No. 1,566.—“Description of the Excavating Machine, or Steam Navy, with the Results of its Use, on the West Lancashire Railway.” Communicated by CHARLES DOUGLAS FOX, M. Inst. C.E.

GENERAL DESCRIPTION.

IMMEDIATELY after receiving possession of the land embracing the deep part of No. 9 cutting, two trial holes were sunk from the surface down to the formation level. It was thus found that the material to be excavated was a stiff brown clay throughout, free from large stones, thereby inducing the belief that it might be worked by machinery, which up to this time had been almost exclusively employed in sand, silt, loose shale, or soft free clay. After visiting two or three of these machines, Messrs. Barnes, Squire, and Co., of Southport, the contractors (who have kindly collated the following facts), put themselves in communication with the makers (Messrs. Ruston, Proctor, and Co., of Lincoln), at the same time suggesting the strengthening of certain parts. The result was the purchase on the 12th of June, 1877, of a steam navy, Plate 7, “consisting (as the makers describe it) of a rectangular truck, supported on four wheels, carrying the engine and boiler, wheel gear, fixed post, and jib. The engine is of the vertical type, of 10 HP. (two cylinders), and gives motion, by a pinion upon its crank shaft, to the main spur wheel upon the main hoisting drum shaft, from which the motion is communicated to the drum for swinging the jib, and the drum for drawing the bucket back. The drum for swinging the jib has a reversing friction motion for swinging both ways. The bucket handle is regulated by hand wheel and chain pinion, which gives motion to a pinion at the top of the jib gearing, into a rack upon the bucket handle. The truck is provided with six strong screws, or lifting-jacks, for the purpose of steadying and taking the whole weight of the navy when at work. The jib which carries the bucket handle is constructed entirely of plate iron, and strengthened with angle iron, as also is the fixed post and truck. At the bottom of the fixed post is a water tank for supplying the boiler. The bucket is of plate iron, and fitted with four steel pointed teeth, and a sharp steel nose where it first enters the ground. Improved propelling gear is also provided for moving the machine along the

rails by a self-acting arrangement of reversing tooth gear, which communicates the motion to the front axle by an endless chain. A corrugated iron roof covers the engine, and the whole of the working parts, except the jib gear."

DESCRIPTION OF WORKING.

The dimensions of the cutting to be excavated were 30 feet wide at the base, slopes 2 to 1, greatest depth 22 feet, smallest depth 12 feet, length about 15 chains, contents about 45,000 cubic yards.

The "navvy" is placed upon the formation level of the cutting, on two lengths of large flat-bottomed rails, laid upon sleepers 12 inches by 6 inches deep, about 2 feet apart. A tramroad for empty wagons follows up the centre line behind the "navvy," and there is a road on each side the machine for filling wagons, parallel to the centre road, but at a level of about 3 feet above formation. The wagons have to be brought up to a position at right angles to the centre line of the machine, and directly under the bucket, for filling. The bucket describes a radius of about 20 feet, thus requiring a width of working room exceeding 40 feet across the cutting. This is secured by taking advantage of the slopes at the false level. The roads are connected at the mouth of the cutting by points, and close behind the "navvy" by jumps, so that all returned empties are passed up the centre road, and supplied to each side alternately by horses through the jump. When filled, they pass out down the side road to form a train at the mouth of the cutting. In this way two wagons can be filled in a few seconds over five minutes. The process of getting the earth by the machine bucket may be best described as paring the surface from the bottom to the top in a series of strips, about 4 or 6 inches deep, from the centre of the cutting to each side wagon, in the form of a basin, resembling the inside of a conchoidal shell. The man at the wheel regulates this motion, and may show great skill or otherwise in its guidance, as the more regular the action the less is the wear and tear of the machinery. When the bucket reaches the top, the driver jibs round to the wagon, drawing slightly in from the face by another motion at the same time, and directly the bucket is over the wagon, the wheel man pulls a string connected with a catch to the trap-door, or lid, at the bottom of the bucket, and the contents fall into the wagon. The catchman refastens the catch (having previously thrown back any lumps which roll in its

way), and the bucket returns and drops to the ground for another slice. Men in the gullet and on the slopes constantly cut out the little corners, which lie outside the basin or bucket radius. This is continued until the face becomes too far advanced for the bucket to reach, when the whole machine is moved onward by screwing up the jacks, pulling the rails forward, lowering it down again on its wheels, and the "navvy" then advances by its own locomotion to the position necessary for a fresh start, an operation which usually occupies about ten minutes. This moving of the machine requires to be done about four or five times a day, and at the close of a good day's work in a cutting, the "navvy" will be about 6 feet in advance of the position in the morning.

COST.

	£.	s.	d.
The net cost of this machine as described was	1,150	0	0
Duplicate parts were added as a provision for breakdowns, viz. :—One $\frac{3}{4}$ -inch main chain; one $\frac{3}{4}$ -inch swinging chain; one spur pinion; four adjusting screws and swivels for bucket; one bevel pinion for swinging gear; two rack pinions; two lengths straight rack; four steel ended teeth with fastenings; one 19-inch sheave pulley; two 10-inch sheave pulleys; four friction rollers; one slewing clutch; one travelling wheel; and two brass bushes for main drum, at an additional cost of	27	0	6
Add carriage from Lincoln to Southport	41	8	1
„ „ Southport to cutting site, say	11	11	5

This distance was about 8 miles, and the weight of the different parts amounted to about 35 tons. A tramway was connected with the railway at Southport, by which the machine was conveyed to within a few yards of its destination.

Cost of machine on the ground	1,230	0	0
The fixing proved a tedious and expensive matter.			
The whole of the machinery arrived on the ground on the 19th of June, but the "navvy" did not commence regular work until the 17th of July, involving a cost in labour of fitters, carpenters, labourers, &c., of	49	19	4
Add to this a proportion of stores, smiths' work, timber foundations, superintendence, &c., estimated at, ...	20	0	8
		70	0
Total estimated cost ready for work	1,300	0	0

COST OF WORKING.

From the 17th of July to the 31st of December the expenditure was as follows:—

<i>Wages:</i>	Days.	s.	d.	£.	s.	d.	£.	s.	d.
One engine driver	126	6	0	37	16	0			
„ cleaner.	126	4	0	25	4	0			
„ stoker	126	2	6	15	15	0			
„ wheelman	126	5	0	31	10	0			
„ ganger	165	8	4	68	15	0			
„ pumper	126	3	0	18	18	0			
„ catchman	126	4	6	28	7	0			
Four gullet trimmers	420	4	3	89	5	0			
„ slope „	360	4	3	76	10	0			
One brakeman	126	4	6	28	7	0			
Two platelayers	242	4	0	48	8	0			
„ horses	330	5	0	82	10	0			
„ drivers	330	4	3	70	2	6			
							621	7	6
<i>Stores:</i>									
32 gallons oil	4	0	6	8	0				
127 lbs. waste	0	3	1	11	9				
21 lbs. tallow	0	5	0	8	9				
86 tons coal.	14	0	60	4	0				
Sundries, including smithy, say			2	17	6				
							71	10	0

Repairs:

There have been about twenty breakdowns, but none of a serious nature. These have varied from a stoppage of one hour to two days, during which time the men have been made useful in lightening the cutting sides, and filling wagons by hand labour. Nine of these breakdowns have occurred through the fracture of the chain gear, which, however well greased, has to sustain a great amount of wear and tear. In one instance the drum had to be lifted, and a new bush inserted. In three or more instances, the catch at the back of the bucket lid got damaged by the shaft falling too quickly, and smashing the bucket against the pillar foot; the valves dropped off the spindle twice, and were once broken; the wheel shaft was bent once, the block check broke three times, &c., the cost being, say ; . . . .

25 2 6

Depreciation:

This has been estimated at 25 per cent. per annum on the total outlay, say therefore 12 per cent. on £1,300

156 0 0

874 0 0

At this cost the earth is delivered at the cutting mouth ready

to be conveyed to its destination. The following is a list of the wagons and their contents, so delivered:—

WAGONS FILLED by STEAM NAVVY in No. 9 CUTTING on the WEST LANCASHIRE RAILWAY from the 17th JULY to 31st DECEMBER, 1877.

	Number each Month.		Contents per Wagon.	Number of Cubic Yards Excavated per Month.			Number of Days Worked.			Daily Average in Cubic Yards.		
	By Machine.	By Hand.		By Machine.	By Hand.	Total.	By Machine.	By Hand.	Each Month.	By Machine.	By Hand.	Each Month.
July.	613	..	3	1,839	..	..	12	..	..	153	..	..
	..	3	2½	..	8	..	..	1	..	..	8	..
	..	..	..	..	..	1,847	..	..	13	..	..	142
August	1,386	..	3	4,158	..	..	16	..	..	260	..	..
	..	134	2½	..	335	..	..	8	..	..	42	..
	..	..	..	..	..	4,493	..	..	24	..	..	187
Sept.	1,841	..	3	5,523	..	..	20	..	..	276	..	..
	..	23	2½	..	57	..	..	1	..	..	57	..
	..	..	..	..	..	5,580	..	..	21	..	..	266
Oct.	1,276	..	3	3,828	..	..	15	..	..	255	..	..
	..	263	2½	..	658	..	..	10	..	..	65	..
	..	..	..	..	..	4,486	..	..	25	..	..	179
Nov.	1,029	..	3	3,087	..	..	13	..	..	237	..	..
	..	174	2½	..	435	..	..	9	..	..	48	..
	..	..	..	..	..	3,522	..	..	22	..	..	160
Dec.	1,258	..	3	3,774	..	..	17	..	..	222	..	..
	..	79	2½	..	298	..	..	4	..	..	74	..
	..	..	..	..	..	4,072	..	..	21	..	..	194
Totals	7,403	676	..	22,209	1,791	24,000	93	33	126	239	54	190

Number of days in the calendar for above period less Sundays = 165, the remainder being lost principally through wet weather.

Greatest number of wagons turned out in one day, September 28th and October 5th, = $123 \times 3 = 369$ cubic yards.

Actual measurement of cutting at the end of the year 24,964 cubic yards, which included a small quantity run out with barrows.

Thus, during the whole period quoted, 24,000 cubic yards of material have been turned out of the cutting at a total cost of £874, or say 8½d. per cubic yard.

Had the cutting been worked entirely by hand labour in the ordinary way, it is estimated that the cost of production would have been as follows, taking the daily average of 190 cubic yards,

and the number of working days at 126. 190 cubic yards at $2\frac{1}{2}$ cubic yards per wagon = 76 wagons per day, say 11 sets per day; 7 wagons in a set, consisting of 2 gullet and 5 wing wagons, which would require—

		s.	d.	£.	s.	d.	£.	s.	d.
One ganger	at	8	4	0	8	4			
Ten gullet men	„	4	3	2	2	6			
Seventeen wing men	„	4	3	3	12	6			
Two platelayers	„	4	0	0	8	0			
One brakesman	„	4	6	0	4	6			
Two horses	„	5	0	0	10	0			
Two drivers	„	4	3	0	8	6			
							7	14	4
Add stores, tools, &c., say							0	15	8
Thus the excavation of 190 cubic yards would cost about							8	10	0
10½d. per yard									

Thus there is a net saving of cost in excavating by the machine of $2\frac{1}{2}$ d. per cubic yard.

This saving has been effected under rather unfavourable circumstances. The summer was wet, and the rain proved injurious to the steep slopes made by the “navvy,” by causing slips, thereby often necessitating a day’s hand-filling to clear the “navvy” again for work. Moreover, delay was frequently occasioned in the middle of a good working day by the opening of a bridge over a river to let boats through just in front of the cutting; and there was an obstruction from an inclined tramway, which ran down one side of the cutting, and had to be kept clear for through traffic, close to the “navvy.” This for fully two months prevented the wagon road being worked on each side of the machine.

REMARKS.

Under favourable circumstances the “navvy” may be considered equal to thirty or forty men. In a cutting of clay of small tenacity the steeply excavated sides, and consequent slips in wet weather, might prove a great disadvantage.

The machine possesses an advantage in the dependence to be placed upon its regular work as compared with the frequent losses of time through the strikes and drinking habits of men; and also, in isolated districts, by its saving in the extent of lodging accommodation required for the men. The existence of boulders in the clay to any extent would probably be fatal to the safe working of the machine.

It will have been observed that the capacity of the wagons filled

by machinery has been reckoned at $\frac{1}{2}$ yard more than for those filled by hand; the reason is that the "navvy" possesses the advantage of filling all wagons by an overhead drop, and collars were therefore fixed on to the sides and back of each wagon, so that they held fully 20 per cent. more than they did before.

The improvements to be effected are—

1. The widening of the bucket bale. At present the bucket displaces a portion of the load in the action of drawing in from the face, almost every time; and whereas four bucketfuls are required for each wagon, three would raise just the same quantity if this portion of the load could be preserved to drop through the bucket into the wagon.

2. It would be a great advantage if the jibbing movement could be carried back to about 120° from the centre line, instead of being restricted as it is to about 90° . It sometimes happens that the wagon cannot be got quite at right angles to the jib, in which case the earth falling out of the bucket does not hit the centre of the wagon, and sometimes partly misses the wagon.

3. The catch gear would be better if it could be protected from being smashed against the jib pillar in an occasionally too rapid descent.

4. For cutting gulleys, a machine with a taller jib of less radius, with a larger bucket, would be more useful, the present one being best adapted for side cutting, and for excavating large areas.

5. Some regulation of the rapidity of motion in several of the working parts, to give a more steady action, is very desirable.

6. An arrangement for pulling the empty wagon out of the centre road into position for filling, without the use of a horse, which in this operation has to run under the bucket into a rather dangerous position, would be of great advantage.

The Paper is illustrated by a drawing, from which Plate 7 has been engraved.