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1885.

may be said now to be practically carried out; and there remains but a much needed improvement in the quality of the fuel from the adjacent coalfield. During the long continued depression in the iron trade, Lincolnshire may be said to have fairly held its own; but with the second condition fulfilled, it will have a great future.

DUNBAR AND RUSTON'S STEAM NAVVY.*

By Mr. JOSEPH RUSTON, M.P., of Lincoln.

IN the large excavations constantly being made for railways, docks, canals, and other engineering works, containing often many hundreds of thousands of cubic yards, a substitute for the pick and spade has long been sought, and various mechanical contrivances have from time to time been adopted, with more or less success. The problem may however be considered to be now solved by the steam navvy forming the subject of the present paper, which is believed by the writer to be, perhaps, the most successful machine yet introduced for this end, being not merely suitable for one form of digging or for one kind of material, but also capable generally of dealing with every large excavation which contractors are called upon to make, and thus proving itself in fact an expeditious, reliable, and most advantageous help. So successfully has it fulfilled the purpose in view, that its use on all works of any magnitude, at least in this country, is the rule rather than the exception; and its manufacture forms an important branch of the business at the writer's works, from which upwards of a hundred of these machines have now been turned out, the majority for use in Great Britain, and the remainder distributed in various parts of the world. Among the completed works on which it has been employed with special success may be mentioned the following: Victoria Dock, London; Coble Dene Dock, Tynemouth; Penarth, Swansea, Silloth, and Greenock Docks; new outfall works at Boston; harbour works at Calais, and at Melbourne, Australia; cuttings on the Great Northern and the London and North-Western Railways at Melton Mowbray, the Midland Railway at Manton and Bootle, the Dover and Deal Railway at Dover, the Rugby and Northampton, the Paisley, and the Didcot and Southampton Railways, the Lanarkshire lines at Airdrie, the North-Eastern Railway at Bishop Auckland, the Guildford and Surbiton, and the Rhymney Railways; and other works.

The steam navvy excavates and delivers into wagons any material capable of being cut, such as sand, gravel, chalk, and clays of all kinds, digging out with equal facility the hardest and toughest, such as require blasting when worked by hand. It can also deal with these materials when thickly interspersed with stones and heavy boulders; and without being unduly strained it cuts through seams of flint, shale, slate, or even sandstone, which may intersect the face of the excavation it is at work upon. With the assistance of blasting, it is also used with advantage in much more difficult stuff, such as hard marl and lias rock.

Development.—Since its introduction many improvements have been made, increasing its power and efficiency. The framework has been considerably strengthened throughout, augmenting the total weight by several successive increments from 22 tons in the earliest machine to 32 tons, which is now adopted as the standard; the scoop averages a capacity of about 25 per cent. larger than at first, and has an increased angular range. The duty has progressed in a greater ratio, nearly 50 per cent. having been added to the original output. At first 180 to 190 wagon-loads were considered a good day's work; now 240 to 250 are often obtained, and even more under very favourable conditions: the day consisting of ten hours, and the wagons being the size ordinarily used by contractors, holding three cubic yards each; however, the stuff is more solidly packed by the navvy than when the wagons are loaded by hand. With extra large wagons holding four cubic yards each, an equal number has been filled in a day, equivalent to the grand total of nearly 1000 cubic yards per day.

Construction.—The machine is shown in the engravings on page 180, Fig. 1 being an elevation, and Fig. 2 a plan. It may be described generally as consisting of a strong rectangular wrought-iron frame mounted on wheels, forming a substantial base to which all the parts are secured. On the back end is placed the engine, beside which the driver stands. At the front end rises a wrought-iron tower carrying the top pivot of a crane jib, the lower pivot resting on girders fixed to the main frame. The jib may be said to be of twin construction, being composed of two sides which are united only at the post and at the outer end or point; between them therefore is a long slot, in which swings an arm of adjustable length, depending from a fulcrum fixed on the upper member of the jib; and at the base of the post is a circular platform, on which a man stands to regulate by means of a handwheel the "reach" or length of radius of the arm. The scoop or bucket is fixed at the lower end of the arm, and is raised or lowered by the main chain passing over the extremity of the jib.

Handling.—The whole of the movements are controlled by two men, called the "driver" and the "wheelman." The driver raises the scoop while making its cut, swings it round into position for discharging; then he moves it back again and lowers it. The wheelman regulates the depth of cut, releases the scoop from the face of the bank, and opens the door or bottom for discharging its contents.

Supposing the navvy to be in position, the mode of working is as follows. The bucket having been lowered till its arm is vertical, as shown by the dotted lines at A in the elevation, Fig. 1, the wheelman regulates the length of the arm by means of his handwheel, so that the cutting edge of the bucket shall get its proper grip of the soil. The driver throws the main chain drum into gear, and the scoop is dragged forwards and upwards by the chain into the position B, describing a circular arc of about 80 deg. By the time it reaches the top it is fully loaded, and the driver throwing the drum out of gear, holds it with a foot brake; at the same instant the wheelman by easing his foot brake allows the bucket to fall back to C, clearing itself from the face of the bank. The driver next swings the jib round till the bucket is over the wagon, when the wheelman releases the latch by means of a cord, and the door falling open, the contents instantly drop through. The driver then swings the jib back again, and at the same time lets go the foot brake of the chain drum, thus causing the bucket to descend through a sort of spiral course, until he brings it up sharply by the brake again when in position D. The wheelman at the same moment adjusts the fall by means of his brake, so as to lower the bucket to A again, with just the right reach of arm for the next cut. During the fall the door of the bucket closes and latches itself automatically by its own weight; and all is then ready for repeating the operation.

Although apparently somewhat complicated when thus performed in combination, the several movements are each very simple; and the whole cycle can be performed in less time than has been taken to describe it. Three-quarters of a minute is sufficient for scooping out from 1 to 2½ tons of stuff, according to the capacity of the bucket, for dropping the stuff into the wagon, and for returning the scoop into place ready for another cut.

After the machine has dug out all within reach, the jack screws which steady it are eased, and the propelling gear being put in action, it is moved forwards 3 ft. or 4 ft.; the screws are then tightened down, and another series of cuts is commenced. The cuts all radiate from the centre round which the jib swings; and they may together form a hole more or less resembling a crater, according to the plan adopted in making the excavation.

Details of Construction.—Proceeding to the constructive details of the navvy, the main frame has its side girders formed much deeper in the centre that at the ends, and they are duplicated on each side at the front end under the tower. There are three internal transverse girders, and longitudinals again under the engine and gearing; all are well tied together, and stiffened by angle irons and gussets. Between the inner longitudinals under the tower a large tank is formed, which when filled with water acts as ballast to steady the machine, and forms a convenient supply for the engine. The whole frame is rivetted together at the works; but to facilitate transport it is divided crossways in the centre, and the two halves are united by bolts and joint plates.

The lower pivot of the jib is carried somewhat in advance of the main frame by a pair of projecting girders rivetted on the top of the transverse members of the frame, and converging in the form of a V to an apex, at which is placed the pivot; these are further stiffened by plates underneath, and the front end of the frame where they are fixed, is made of double thickness the whole way across. This construction has been found necessary in order to provide for the enormous stress which has to be resisted at this point if the bucket is allowed to jam itself when cutting; the force is indeed sufficient sometimes to lift the back or engine end of the machine almost off its legs. The plan of carrying the pivot well in advance of the main frame, which is a distinctive feature of the navvy, enables the jib to be swung round further, and renders the ground in front much more accessible when laying down the rails.

At each corner of the frame is a strong jack-screw, and a fifth is placed immediately under the pivot of the jib; these take the entire weight when at work. The outside wheels on which the machine is mounted, are double-flanged and 10½ ft. gauge; and for transport from one cutting to another ordinary single-flanged wheels are also furnished inside, to the standard 4 ft. 8½ in. gauge.

The tower may be described as an oblique truncated pyramid, well extended at the base for bolting to the longitudinals of the main frame. It is formed of two plate-sides, stiffened with T irons, and braced together with crossplates and stays; between them is an opening large enough for the driver to watch the motion of the bucket, even when the jib is straight ahead. The top of the pyramid is finished with a roof-plate extended forwards in front for taking the top pivot of the jib, and stiffened by a V shaped girder like that for the bottom pivot; on this table are placed also the guide pulleys for the main chain.

The jib is stiffened laterally by rivetting to its lower member on each side a broad plate placed on edge so as to form an L section in plan, the two sides of the angle being united with knees and gussets. This enables it securely to withstand the heavy twisting strains when cutting in any such material as tough clay mixed with boulders. Round the platform at the base of the post are led the chains connected with the swinging gear.

The engine is of the ordinary vertical type, with a cross-tube boiler carrying usually 80 lb. pressure, and a pair of cylinders of 10 horse-power nominal; it runs up to 160 or 170 revolutions per minute under the control of a governor. On the crankshaft is keyed a pinion, gearing into a spur-wheel four times its size on the main drum shaft, from which all the other motions are transmitted.

The main drum is tapered, so as to give the engine the most power when the chain is pulling at least advantage, and *vice versâ*; it is loose on the shaft, and is driven by a clutch, and controlled by a powerful foot brake. By a pair of equal spur-wheels motion is given to a second shaft, on which is mounted a small drum having its own clutch and brake, and winding a light chain for pulling the bucket back; this however is very seldom required, except when the machine is used for dredging.

On the other end of the second shaft is a double-cone friction clutch with a pair of reverse bevel wheels, for driving in either direction a short longitudinal shaft, which at its front end drives a third cross-shaft giving motion to the swinging and propelling gears through a double-ended clutch. A drum on the shaft winds the swinging chain that is led round the circular platform on the foot of the jib post; and this drum also has a brake under command of the driver. A pitch-chain from a pinion upon the shaft drives a wheel keyed on the axle of the front travelling wheels. By means therefore of the bevel wheels and friction cones the driver can move the navvy backwards or forwards, or swing the jib in either direction; and all the different movements can be effected without reversing or stopping the engine, so that no time is lost. A strong cast-iron framework, firmly bolted to the main frame, carries the various shafts.

The bucket arm is made of two oak planks, bolted together at top and bottom, so as to leave a long slot between them, through which passes the main chain. On the back edge of each plank is a rack, gearing with a pinion fixed on the fulcrum shaft on the top of the jib. The same shaft also carries a swing frame provided with four rollers, which press on iron bars or runners fixed along the front edge of the arm, so as to hold it up close to the fulcrum, while yet allowing it to be moved longitudinally by the racks and pinions for lengthening or shortening it; the movement is given by a pitch-chain wheel on the outer end of the fulcrum shaft, driven from a pinion on the handwheel shaft, which as already explained, is under the control of the wheelman.

The main lifting chain passes from the winding drum, through the tower and over the pulleys on the top, through the bucket arm, over a sheave on the end of the jib, round a snatch block on the handle of the bucket, up to another sheave on the jib, and down again to the snatch block, obtaining therefore a treble purchase.

The bucket is shown in detail in Figs. 4 and 5. Its mouth is semi-elliptical; its cutting edge is of steel, and is protected by four strong picks or teeth, which are made so as to be easily renewed when worn, being fixed to the lip of the bucket by countersunk bolts and nuts, as shown. These picks or teeth are of different strengths according to the stuff to be excavated; the chisel-shaped head of one of the stronger kind is shown in Fig. 3, and is suitable for the hardest boulder clay. On the top of the bucket are fixed two plates strongly gussetted, between which the lower end of the arm is secured by a through pin. There are also four shackles furnished with screw swivels, which distribute the strain, and permit the adjustment of the angle that the cutting edge of the bucket makes with the arm. The two top plates also carry the L shaped hinges rivetted to the flap or door. The handle or "bale" of the bucket swings on pins fixed about centrally on each side; it is well arched to allow room for the dirt, and is secured to the snatch block by a pin and strap. The door is fastened by a stout bolt, fixed on the outside opposite to the hinges, and kept closed by a spiral spring protected by a casing. On the bolt is a short arm passing through a slot in the casing, and connected by a link to the catch lever for opening the door; at the outer end of this lever is a pulley, round which a cord is rove, the free end passing through a sheave on the bucket arm and thence to the wheelman. By pulling the cord the bolt is withdrawn out of its socket, and the door falls open by its own weight, and hangs vertically; when the bucket falls back from position C to D, Fig. 1, it overtakes the door, and the bolt and socket being both made with sloping edges, the door latches itself automatically in closing.

(*To be continued.*)

* Paper read before the Institution of Mechanical Engineers at Lincoln.

NOTES FROM THE SOUTH-WEST.

Rhondda and Swansea Bay Railway.—The works between Pontrhydyfen and Cymmer, with the exception of the station at the latter place, have for some time been practically finished. Pending arrangements which may render a second permanent station at Cymmer unnecessary, a temporary station for the intermediate service of the passenger traffic is in course of erection at that place. The construction of the Rhondda Tunnel was commenced in June, and the works at both ends are being pushed forward with all possible speed. An agreement for an interchange of traffic between the company and the Great Western Railway Company at Port Talbot, has been entered into. The effect of this agreement will be to dispense with the necessity of constructing a tunnel under the Neath, as well as some other portions of the works originally contemplated.

Gloucester Wagon Company (Limited).—Including the balance brought forward from 1883-84, the revenue of this company for the year ending June 30, 1885, was 32,109*l.* 7s. 10d. From this sum the directors deducted 10,131*l.* 13s. 6d. for the usual depreciation of wagons, and 1296*l.* 14s. 6d. for depreciation of buildings and machinery, leaving a final balance of 20,690*l.* 19s. 10d., which may be regarded as the amount available for dividend for the year. The directors recommend a dividend upon this capital for the past year at the rate of 4 per cent. per annum, adding 3000*l.* to the reserve fund, and carrying forward 1296*l.* 3s. 10d. to the next account. The rolling stock belonging to the company now consists of 5685 wagons let on simple hire, and 3280 sold on deferred payments. In addition to work done for cash payments, 112 wagons have been built for the company's stock, all of which have been sold on deferred payments. The company has now to repair and maintain 13,179 wagons, 4970 of which are not its property.

The "Curlew."—The boilers and part of the machinery of the Curlew, a new steel gun and torpedo vessel which is being built at Devonport, have arrived at the dockyard.

DUNBAR AND RUSTON'S STEAM NAVVY.

CONSTRUCTED BY MESSRS. RUSTON, PROCTOR, AND CO., ENGINEERS, LINCOLN.

(*For Description, see Page* 178.)

Fig. 1.

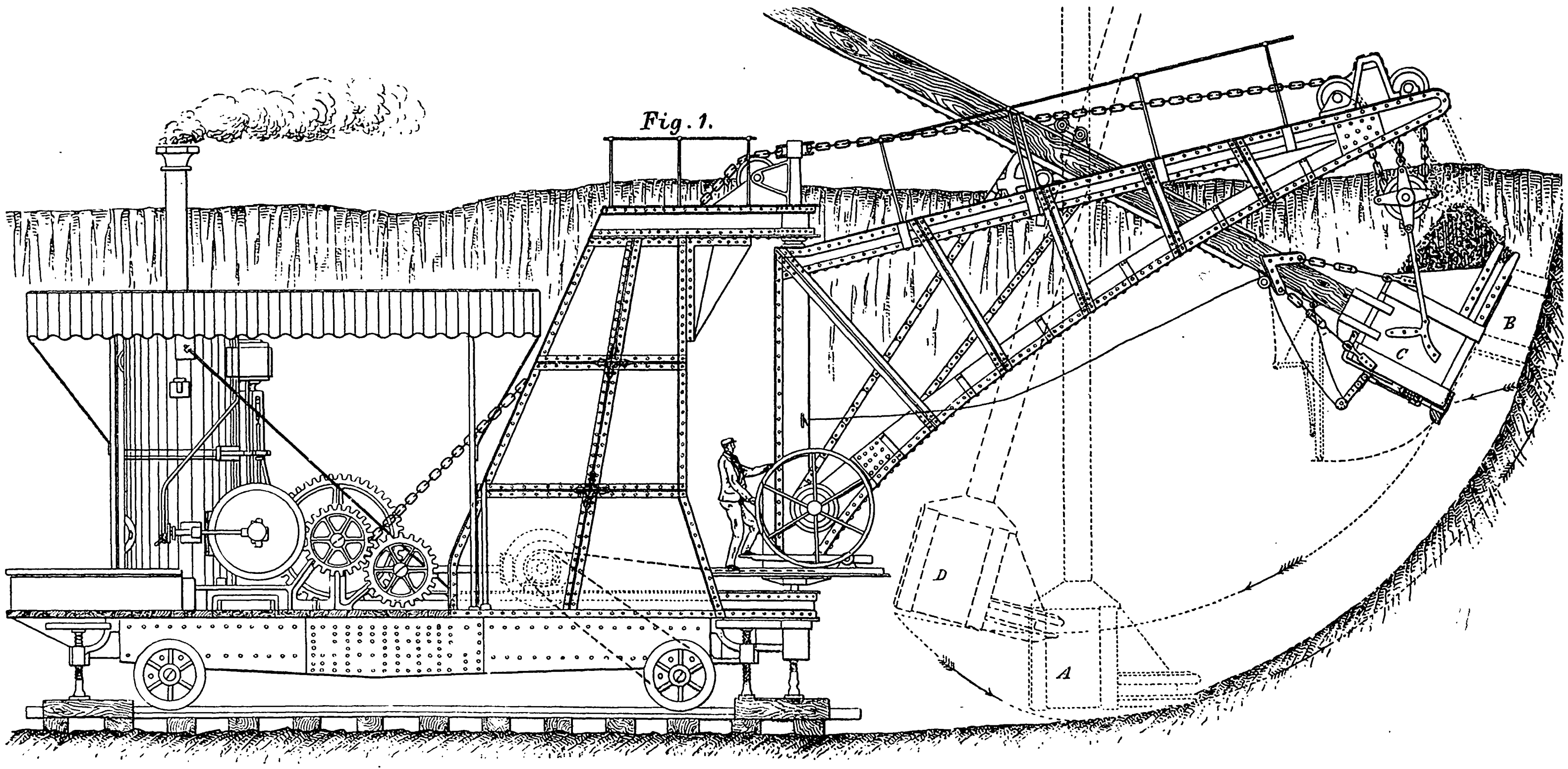


Fig. 2.

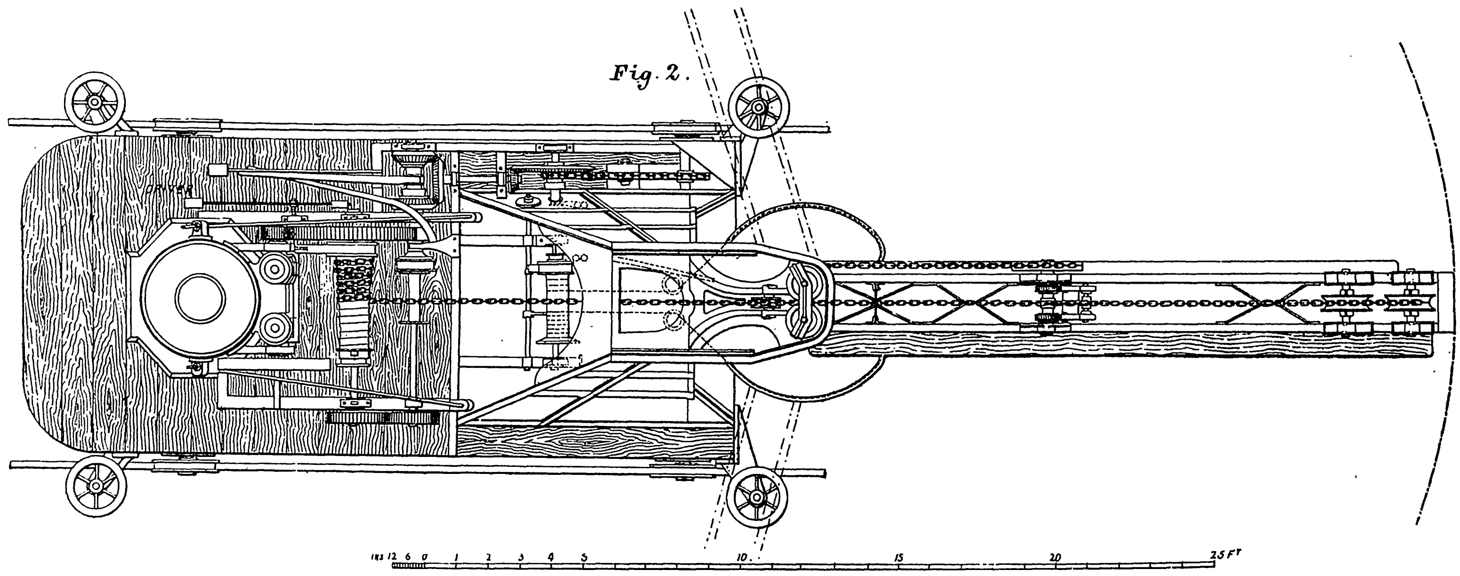
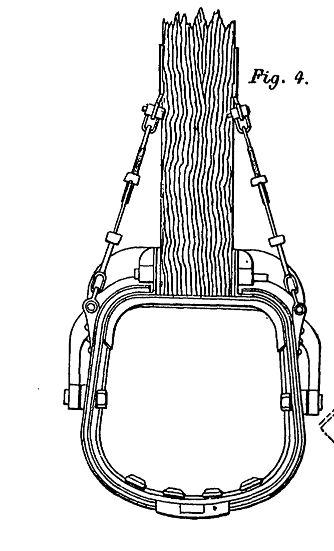
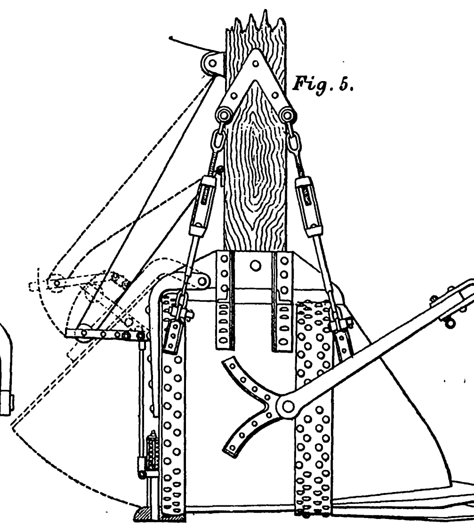
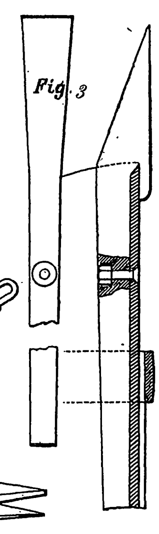


Fig. 4. Fig. 5. Fig. 3







Iron Company are in this satisfactory condition, and the North-Eastern Steel Works at Middlesbrough have also a number of important contracts. Messrs. Bolckow, Vaughan, and Co. feel the scarcity of orders, and their great plant at the gigantic Eston Steel Works is only fitfully employed. During this week a number of gentlemen, including amongst others several members of Lloyd's Committee, have visited the Eston Steel Works and have been very much interested in the mode of producing steel and the quality of the shipbuilding material at that establishment.

Wages in the Iron Trade.—The blast furnacemen of the North of England are still discussing the wages question. It is hoped and believed that a sliding scale will yet be arranged. With regard to the manufactured iron trade, the wages question is still occupying the attention of both employers and men. The Board of Arbitration having failed to formulate a sliding scale for the regulation of wages, the whole question is likely to be submitted to an arbitrator. On Monday a special meeting of the Board is to be held at Darlington, when the question will be further discussed and arrangements made for holding a court of arbitration.

German Coal Exports.—The exports of coal from Germany would appear to be still increasing. In the first five months of this year these exports were 3,558,791 tons as compared with 3,448,981 tons in the corresponding period of 1884, showing an advance of 109,810 tons in 1885.

Gas at Paris.—The revenue of the Parisian Company for Lighting and Heating by Gas amounted in the first six months of this year to 1,446,792*l.*, showing a decrease of 12,846*l.* as compared with the corresponding revenue in the corresponding period of 1884. The check which the company's revenue has experienced this year is quite an unusual feature in the history of the undertaking as for a long time past it has shown a steady and continuous progress year by year.

STERN-WHEEL STEAMER FOR THE BRAZILIAN GOVERNMENT.

CONSTRUCTED BY MESSRS. FORRESTT AND SONS, LONDON.

Fig. 1.

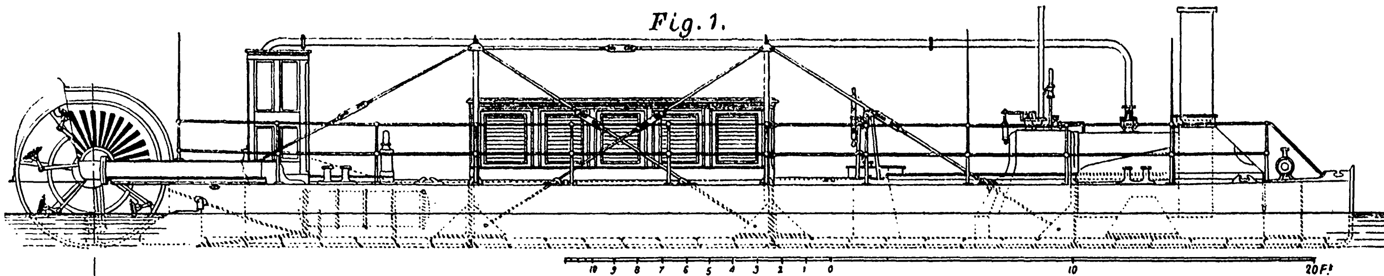
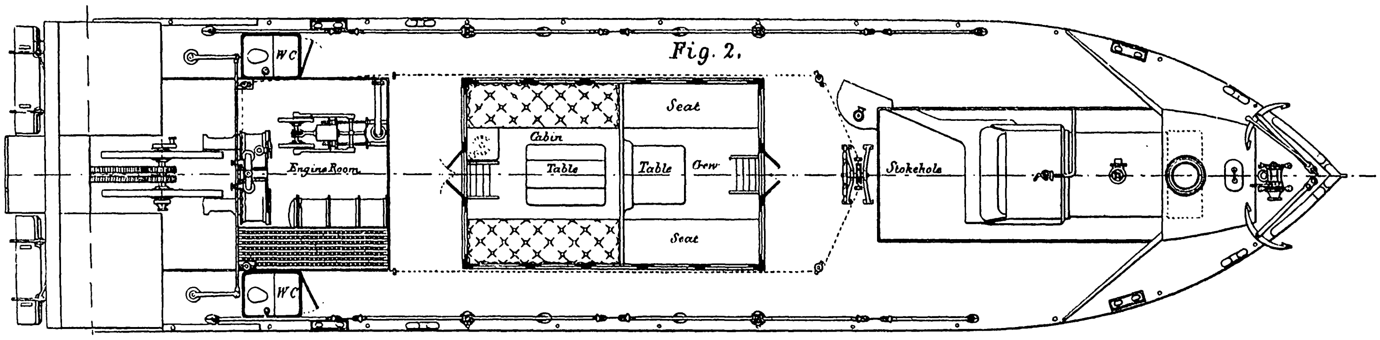


Fig. 2.



We illustrate above a stern-wheel steamer lately constructed by Messrs. Forrestt and Son, of Millwall and Limehouse, for the Brazilian Government. The weights are arranged at the ends; the boiler being forward and the engine aft, longitudinal strength being obtained by trussing posts and rods. The boiler is of the locomotive type, and is constructed entirely of steel. It is 7 ft. long by 3 ft. 6 in. in diameter. The grate area is 13 ft. 6 in., and the area of the firebox 75 square feet. There are 139 brass tubes, 7 ft. long and $1\frac{3}{4}$ in. in diameter; the total heating surface being 520 square feet. There is a forced blast worked by a fan driven by a small vertical engine at the side of the boiler, and the steam pressure is 120 lb. per square inch. There are two feathering paddle-wheels, 6 ft. 4 in. in diameter, driven by spur gear from a compound surface-condensing engine of 150 horse-power indicated, having cylinders 8 in. and 14 in. in diameter respectively, with a stroke of 10 in., and running at 425 revolutions per minute. The crankshaft, pistons, and connecting rods are of steel. The dimensions of the boat are: Length on deck, 50 ft.; extreme breadth, 13 ft.; and depth, 2 ft. 10 in. The draught is $15\frac{1}{2}$ in. with a displacement of 17 tons. The hull is of steel, and is built in four sections, the skin plating being $\frac{1}{8}$ in. thick. The deck is also of steel, and is covered with linoleum. A mahogany deck-house amidships provides accommodation for the officers and crew. The officers' cabin is upholstered in blue rep, and is provided with settees, which can be used as beds when required; the fittings are of mahogany. The boat is provided with two rudders, worked from a wheel amidships, and steers very well. On the trial trip, in spite of a high wind and a lumpy sea, she made a speed of 9.1 knots, which was considered highly satisfactory by Admiral Azavedo and Captain Carvalho, who represented the Brazilian Government. The vessel was afterwards taken to pieces and shipped to its destination.

DUNBAR AND RUSTON'S STEAM NAVVY.*

By Mr. Joseph Ruston, M.P., of Lincoln.

(*Concluded from page* 178.)

Plan of Excavation.—When making a cutting, the navvy first drives a "gullet," unless the excavation be commenced along the side of a bank or hill, as shown in Figs. 7 and 8. The output depends mainly upon the completeness of the means for removing the excavated stuff.

The most effective way is to provide double roads, one on either side, branching out by proper curves from a central road, and also connected with the latter by short "jump" lines at abrupt angles immediately behind the navvy, as shown in Fig. 6. On the central road are kept the empty wagons, and on each side is a man with a horse, by whom an empty wagon is brought forwards along the jump to the side of the machine; and as soon as it is filled it is run back along the branch and another empty is brought up. Meanwhile the wagon on the other side is being filled; and while this is in its turn being exchanged for an empty, a second wagon is being filled on the first side. As the work thus proceeds on either side alternately, not a moment need be lost in waiting for wagons; and the jib has the minimum distance to swing round, the dirt from each half of its sweep being delivered on its own side. When, say, a dozen wagons have accumulated on each of the side roads, the shunting engine makes up a train, and takes them away to be tipped. The central siding behind the machine should be long enough for say 32 wagons at least; and other sidings are of course necessary if the "lead" to the tips be a long distance.

The gullet thus made may be 20 ft. or even 30 ft. deep, according to the nature of the stuff; but 25 ft. is about the most economical depth, because the machine has then sufficient reach to make the cutting exactly large enough for an ordinary double-line railway of standard gauge, the slopes requiring very little handwork to finish them, as shown by the section in Fig. 11. In Fig. 12 is shown a cutting 50 ft. deep for a similar railway, which can be best made by driving two navvies, one in advance of the other, to take out the first 25 ft.; and then finishing the lower half of the depth with a gullet similar to that shown in Fig. 11. In each case the completed cutting is shown by the dark section, and the part to be taken out by hand by a light colour. In the deep cutting, Fig. 12, the sleepers and ballast of the permanent way are drawn in; whilst in the other, Fig. 11, are shown the positions of the side roads while the work is in progress.

Where the railway has only a single line, as in Fig. 13, the cutting must be made narrower; the navvy is then placed out of centre, and one side road only can be used. More attention is therefore required for keeping up the supply of empty wagons; and the jib having to swing round through a greater average distance, the output is not quite so good. In Fig. 13 is represented a cutting 25 ft. deep for a single line.

For a wide canal, Fig. 14, three or more machines slightly in advance of one another may be used, the centre one leading. A similar arrangement was employed in making the new channel of the River Witham, near Boston.

After a gullet has been driven, the excavation may, however, be widened in another way, often employed in dock and harbour works, namely, by working along a "side face" with a single road, as shown in Fig. 7. A train of empty wagons can then be drawn up alongside the navvy, and each truck as it is filled is pulled backwards by the locomotive, so as to bring the next one into the right place for receiving the contents of the bucket, no horse being then required. But although this appears a very simple plan, it is found difficult in practice to move each wagon through just the right distance, and time is lost, and the dirt spilt about. It is therefore best to store the empties behind the machine as before, and bring each forward over a jump to be loaded; in this way, with experienced men on the machine, two horses can be kept going. The jump lines should of course be as near to the machine as possible, and the central track should follow up close with the coal truck and the water-tank wagon. Two or more navvies also can be worked along the same face ahead of each other, the centre road forming the side road for the one behind, and so on, as in the section, Fig. 15.

The size of the excavation, the material, the facilities for tipping, &c., will in each case determine which system can be used with the greatest advantage. With the hardest and most tenacious clay, about 22 ft. is the best depth, as then no wedging down is required of the stuff above the reach of the bucket teeth. With loose earth 30 ft. can be just as easily taken, since it all falls down to the machine. Within these limits, the deeper the face the better, as the greatest quantity can then be scooped out between each forward movement. To stop, ease the jack-screws, lay rails, run the navvy forwards, tighten down the screws, and get to work again, requires from five to ten minutes, during which of course no wagons are filled. The fewer the stops in the day, the greater will be the number of wagons filled; and the larger the quantity of material within reach of the bucket, the less seldom need the navvy be moved forwards. A good deep gullet offers as a rule the most advantage, because the whole of the semicircle in front of the machine can be cut round, and not merely part as in the side-face cutting; there is better facility for changing the wagons smartly, and there is a shorter average distance for the jib to swing through in order to get over the wagon. All these things economise time and increase the duty, for a few minutes' loss now and then means fewer cubic yards got out in the day.

Men Employed.—How small this loss is permitted to be depends even more upon good management than upon the system employed; and of equal importance is the skill of the driver and wheelman on the machine. From the nature of their duties it will be apparent that they must work well together; and good sense and smartness are necessary for obtaining the best results. When handy and suitable men are chosen, their training is soon accomplished; indeed, by the time the excavating is in full working order, it will generally be found that the necessary dexterity has been acquired. The driver takes the lead, and is usually paid so much extra for each wagon filled per day beyond a stipulated number. If he fills 230 wagons, for instance, he receives his day's pay; but if 280 wagons, $1\frac{1}{4}$ day's pay; it is thus to his interest to take care no time is lost. Besides these two there is a fireman to stoke and clean.

The rest of the help depends upon the cutting. As a rule there may be added one ganger and eight men, to act as plate-layers and lay the roads for the wagons and navvy, and to trim the slopes; one man on the top to break down the loose earth, and either one or two horses with their drivers, or say a total of fifteen men and two horses. Where the excavation is extra deep and of very hard material, another man may be required on the bank above, and perhaps extra help on the slopes. With these exceptions the labour remains fairly the same, whatever be the kind of stuff. For dock work, where the slopes do not require finishing till the side is reached, the labour will be proportionately somewhat less than in a railway cutting, and nine to twelve men may be taken as the average. When blasting is necessary, extra help has of course to be reckoned for.

Output.—The output is affected by the hardness of the stuff. For the very hardest clay intermixed with stones and boulders, the capacity of the bucket is 1 cubic yard; for all other hard stuff $1\frac{1}{4}$ yard, which is the most useful size; whilst for loose earth, sand, gravel, or drift, $1\frac{1}{2}$ or even $1\frac{3}{4}$ yards can be used.

For all sizes of bucket the number of cuts per hour remains approximately the same, about three-quarters of a minute being the time necessary for each. Moving forwards, laying rails, and waiting for wagons may be set down as a deduction of ten minutes per hour, leaving fifty minutes for cutting, which gives say sixty as the number of bucket loads per hour, or 600 per day of ten hours, as the theoretical capacity, equivalent to a daily output of 600, 750, and 900 cubic yards with the 1-yard, $1\frac{1}{4}$-yard, and $1\frac{1}{2}$-yard buckets respectively; and this agrees well with the results actually obtained.

Working Expenses.—The working expenses vary according to the locality. The following examples, taken from two different contracts, in the south of England and in Scotland respectively, may be considered as representing the two extremes, the output being in each case about equal:

* Paper read before the Institution of Mechanical Engineers at Lincoln.

DUNBAR AND RUSTON'S STEAM NAVVY.

CONSTRUCTED BY MESSRS. RUSTON, PROCTOR, AND CO., ENGINEERS, LINCOLN.

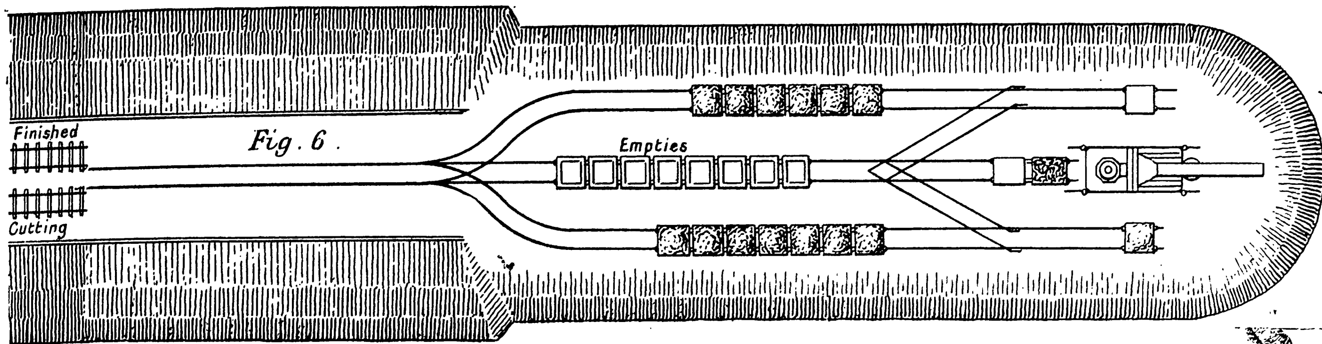


Fig. 6.

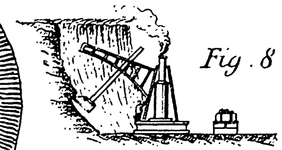
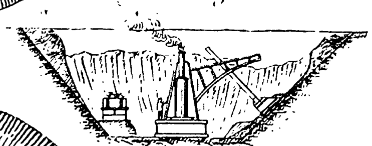


Fig. 8.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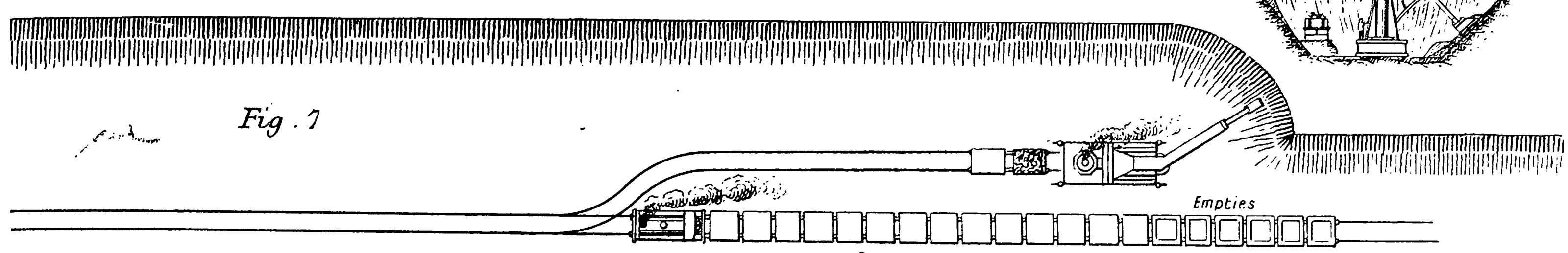

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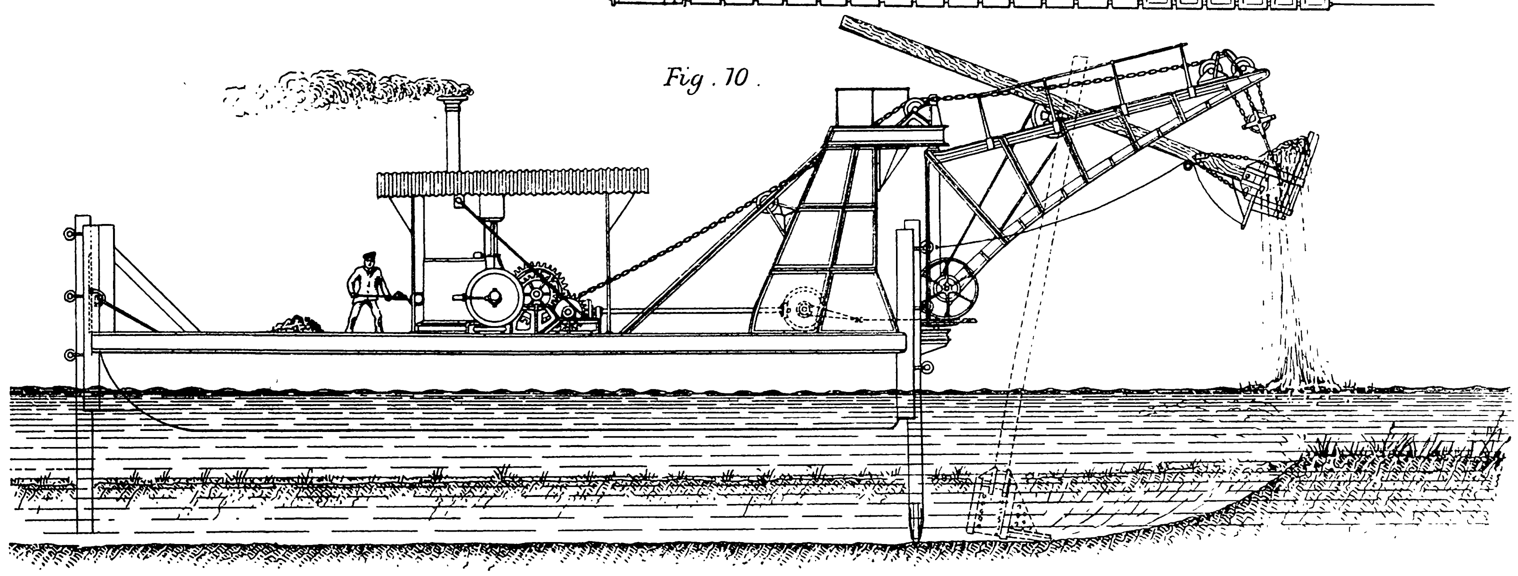
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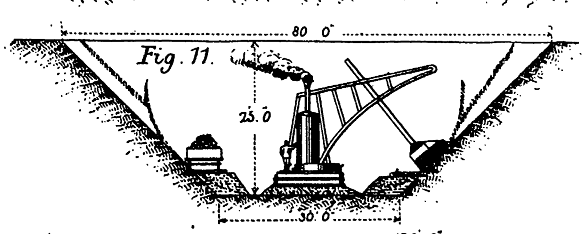

Fig. 11.

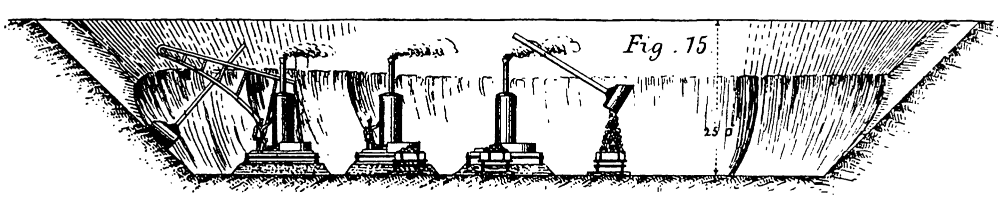

Fig. 15.

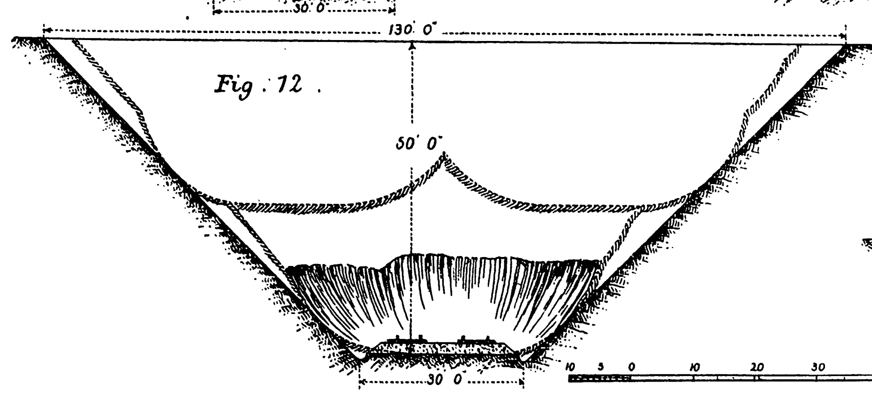

Fig. 12.

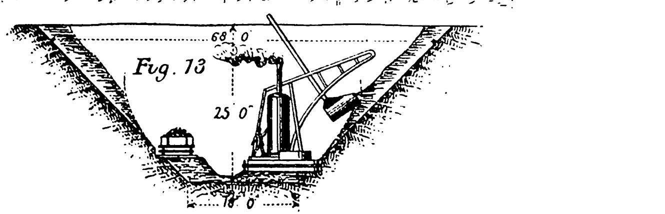

Fig. 13.

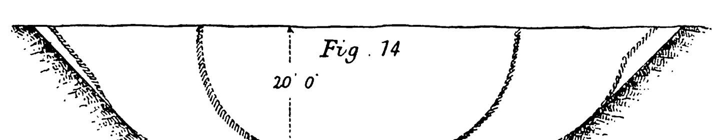

Fig. 14.

10 5 0 10 20 30 40 50 FT.

South of England.

	£	s.	d.
One engine driver	0	7	6
,, wheelman	0	4	6
,, fireman	0	3	6
,, ganger	0	8	4
Eight men at 4s. 6d.	1	16	0
Two horses and two drivers	1	0	0
One man at top	0	4	6
10 cwt. of coal at 36s.	0	18	0
Water, oil, and waste	0	2	6
Total per day	5	4	10

Scotland.

	£	s.	d.
One engine driver	0	5	0
,, wheelman	0	4	0
,, fireman	0	2	6
,, ganger	0	4	6
Eight men at 3s.	1	4	0
One horse and driver	0	10	0
,, man at top	0	3	0
10 cwt. of coal at 6s.	0	3	0
500 gallons of water	0	0	3
Oil, tallow, and waste	0	2	6
Total per day	2	18	9

In the first example the prices are all high, particularly that of the coal. In the second the prices are moderately low. The average may therefore be set down at from 3*l*. 10s. to 4*l*. per day.

For depreciation, repairs, and interest on capital, about 1*l*. per day may be reckoned, being arrived at as follows :

The total cost of the machine weighing 32 tons is about 1250*l*., namely, 1175*l*. price at the works, and 75*l*. for carriage and erection on the site of the excavation ; but in many cases the amount allowed for erection can be considerably reduced :

	£	s.	d.
Depreciation at 10 per cent. on 1250*l*.	125	0	0
Repairs and renewals at 5 per cent.	62	10	0
Interest on outlay at 5 per cent. ...	62	10	0
Total per year	250	0	0

This amount may be considered to be well over the ark. Allowing, therefore, 300 working days in the year, and deducting two days per month for stoppages through bad weather, about 270 available days will remain. The amount to be reckoned under the above items will therefore be 18s. 6d. per day, or about ⅓d. per cubic yard, or say from ¾d. to 1d. per wagon.

Making all allowances therefore, the total cost of the machine may be set down at say 4*l*. 15s. per day; which, divided by the output, gives as the cost of excavation say 1½d. per cubic yard for sand or gravel, and 2d. for hard clay. Where the excavation is small, or the machine is under a disadvantage, these prices will of course be somewhat exceeded; and 2d. to 3d. per cubic yard may be then allowed. The following results, obtained directly from contractors using the navvy, show a substantial agreement in this respect.

Kind of Cutting.	Material.	Size of Bucket.	Cubic Yards per Day.	Cost per Cubic Yard.
		cub. yd.		d.
1. Dock works ..	Boulder clay	1	480	1½
2. Railway cuttings	Chalk with stratum of flints	1½	500	2½
3. Harbour works ..	Clay	1	660	3
4. Dock works ..	Hard red marl	1½	940	2
5. " " ..	" "	1½	740	2½

It is difficult to estimate the cost of doing the same amount of work by hand, but a saving of 2d. to 6d. per cubic yard may be safely reckoned upon. Where the stuff is hard it is still greater. For stiff brown clay 10¾d. per yard has been given as the cost; and for stiff hard tough clay, containing boulders weighing from ½ cwt. to 4 tons, the cost was estimated at 1s. 6d. per cubic yard by hand labour, whilst the cost was 4¾d. by the machine, which was one of the earliest sent out. With the present stronger machines the cost would have been still less; in short the harder the stuff, the greater is the economy over handwork.

Equivalent Hand Labour.—The number of men required to do the work by hand will vary very much. For instance, in excavating 190 cubic yards per day the following men were necessary: one ganger, ten gullet men, seventeen wingmen, two platelayers, one brakesman, two horses and two drivers; or a total of thirty-three men and two horses. At the same rate to excavate by hand 600 yards per day, as the navvy does, ninety men would be required. The steam navvy may therefore be considered equal to at least sixty or seventy men.

The machine gives also the important advantages of enabling faster progress to be made, and economising time, as none is lost in disputes with the men; the cost of excavation can therefore be estimated with greater accuracy, and when once it has been determined for a given cutting, the rate may be relied upon till its completion. The contractor therefore is practically independent of strikes in this department of his business; and is further relieved of the trouble of getting together so large a body of men, and of housing and providing for them in out-of-the-way districts.

Subaqueous Work.—The navvy can also be worked for excavations under water, for which purpose it is mounted on a pontoon, as shown in Fig. 10. The pontoon is about 50 ft. long by 22 ft. wide, and draws 2½ ft. of water; it is built specially to receive the machine, and is most conveniently made of iron; but where timber is on the spot and plentiful, it may be of course substituted with advantage. For better distributing the weight in the pontoon, the frame of the navvy is divided transversely, and a distance-piece is bolted in between for completing the continuity. Extra stays are carried back from the top of the tower down to the engine end; and an extra roller is put in, to take the sag out of the main chain. Rollers are also provided under the step of the jib for the drawing back chain that winds upon the drum on the second shaft. The bucket arm has of course to be lengthened, according to the depth to be taken out; and the bucket is made with rather more taper, for the stuff to clear itself, and is pierced with holes to let out the water. The action is similar to that on land, except that the resistance of the water somewhat impedes the back swing of the bucket, necessitating the use of the drawback chain. The pontoon is steadied by three piles or legs, one at each front corner on either side of the jib, and one centrally behind the engine; these are provided with racks and pauls, and are raised by hand levers; two or three crabs, with guy ropes attached to anchors or otherwise, are also necessary. The machine delivers into a barge moored on one side of the pontoon, a second empty barge being brought up on the other side ready to receive the stuff as soon as the first is full. When all within reach of the bucket has been excavated to the required depth, the piles are raised, and the pontoon hauled forwards by the guy ropes; the piles are then dropped again, and the next piece in front is excavated.

The deeper the face, the better; indeed a very shallow face can hardly be dealt with successfully. The water also should be comparatively still, as waves lift the pontoon and interfere with the bucket taking its proper cut; the output can be averaged at about half what it would be on land. The cost per cubic yard may be taken at about double that of a dry excavation with similar depth of face, up to say 6 ft.; but it will also vary according to the depth below the water line.

As a dredger the machine has not been extensively tried. For mud and sand it is hardly considered as a competitor of the dredgers in ordinary use; but where there is a very hard bottom and a fair face to work at, it offers without doubt very considerable advantages.

INSTITUTION OF MECHANICAL ENGINEERS.

Address of the President, Mr. Jeremiah Head.*

(*Concluded from page* 192.)

Smith Work.—Within a certain range of temperature steel can be more successfully worked than iron; but that range is narrower. Thus at the temperature familiarly known as cherry-red, a good steel plate can be bent double, and then redoubled crosswise. An iron boiler plate is considered good if it bends double with the fibre, and to a right angle across, at a full red heat.

Steel plates are best worked at a low heat, iron ones at a somewhat higher heat. At a welding heat steel plates require the utmost care to avoid burning or fusing, after which they become quite brittle. A number of steel plates which I saw lately being dished hot to a very awkward form, between two dies under a steam hammer, were mostly failing. The men were advised to lower the temperature to cherry-red, and the remaining plates all stood the test.

Steel is less easily welded than iron. Thus the blow-holes, or piping, which occasionally occur in ingots, are never welded up in subsequent rolling. They become enlarged, and are the cause of the lamination which is not infrequently found in steel plates. Mr. Adamson, in the course of his paper read at Paris in 1878,† gave it as his experience that some steel could be welded, but not all. He believed that for this purpose the carbon contained should not exceed 0.125 per cent. It is still true that all steel will not weld with ease and certainty; and it is not yet quite clear wherein the difference lies.

It must not be forgotten that there are welds and welds. A good weld is one where the welded pieces will afterwards bear the same cold bending through the weld as through the neighbouring solid part. Probably there are very few welds, though to all appearance perfect, which would stand this test. As an instance of good practice in welding steel, I may mention that at Messrs. R. and W. Hawthorn's works at St. Peter's, Newcastle, marine boiler flues, 7 ft. long, are soundly welded at one heat. A V groove joint, carefully planed out, is adopted; and certain fluxes are used to fuse the scale, which would otherwise prevent adhesion of the surfaces.

Flue rings, conical tubes, and other details of boiler work, involving welding and subsequent flanging, can now be made of suitable steel almost as easily as of iron; and when made, they are incomparably better. For to make a welded and flanged tube of iron not more than 7/16 in. thick, a very high quality of iron must be used; and even then the tube will be found unable to stand subsequent rough usage, such as setting cold to suit deviations in the dimensions of the flues. The repeated heatings undergone during welding and flanging have indeed taken the "nature" out of the iron, and left it brittle. But steel tubes when finished and annealed will stand battering about cold, without any fear of damage whatever.

Let us now consider for a moment the behaviour of steel at higher than atmospheric, but yet non-luminous temperatures. Iron plates will bend with the grain to certain moderate angles, inversely proportionate to their thickness. Across grain they will bend much less. If, however, they be heated, their bending capacity is improved more and more up to a full red heat. In making iron masts and yards for ships, it is necessary to bend the plates across grain to a rather quick curve. On account of the great length and small breadth of such plates, it is impossible to develop much fibre by rolling in a cross direction; and consequently, if bent cold, longitudinal cracks are apt to appear. But if heated to a very moderate extent they will bend easily. So in closing seams in iron boilers, it is customary to warm the parts to be closed by heaters, and then beat in with heavy hammers. In setting studs or straightening anything accidentally bent, the application of a little heat has always been found, in the case of iron, to make easy and safe what would otherwise be difficult and risky.

Now steel appears to differ entirely from iron in this respect. If five pieces be cut from a steel plate and tested in different ways it will be found that: the first may be bent nearly double cold; the second may be doubled and redoubled at a cherry-red heat; the third will successfully undergo Lloyd's quenching test. If the fourth be then filed bright on the edges, and held over a smith's fire until the bright edges turn blue or straw colour, and it be then bent, it will probably be found to break short at about a right angle, the colour of the fracture being the same as of the edges, and it will have all the appearance of brittleness. If the fifth piece be heated red-hot, and then slowly cooled until the edges, which must be kept bright, turn blue or straw colour, the same brittleness as in the last case will probably be found, though not quite to the same extent.

Attention was called to this unreliability of steel at a non-luminous heat, by Mr. Adamson in the paper already referred to; and since then the facts have been confirmed by experiments made in this country and in America, though no explanation of the phenomenon has to my knowledge, ever been given. Mr. Ephraim Jones, of Middlesbrough, who rolls sheet steel, informs me that down to 1/16 in. and ¼ in. thickness he has experienced no trouble from brittleness. Nor has he with the very thin gauges, which he always anneals. But with the intermediate gauges, which were finished at a black heat, he had great trouble until he determined to anneal them also. There are many circumstances, however, wherein it is obviously difficult to avoid working steel at a low or brittle heat, and therein lies one of its great dangers.

Corrosion.—No inquiry into the relative suitability of such materials as wrought iron and steel for permanent constructive works would be complete, which took no account of their respective capacities to resist corrosive influences. Both of them are obtained from the mixtures of metallic and non-metallic oxides which we call ores. These ores when found are, as regards oxidation, in a stable condition; whereas the purer the derived metals, the more unstable they are. They are always seeking, as it were, to return to their primitive condition; and this return we call corrosion.

To prevent it, requires constant care, watchfulness, and expense. Coating with paint is the usual device. This is an attempt to cover with an air-tight film of metallic oxides or metalloids, themselves in a stable condition. In order to secure adhesion it is customary to mix these with vegetable oil, a substance which is not in a permanently stable condition. Pure metallic oxide coverings, such as that which is obtained by the Bower-Barff process, might be expected to last for ever. But it is only too well known that the protection afforded by painting is of limited duration, and that corrosion goes on in spite of it. Indeed any iron or steel structure in the open air, well painted and then neglected for, say, ten years, will by that time be found to have shed off almost every vestige of paint; and nothing but a rapidly rusting surface will be visible. Therefore the intrinsic anti-corrosive qualities of the metals forming permanent structures, such as railway bridges and roofs, are of the greatest importance.

Authorities differ widely as to the relative liability to corrosion of wrought iron and steel. Sir I. Lowthian Bell said at Paris, in 1878,* that he should have expected *à priori* that steel would corrode less than iron, because the first was pure and homogeneous, and the second composed of alternate layers of metal and cinder. Every statement of so high an authority as your ex-president deserves most serious consideration. But after much reflection upon this particular one, I have hitherto been unable to assimilate it. The cinder which is the principal impurity in wrought iron, which causes its diminished tenacity, and gives it its superiority in welding, is a basic silicate of iron. It is in a perfectly stable condition, or in other words a perfect paint. Lumps of it exposed for years to atmospheric influences will still be found unaffected by corrosion. Mild steel is nearly pure metallic iron, and there is nothing in it (except minute quantities of carbon, &c.) which is not unstable, and eager to return to its primitive oxidised condition. The lines or layers of metallic iron in commercial wrought iron are of course as liable to corrosion as mild steel. But every line and every layer is surrounded and coated with a film of non-corrodible cinder. It is in a sense painted throughout. No doubt these sheaths of cinder are not completely continuous, and therefore corrosion will work its way through in time. But their tendency must be to impede it. Wrought iron therefore, containing as it does a smaller proportion of corrodible material, and intermixed as it is with a larger proportion of non-corrodible material, may I think be expected *à priori* to be less liable to a rapid return to its pristine condition than the purer article mild steel: and not more so.

But after all, this question must be decided rather by direct experiment than by *à priori* expectations. The British Admiralty appointed a committee in June, 1874, to examine into the causes of corrosion in marine boilers. This committee investigated the subject very carefully, perseveringly, and conscientiously. Nothing done before or since can compare in extent or importance with the results of their labours. They took evidence of leading chemists, metallurgists, engineers, iron and steel makers, naval engineers, inspectors of steamer lines, Board of Trade and Lloyd's officers, foremen boilermakers, and others; and they visited the principal localities and works in the country where there was a reasonable prospect of obtaining information. After three years of laborious work they published their final report in 1877. In it they say that the opinions given by the authorities they examined were so utterly divergent that they had been compelled to reserve their own until they had attempted to reconcile some of the discordant statements by actual experiments. Of these they had made a long and careful series.

The specimens operated on included sixteen kinds of iron and steel plate discs, including ordinary and high-class iron, Lowmoor iron, Bessemer, open-hearth, and crucible steel, and Whitworth compressed steel. These were tested in fresh water from several sources, and sea water of various degrees of saltness; in land and marine boilers; in the water space, the steam space, and at water level; with air admitted, and without; with lubricants in the water, and the reverse; with zinc, and without. The conditions which applied to one specimen applied to all in each case.

The following is the pith of the committee's conclusions in their own words:

"It was reasonably expected that . . . . those materials made by fusion, and consequently free from cinder, and in a condition of more perfect mixture, should have resisted the 'pitting' action much better than piled iron. Such, however, is not the case."†

* Delivered at the Lincoln meeting, August 4, 1885.

† Journal of the Iron and Steel Institute, 1878, pages 395-6.

* Journal of Iron and Steel Institute, No. 2, 1878, p. 450.

† Third report of Admiralty Boiler Committee, page xxxvii.