—of almost pure carbon—it follows, remarkably, that the property of smoke-making is connected with the presence of hydrogen in the coal, and that this gas, the most perfect type of gaseity which chemistry has discovered, is really the cause of all those difficulties which have stood between us and the coveted desideratum of a smokeless furnace. It is in the transformation of the heavy hydro-carbons, given off from coal freshly stoked in the furnace, into gases of more and more permanent forms, by precipitating some portion of their carbon, that the great body of smoke is produced; for, in ordinary circumstances, most of the precipitate of carbon is of course carried off uncombined in the general current passing through the furnace. This invariably and necessarily takes place by the usual slovenly mode of hand-firing, which consists of shovelling a bin of coal into the furnace, and after it is discovered that the steam has gone down, stoking the distilling mass, to get it up again. "It is not to be expected," said the late Mr. W. M. Buchanan, writing in 1852, "that firemen will improve under a system which offers little or no inducement to excel; it is necessary that there be a stimulus, a compelling necessity to strengthen and sustain the sense of duty; and this implies a knowledge of the subject and an energy of purpose somewhere else, and where presently the whole tone of expression is that of hopeless apathy to the whole question. Much of this apathetic feeling has, no doubt, been engendered by the repeated disappointments hitherto experienced at almost every factory of note, for few have escaped entirely the tempting promises of some one or other of the smoke-burning doctors. The feeling has at length passed into the public mind; and while everybody admits that clouds of smoke, condensed into showers of blacks, are none of the most benign of meteorological phenomena, there are few to whom the subject may be mentioned who will not add, with a significant shake of the head, that 'the evil is to be borne with; the thing is at it is, and cannot be better. If further urged, reference is made to the thousand-and-one schemes of smoke-burning that have been tried and failed.'" This was written fifteen years ago, and it very fairly represented public opinion until within the last few years, when Lord Palmerston, that sagacious practitioner, initiated a crusade against the foul-mouthed chimneys of the metropolis, and got an Act passed for the suppression, in this quarter at least, of the universal nuisance.

Encouraged by the success of the decided measures taken to carry out the provisions of the Metropolitan Act, under the intelligent inspection and energetic action of the inspecting engineer appointed by Government, which has resulted in such a purification of the atmosphere that a clean shirt, which formerly lasted only a day, now lasts four days in good condition, Parliament has wisely followed up its beneficial action in the metropolis by the Act of 1866, already referred to, applicable to the whole of the United Kingdom.

Of the schemes for smoke-burning, to which Mr. Buchanan made reference—most of them patented—it is to be borne in mind that he wrote of what was known fifteen years ago; and it would be unjust to ignore the labours of inventors during that interval. It would also be unjust to the memory of Mr. C. W. Williams, notwithstanding his incessant blasts of his own trumpet while he lived, did we not recognise in all its force the great practical fact that was drilled into the heads of all who attentively read his works, or listened to him in conversation, that in order to consume—we beg his pardon—to "prevent," smoke, air must be supplied above the fuel in sufficient quantity, and thoroughly mixed with the smoke, there and then. The practical difficulty was to effect this mixture. Mr. Buchanan was evidently cognisant of the difficulty when, contrary to much authority, he condemned the languid circulation of the air in the furnace as a condition of perfect combustion, and advocated a brisk draught, as the one practical condition necessary and sufficient for the prevention of

smoke. "The effect of draught," he said, "is virtually, in fact, to increase the combining power of the saturating constituent—the oxygen of the air—not only by continually bringing fresh portions of it into contiguity with the body of combustible matter, but further by impelling it into contact with the combustible before the air has absorbed heat and expanded."* Mr. C. W. Williams, writing in 1861, appears to have formed a like opinion of the necessity for an active draught. He says "that in many cases steam-boilers were practically deficient in draught for the combustion of the gas in the furnace-chamber, although an adequate number of orifices had been furnished." . . . "The deficiency in the supply of air was ascertained to be caused either by the absence of a sufficient natural draught, or the generation of so large a volume of gas in the furnaces by reason of their great length and consequent great superficial area, as to be far in excess of what could be supplied by the perforated plates by the natural draught alone. The only alternatives then were either to shorten the length of the grate area, or increase the draught by mechanical means."†

Within the scope of an article of this sort, one cannot pretend to notice all that has been tried for smoke prevention. We must content ourselves, for the present, by saying that an artificial stimulant is now, by almost universal consent, acknowledged to be necessary for securing in practice the satisfactory combustion of a smoke-making fuel. Special trials and experiments we know have been made, and made successfully, to show that such fuel may be consumed without smoke, independently of the aid of stimulants to draught; but there is no room for questioning that when that has been done regularly, and for a length of time, it has been effected by the agency of extra careful and intelligent stoking, in conjunction with favourable proportions of boiler and, above all, plenty of boiler-power. Mr. Fairbairn told us long ago that forcing the fire is the gangrene that infests the whole system of boiler-service, boiler-power in general having been barely sufficient. But since he wrote this, boiler-service has, no doubt, been improved.

In fine, if we are to take boilers and stokers as we find them, there can be no question that if smoke is to be generally banished from the face of the country, furnaces must be worked with a brisk draught induced or accelerated by mechanical means. Such means as have come under our observation for accelerating the draught in ordinary furnaces we shall consider in another article.

The foregoing observations, it should be remarked, have reference generally to all sorts of furnaces, but more especially to those of ordinary stationary and marine boilers. The fireboxes of locomotives and (now, from their importance, we must add) portable engines, are a class by themselves, to which we shall return.

THE LORD WARREN.

THE armour-plated screw steam-ship Lord Warden was tested, on her deep draught, at the measured mile, outside Plymouth breakwater, on Friday last. This ship is of 4080 tons burden, and on Friday's trial had a displacement of 7839 tons, and a midship section of 1280 square feet. The draught of water was several inches more than intended, on account of the ship having been finally mounted with 9 ton and 12 ton guns, instead of the lighter armament originally contemplated. The draught forward was 23 ft. 7 in., and aft 27 ft. 9 in.

The engines of the Lord Warden are by Messrs. Maudslay, Sons, and Field. They have three cylinders, 91 in. in diameter and 4 ft. 6 in. stroke, working cranks at 120° apart. They are rated nominally as of 1000 horse power. Their boilers have 700 square feet of grate area and 19,000 square feet of total heating surface, and they are provided with superheaters. The engines drive a four-bladed screw of increasing pitch, 22 ft. 9 in. in diameter and 21 ft. 4½ in. mean pitch. On the trial, the safety-valves were loaded to 31½ lb., the pressure in the boilers being 28.1 lb. on the full power, and 30 lb. on the half-power trial. On the full trial 63,327 revolutions were made per minute, equal to 570 ft. of piston. The engines worked to 6705 indicated horse power, or to 6.7 times their nominal power, and drove the ship, as a mean of six runs, at 13.496 knots, or very nearly 13½ knots an hour. This performance does not, however, give high coefficients by either formula.

By the midship-section formula, $\frac{S^3 \times MS^3}{I.H.P.}$, the co-efficient at full speed was 469.26; and by the displacement formula, $\frac{S^3 \times D^3}{I.H.P.}$, the co-efficient was 144.66.

At half power 4080 indicated horse power was exerted; the speed was 11.777 knots, and the respective co-efficients were 512.47 and 157.9.

The Lord Warden had a light-draught trial, last year, with 7024 tons displacement, 1162 square feet of midship section, and 5038 horse power. She made 13.139 knots, and gave co-efficients of 523.1 and 165.1 respectively. She also had a deep-draught trial last month, with 7429 tons displacement, 1233 square feet of immersed midship section, and 6395 horse power. She went at 13.439 knots, and gave co-efficients, respectively, of 468 and 144.5. At half-boiler power, with 3346 horse power, she made 11.201 knots, and gave co-efficients of 517.5 and 159.8.

AGRICULTURE IN MADRAS.

THE use of agricultural implements appears to be making some progress in the Madras presidency, and from a letter addressed by Dr. Hunter, superintendent of the School of Arts, to the superintending engineer in the Punjab, we have gathered the following very interesting particulars.

Considerable success, we are assured, has attended the employment of European agricultural implements lately received in that presidency from England; and of these the most useful appear to have been Howard's iron ploughs, which are now being extensively manufactured at the gun-carriage manufactory, mint, and public works department workshops. One of the winnowing-machines is in great favour with the natives, but by whom manufactured does not appear; so are the large and small scythes. The natives soon learn to handle these, and they become very dexterous in the use of the plough and scythe; the light steel hoes and rakes they likewise soon get accustomed to, but the spade and steel fork do not seem to suit the hard soils of Madras. The coffee-planters and cultivators of potatoes and vegetables on the hill stations get the natives to use the fork freely; but General Outley's mamooties, it is stated, beat all the European spades for efficiency and rapidity of digging.

The horse-drill, the hand-sower, and the harrow-sower are gradually getting into favour, because they resemble some of the native dibbling and sowing machines, and are more durable and efficient from being of a larger size and light. Several gentlemen got chaff-cutting machines made at the Mint, and find them of use for feeding horses and cattle; several have also got lawn-movers from Europe, which have been found to answer well for croquet-grounds and neat plots of grass. The horse mowing-machine has been found very serviceable at the Government Farm and the Remount Depot at Oosoor, and there is no difficulty in introducing the use of any of the above machines where one can command skilled European and native workmen who pull well together. Colonel Thompson, it appears, has tried a great many ploughs, reaping-machines, harrows, grubbers, winnowing and thrashing machines, both with horses and bullocks, at Oosoor, and has had very fine crops of raghy, cholom, rice, guinea-grass, and oats. Dr. Hunter says: "I have seen a good many of the above tried at the Government farm, and a few at the Horticultural Gardens. We find that Howard's iron plough, with two wheels, and the small pony plough can both be used with very moderately sized bullocks, and that the horse reaping-machine works fully better with bullocks than with horses."

The productiveness and fertility of irrigated land, as shown in the following further extract from Dr. Hunter's letter, will doubtless astonish some of our English farmers, who rarely expect more than two crops in the year off their grass land: "This season I propose irrigating the same land, as several people now get twelve crops of hay in Madras from the use of manure and water. Each acre should yield one ton of Hurriallee grass per month; this is the Dooab grass of Bengal. I find that cholom or guinea-grass gives heavier crops, but both are more exhausting. We can get about eight crops of them in the year from the same roots, cutting down the crops every six weeks, and running in tank-bed earth or fine road-dust, and about an inch depth of water after each crop is cut, and then watering twice a week. The heaviest crops are cut in the hot weather."

We might enlarge considerably upon the use of agricultural implements of modern manufacture upon

* "Notes towards a Solution of the Smoke Nuisance Question," by W. M. Buchanan, 1852, page 48.

* "Notes," page 39.

† "On Heat in its Relations to Water and Steam," 1861, pages 199, 200.

the fertile plains of India, and the advantages that must follow their use in preference to the clumsy and old-fashioned native implements. A large collection of models representing these native implements is to be found in one of the annexes to the Paris Exhibition, and doubtless they have been examined by many of our readers. There is undoubtedly a large field open for English agricultural implement makers in our Eastern empire, which, if properly worked, should contribute largely to increase our annual exports in that class of machinery.

AN ENGINEERS' CONVENTION.

WE have in type the proceedings of a convention of American engineers which recently assembled at St. Louis, to consider the plan and mode of constructing a great bridge across the Mississippi at that place. The length of the bridge will be about 2000 ft., and by a law of Congress, regulating the navigation of the great American rivers, it must have at least one span of 500 ft., or two of not less than 350 ft. each, and the underside of the spans must be at least 85 ft. above water, and this although the banks of the river are low. The river bottom consists of shifting sand and alluvium to a depth varying from 28 ft. on one side of the river to about 125 ft. on the other. The difficulties of the task are undoubtedly great, and the promoters of the undertaking are meeting them in a way as novel as it is creditable to our profession in America. The first engineers in the country were invited to visit the site of the intended work, and to confer freely together; and they have done so with a readiness and unanimity which will be appreciated here when our account of the proceedings, crowded from our columns this week, shall appear in our next number. Among these engineers was the Honourable William J. McAlpine, whose visit to London, last year, is so agreeably remembered in professional circles, and who, as standing at the head of the profession in his own country, was chosen as the chairman of the convention. There were also Mr. Chesbrough, the engineer of the Chicago tunnel extending for two miles under Lake Michigan, Mr. S. S. Post, a leading bridge engineer, Mr. George A. Parker and Mr. L. J. Fleming, both of whom have put in deep foundations under somewhat novel circumstances, besides other engineers less widely known. The idea of divided professional labour and responsibility which this convention conveys will not strike the English mind favourably, leading as it almost inevitably must to future disputes and contentions; yet it is not unlikely that it is the best possible course for the company by whom the construction of the bridge has been undertaken.

BESSEMER STEEL PLANT.

THE construction of converters, blowing-engines, hydraulic apparatus, &c., for the Bessemer process has been chiefly carried on by two large firms—one in Manchester, and the other in Bolton. In addition to these Messrs. Tannett, Walker, and Co., of Leeds, are makers of Bessemer plant, and are now making a pair of 6-ton converters for Sir John Brown and Co. The greater portion of the plant for a Bessemer steel works in America, that of the Freedom Iron and Steel Company, at Lewistown, Pennsylvania, was lately sent off from these works, as was also a heavy plate-mill, with a pair of horizontal engines, of 3 ft. cylinders, and 5 ft. stroke. Messrs. Tannett, Walker, and Co. are almost exclusively engaged upon the machinery of iron and steel-works, including blowing and mill engines, rolling-mills, steam-hammers, Bessemer plant, &c., with, occasionally, engineers' tools of special construction. The steam-hammers have a peculiar and excellent valve motion, which we shall illustrate in an early number.

Not long since Sir John Brown and Co., of the Atlas Works, Sheffield, required an accumulator cylinder 36 ft. in length. The outer diameter was 36 in., the inner 26 in., for a 24 in. ram, and the total weight was to be about 25 tons. Several makers tendered for the casting, in four 9 ft. lengths; but Messrs. Tannett, Walker, and Co. successfully undertook to cast it in one. They dug a pit in their foundry-floor, 34 ft. deep, and built up a mould in strong cast-iron boxes, carefully jointed together. The casting was poured so that the lower half rose from the bottom, the upper half being afterwards poured from the top. The ferrostic head of a column of iron 36 ft. high is about 1 cwt. per square inch; so that the mould had to be very strong. The iron, before entering at the bottom, fell upon a wrought-iron plate, which broke the shock of the fall, and secured the steady rise of the metal in the mould. This remarkable

work may be compared, with some reason, to a cast-iron gun 36 ft. long, and of 26 in. bore—a gun heavier than the 15 in. Rodman. The casting was completely successful, and the cylinder is now in use at the Atlas Works.

Messrs. Tannett, Walker, and Co. have made many tyre-rolling mills, among them that which we illustrated some time ago, as in use at the new Grimesthorpe Works of Messrs. Charles Cammell and Co., of Sheffield. The same tyre-mills have been made for the Lowmoor Iron Company; the Bowling Iron Company; Messrs. Taylor Brothers, of Leeds; Messrs. Hood and Cooper, of Leeds; the Farnley Iron Company, &c.

EXPERIMENTS ON STEEL.

A GLANCE at the tabulated results of the important series of experiments recently made by Mr. Fairbairn to ascertain the powers of resistance of steel (tables which we publish to-day from the author's own manuscript) will show which makes possess the highest structural value, and it will also be seen that these makes show the greatest uniformity of any in quality. The value of "U" in Table II. tells the whole story of the behaviour of the steel in tension, and it will be seen that Messrs. Cammell and Co.'s steel, made, we take it, by the Bessemer process (for they also make crucible steel), did the best of all, while the specimens showed also the most regular gradation of quality. Mr. Fairbairn, in expressing certain doubts as to the uniformity of the steel available for construction, hardly appears to be aware that the quality of Bessemer steel, as respects hardness, on the one hand, or ductility and great dynamic value on the other, is under nearly perfect control, although he himself admits this in the earlier portion of his paper. In all first-class Bessemer works, every "blow" is tested, and the steel classified exactly for rails, for forgings, and for plates, according to its percentage of carbon, which may be always regulated to less than one-tenth of one per cent. The introduction of steel, in place of iron, in works of construction now depends chiefly upon the steel-makers themselves. But for the absurdly false report, first made by a contemporary, that Joret's Bessemer steel bridge on the Quai d'Orsay, Paris, had sunk at the crown, a report at once contradicted on the highest authority, and now known by every visitor to Paris to be untrue, steel would have already taken a more prominent place in respect of such applications. Its general adoption cannot, however, be much longer delayed. If engineers will employ it, they can have it of any desired quality and of the uniformity of any iron now used.

OPENING OF THE BARROW DOCKS.

(By Telegraph.)

BARROW, September 19, 1867.

THE Barrow Docks, of which we gave a plan on page 260 and a description on page 263 of the present number, were formally opened to-day, a steamer leaving the Buccleuch Dock, passing round Old Barrow Island, and re-entering the docks at the north-western entrance. The Duke of Devonshire and Mr. Gladstone were present at the ceremony; and so were Mr. McClean, Mr. Brassey, Mr. Platt, Mr. Richardson, Mr. Longsdon, Mr. Galloway, Mr. Adamson, Mr. Beyer, Mr. Bell, Mr. Lloyd, and Mr. Musgrave. At the Barrow Works a charge was blown in one of the five-ton converters, and all the hammers, tyre mill, and rail mill were shown at work. A banquet was served in the new carriage-shed at the railway station.

THE STEAM PLOUGH WORKS, LEEDS.

WHEN the late Mr. John Fowler had brought the steam plough to nearly its present state of perfection, he made arrangements with the firm of Messrs. Kitson and Hewitson, of Leeds, to manufacture it, together with the engines for working it. The business grew so rapidly, however, that an establishment specially devoted to this class of work soon became necessary, and Mr. Fowler and his partners started the present well-known Steam Plough Works, which have at times employed as many as 1100 men and boys, and which have sent out many hundred sets of steam tackle for use in England and abroad. During the American war, when the cotton trade was greatly stimulated in India and in Egypt, the demand for steam-cultivating machinery was very great, and the works under notice sent, in all, nearly 300 sets of tackle to the last named country alone. The steam plough has made fair progress at home, but it has not come into use to any

thing approaching the extent which the best interests of British agriculture require. About 250 sets of Fowler's tackle are in use, and since the recent important reports upon steam-cultivation, by the committees of the Royal Agricultural Society, a fresh demand has sprung up, and about 100 sets will have been added this year to the number at work.

During the lull in the trade which followed the cessation of Egyptian orders, the Steam Plough Works commenced the construction of locomotives. A considerable order was taken for engines for the Imperial Mexican Railway, including those for working the 21 mile incline of 1 in 25 between Ingenio and Boca del Monte. (See ENGINEERING, vol. ii., pp. 9 and 13.) These are to be pairs of engines, worked with their foot-plates towards each other, but having a steam tender between them, the total weight being 90 tons. None of the engines of this class have been yet commenced, but a number of the ordinary class of goods and passenger engines have been completed and sent to Mexico. Engines are being made also for the Ceylon Railway, from designs supplied by the Government engineers. It is anticipated, however, that the steam plough trade will soon recover to an extent which will fully occupy the works, when locomotive building, except for common roads and the fields, will be discontinued.

In the construction of ploughing engines, the large spur-wheel on the driving axle is now cast in steel, as are also the skifes of the ploughs themselves, and it is intended to cast the brackets supporting the crank-shaft also in steel. The large steel spur-wheels have been cast by Messrs. Naylor, Vickers and Co., of Sheffield, and by Messrs. Taylor Brothers, of Leeds. At the works of the last-named makers, Mr. David Greig, the manager of the Steam Plough Works, instituted a series of experiments to show the relative strength of cast-iron and cast-steel gearing. A short segment of the wheel referred to was cast both in the best cold blast iron, worth 5*l.* a ton, and in steel. The cast-iron segment was placed so that its upper tooth might be struck fairly by a hammer, whose arm or handle was jointed to a fixed pin, and of which the weight and height of fall were finally adjusted so as to break off the tooth at one blow. On placing the steel segment under this hammer, 200 blows of the same weight and height produced no impression, save slightly battering or indenting the steel. Mr. Greig is contemplating a very extensive use of steel in his engines, and is arranging to introduce Bessemer steel in place of iron for his boilers. This plate steel will be of the best make procurable in England, and its use is now abundantly sanctioned by the practice of some of our very first engineering firms.

In their arrangement and plant the Steam Plough Works present a few features of interest to the mechanical engineer. The overhead travellers were at first worked with a "flying rope" running at 26 miles an hour, and one of these is still in use. This is practically the same system as that so largely adopted at Crewe. When, however, we consider that the main shafting, from which the motion of the traveller is derived, runs at a moderate speed, and that the rate of the traveller itself is hardly 3 miles an hour, it appears a little extraordinary that the speed should first be got up to such a high rate to be immediately got down again. The explanation is that the strains upon the rope are inversely as the speed at which it runs, and thus a high-speed rope may be made correspondingly light. But as it is always running, whether the travellers are in use or not, it is subjected to considerable wear, and involves a continuous loss of power, the power required to work the rope alone being often much greater than that expended in hoisting and moving weights. The new travellers at the Steam Plough Works are worked by a steel rope, which is in motion only when weights are being moved, its rate being then about 3 miles an hour. The motion is communicated to it through Mr. Fowler's well-known clip pulley, which is started or stopped by a cord from the traveller. For factories of great length this mode of working travellers is well adapted, as the rope may be stretched even over a span of 200 yards without intermediate supports. We have a drawing of the arrangement in hand for our next number.

As in so many other works, the boilers are rivetted up by steam rivetters. More than this, the stay bolts are also put in by steam. Mr. Parker, of the Steam Plough Works, was some years ago a leading foreman in the Great Northern shops at Doncaster. Under the pressure of an emergency, he schemed and soon got to work an apparatus for tapping the holes in the fireboxes and screwing in the stay bolts by a simple machine, perfectly adjustable to the position of each stay. Of this machine we also expect to give a draw

ing next week. It formerly cost from 10d. to 18d. each for labour in making and putting in firebox stay bolts. The cost is now 1½d. The copper rods are forged under Ryder's forging-machine, giving 700 blows a minute. They are then centred and turned in a lathe of which the tool requires but one adjustment for a day's working, then screwed, the holes in the firebox tapped by the machine, and the stay also put in by the same machine, at the rate, for both tapping and screwing in, of 40 an hour. The same machine is now in use at Doncaster and at Messrs. Kitson's. Mr. Parker, when at Doncaster, also introduced an improvement in double-tyre lathes, having a face-plate at each end of the central head stock. Formerly both face-plates had to be stopped when removing or putting on a single tyre. Mr. Parker fitted each face-plate with a spindle of its own, both being driven, however, from the same driving-shaft; and by a lever, throwing in or out the driving-pinion, either face-plate may be worked independently of the other. These lathes have now become comparatively common, Messrs. Smith, Beacock, and Tannett having made a number of them for various railway and engine shops.

We have often expressed our opinion that no field of mechanical engineering has now such a future before it as agricultural engineering; and we may expect to see establishments like the Steam Plough Works greatly increased in extent and number. We are only beginning to comprehend that the soil of England has never been half cultivated, even for that part brought under cultivation. It is only the power of steam that can enable us properly to stir the soil to the full depth reached in the occasional and fragmentary experiments in spade-husbandry; and it is only the power of steam that will effectually and cheaply underdrain wet and retentive soils. Those periodical accesses of prosperity which have attended English trade from the beginning of the present century have always followed the development of some important invention, like steamships, railways, mule-spinning, hot-blast smelting, &c.; and there is no invention which, already stamped with success, but still not fully introduced, affords so wide a prospect of further prosperity as that of steam-cultivation. It owes its practical introduction to the late Mr. John Fowler; and although his loss was a heavy one to the cause in which he had laboured with so much ingenuity, perseverance, and success, his work is being followed up by his former assistants with an energy and practical ability which leave little to fear for the cause of steam-cultivation in the future.

HIGHLAND AND AGRICULTURAL SOCIETY.

REAPING-MACHINE COMPETITION.

At the annual show held by the above-named society in Glasgow in the early part of last month, when we gave our readers some account of the exhibition in the department of agricultural implements and machinery, Professor Rankine and his fellow-judges selected, amongst other things, a number of reaping-machines to be put in competition with each other as the season advanced. A notice of the trial of the potato-diggers has already appeared in these columns, and now we have to chronicle the results attained by the reaping-machines at the competition held near Glasgow last week. The competition in question was held almost simultaneously with the reading of the paper on "Reaping-machines," at the British Association Meeting, by the Rev. Patrick Bell, the original inventor of the "reaper" in 1826, and thus it has a peculiar interest imparted to it.

The trial took place on Hamilton Farm, between Rutherglen and Cambuslang, a few miles from Glasgow, and no fewer than eighteen of the thirty-eight reapers selected at the show were on the ground. The field chosen for the strife lies close to the river Clyde, and showed by its deep rich alluvial soil that it had benefited greatly by its proximity to it. The crop to be cut consisted of a mixture of what Scotch farmers know as Hoptoun and potato oats. It was an excellent crop of the sort; it was even entitled to be called heavy; and when selected by the committee some days before the trial, it stood up well; but the heavy rains of the few days immediately preceding had so laid and twisted the crop, that the reaping operation proved to be a very troublesome task, so much so, indeed, that the farmers—of whom there were some hundreds present—universally admitted that if the machines would reap "that stuff," they would do anything. The day itself was all that could be desired, and two or three days of such weather would have so dried the crop that the machinery would doubtless have had but little difficulty with it, even with its "lain" condition. In some few places it was so very wet as to be almost rotten, and in these places most of the machines slid over the crop as though they were snow-sledges almost. They really had not a fair opportunity for the testing of their powers, but the committee who selected the ground and acted as judges during the competition were no way to blame. The weather, and that only, was at fault.

Four different kinds of machines were put on trial:—1. Combined Reapers and Mowers; 2. Two-horse Reapers; 3. One-horse Reapers, with manual delivery; 4. Two-horse Reapers, with self-acting delivery. Of the first class there were five machines brought into competition, and the prepared plots of ground were taken possession of in the following order:—first plot by the machine made by Messrs. John Wallace and Son, Glasgow; second plot by that of Messrs. Brigham and Bickerton, of

Berwick-upon-Tweed; third, by that of Messrs. Kemp, Murray, and Nicholson, of Stirling; fourth, by that of Messrs. Lillie, Goodlet, Elder and Co., also of Berwick-upon-Tweed; and fifth, by that of Messrs. Alexander Jack and Sons, of Maybole.

The judges were all practical, and perhaps it should be said gentlemen farmers—Mr. John Wallace, Stonelaw, Rutherglen; Mr. Robert Murdoch, Hallside, Cambuslang; Mr. Archibald Russell, jun., Flemington, Cambuslang; Mr. Laurence Drew, Merryton, Hamilton; and Mr. Wm. Robertson, Old Hall, Paisley. In awarding their verdict they resolved to take the following elements into consideration: time occupied in cutting the plots, ease with which the machines worked, character of the sheaving, character of the stubble left, draught weight as tested by the dynamometer, and breadth of cut at the time of applying it. The results may perhaps prove most instructive when seen in the tabulated form.

Makers.	Extent of Plot.	Width of Cutter.	Average Cut.	Time when Tested.	Draught by Dynamometer.	Time taken.
	rds. pls.	ft. in.	ft. in.	ft. in.	cwt.	h. m.
Wallace & Son	2 31	5 0	$\left\{ \begin{array}{l} 3 \text{ } 6 \\ 4 \text{ } 0 \\ 4 \text{ } 3 \end{array} \right\}$	3 3	4	1 50
Brigham & Bickerton	2 34	4 11½	$\left\{ \begin{array}{l} 4 \text{ } 6 \\ 4 \text{ } 0 \\ 4 \text{ } 3 \end{array} \right\}$	4 3	3½	1 33
Kemp, Murray, and Nicholson	3 3	5 0	$\left\{ \begin{array}{l} 4 \text{ } 0 \\ 4 \text{ } 6 \end{array} \right\}$	3 3	4	1 54
Lillie, Goodlet, Elder, and Co.	3 4	4 9½	3 6	3 6	3½	1 57
Jack and Sons	3 5	5 0	3 6	3 6	3½	2 10

One or two qualifying remarks may not be out of place regarding these machines and their work. Messrs. Brigham and Bickerton's was the only one which had no serious "hitch." It was rarely brought to a standstill by any materials entangling the wheels or other parts of the gearing; it worked smoothly, did the sheaving well, and left a very fair stubble. The only one which came close upon its heels in these particulars was that owned by the Stirling firm. It had, however, a larger plot of corn to reap, one that was also more severely laid and twisted than either No. 1 or No. 2. The platform of this machine was peculiar in the circumstance that it was spalled, all the others being plain and covered with sheet zinc, to give such a degree of smoothness as would facilitate the making of the sheaves. No. 1 had a serrated cutter, and in this sense it was peculiar, as all the others had plain teeth. From choking or other circumstances it came to a standstill more frequently than either of the two just referred to; but in this respect it was outstripped by those owned by Messrs. Lillie, Goodlet, Elder, and Co. and Messrs. Jack and Sons. These two, however, had to attack the worst portion of the crop, where it was in many places quite "heads and thraws," in fact.

Taking all the circumstances into consideration—the quality and sizes of the plots, the mode in which the operation was executed, the corn after cutting, and the condition of the stubble—the judges had no difficulty in awarding the first place to Messrs. Brigham and Bickerton's "Buckeye" reaping-machine, and the second to that of Messrs. Kemp, Murray, and Nicholson. It should be mentioned that the Highland and Agricultural Society does not make any pecuniary award in respect of these machines, or, indeed, in respect of any implements or machines exhibited during several years; the money awards are all given for live stock and dairy produce. It is something, however, for Messrs. Brigham and Bickerton to be able to say that their "Buckeye" reaper has received the first award of the Highland and Agricultural Society, even though that award is only honorary. It will, doubtless, be much run upon for next harvest; it is too late for this present harvest. In justice both to the judges and the makers of Nos. 2 and 3 machines, it is proper to mention that the keen anxious onlookers among the farmers present generally agreed in the verdict arrived at by the society's judges.

Of the two-horse reapers there were three brought into competition. Mr. McCutcheon had one of Wood's American reapers; Messrs. Kemp, Murray, and Nicholson had one of their own manufacture; and Messrs. Allan, of Dunkeld, worked a "Hornshy" made by themselves. The judges would not undertake the responsibility of making any award in this class. They saw that the ground and the portion of the crop selected for the trial of the two-horse reapers were not such as could legitimately be employed in testing them.

In the third class—one-horse reapers—there were five machines for competition: Messrs. Hornshy and Sons'; Messrs. Samuelson and Co.'s "Eclipse" (exhibited by Mr. John Pringle, Edinburgh); Messrs. Brigham and Bickerton's "Buckeye Junior"; another of Wood's American machines, exhibited by Mr. McCutcheon; and one owned by Messrs. Jack and Sons. In each case the work done was highly commendable, but still there were such features of excellence in that done by the "Hornshy" and the "Eclipse" that the committee of judges had very little difficulty in saying that these two machines should rank in the order here given—first and second.

The competition of the reapers with self-acting delivery, of which there were also five, was very unsatisfactory. The machines of this class were—a back deliverer by Messrs. Bisset and Son, of Blairgowrie; Messrs. Samuelson and Co.'s four-armed reaper; Messrs. Hornshy and Sons' four-armed reaper; and a couple of two-armed machines by Messrs. Brigham and Bickerton and Mr. Winton, of Falkirk. Owing to the quality of the work executed by these machines, which was unsatisfactory on account of the bad condition of the ground and the crop, the judges again decided to give no verdict.

The society's secretary, Mr. F. N. Menzies, the chairman of the Implement Committee, Mr. Gibson, Woolmet, and Mr. Slight, Edinburgh, the society's consulting engineer, were all present on the trial ground during the day. The last-mentioned gentleman was responsible for the application of the dynamometer to test the draught of the machines.

COMSTOCK'S ROTARY SPADER.

In the course of our account of the recent show of the Royal Agricultural Society at Bury St. Edmunds, we noticed a useful implement, Comstock's rotary spader, exhibited by Mr. J. T. B. Porter, of Lincoln, and of this implement we witnessed a public trial on Saturday last, on the form of Mr. Boyall, near Grantham. The "spader," which is an American invention, and has been used to a considerable extent in the United States, is a very simple machine. The digging portion of it consists of a number of forks or prongs fixed to a series of transverse bars, which are connected at their extremities by links, so as to form an endless chain. This chain is led over chain-wheels fixed on the main axis of the machine, and as the latter is drawn forward, the forks are successively forced into the ground. The ends of the transverse bars carry short arms provided with rollers which work over fixed cams, these cams being something of a Δ shape. The effect of the cams is to give the prongs a motion somewhat resembling that of the floats of a feathering-paddle, causing them to enter the ground fairly and to tilt over as they rise from it, and thus thoroughly break up the soil. When the machine has to be turned, or whilst it is being removed from place to place, the "diggers" are raised clear of the ground by a simple lifting arrangement designed by Mr. Porter. The lifting gear fitted to the American machines was scarcely suited to the requirements of English farmers, and it was, moreover, far less convenient than that now adopted. In the machine tried on Saturday, the wheels on which it runs, when being transported from place to place, are carried by the shorter arms of a pair of bell-cranks, placed one on each side of the machine, these arms lying horizontally when the machine is in use, at which time the longer arms stand vertically. The upper ends of the longer arms are connected by chains to a pair of small drums placed on a shaft carried across the front part of the machine, this shaft being capable of being rotated, when required, by means of a hand-wheel acting through bevel gearing. The main shaft, carrying the wheels around which the diggers travel, passes through the angles of the bell-cranks, and thus forms the fulcrum on which the latter work. When the diggers are to be raised clear of the ground, the longer arms of the bell-cranks are, by means of the chains and hand-wheel, hauled down into a horizontal position, this operation bringing the shorter arms vertical, and causing the wheels carried by them to take the weight of the machine. By turning the hand-wheel the other way the machine can be readily lowered again, counter chains serving to bring the bell-cranks into their former position.

On Saturday the machine was drawn by four horses, and did very good work over some wheat stubble, thoroughly breaking up the ground to a depth of from 6 in. to 8 in. The breadth of land broken up at each course of the machine varied from 3 ft. to about 3 ft. 8 in., the speed of working being at the rate of between three and four acres per day. Mr. Porter also makes a larger machine, which acts on a width of 4 ft. 6 in., and when drawn by six horses opens up about six acres per day in any ordinary land. The land upon which the "spader" was tested on Saturday was in many places very hard, one portion having been used as a road over which large quantities of corn had been led. After its trial on the wheat-stubble, the machine was taken on to some very hard seed land, and here it was found necessary to place an extra number of men on the machine, in order to enable the forks to penetrate the surface. When once the machine was sufficiently loaded, however, it did its work as well as on the wheat stubble. The trials were witnessed by a large number of farmers, and much satisfaction was expressed at the effective manner in which the ground was broken up, and the light and open condition in which it was left.

Although the rotary spader will never replace the plough entirely—as indeed its makers would be the last to assert—it may be advantageously substituted for the latter for performing many farming operations, its chief advantages being that it requires less power to drive, and a less amount of attendance to do a given quantity of work, than a plough does. Mr. Porter is, we believe, intending to adapt the "spader" to be worked by steam power, when there will be a still better chance of comparing its efficiency with that of other cultivators.

THE TELEGRAPHIC CONFERENCE.—The Telegraphic Conference of Representatives from the French, Austrian, Turkish, and Swiss Governments has determined to reduce by one-third the telegraphic charges for the passing over their territories of messages between England and India and between London and Austria, provided that this reduction should be ratified by their respective Governments.

THE FLORIDA AND CUBA CABLE.—The Florida and Cuba cable is still incomplete, owing to the failure thus far to lay the connecting link between Punta Rosa and Key West. On the 30th of August the Narva was believed to be at work, but nothing positively is known of it, and no later despatches have been received. News is now received from Havannah through the incomplete cable, and by means of a despatch boat across the break, in three days.

ARTIFICIAL SUGAR.—Chemically, grape sugar may be produced by the action of sulphuric acid upon starch. This process of conversion is now being practically carried out, and beer has been brewed from the saccharine solution prepared with the product. The Worcester Engine Company are making an apparatus for the purpose, consisting in part of a lead-lined cast-iron receiver, to bear the considerable pressure required in working.