ON THE CONSTRUCTION AND WORKING OF A VERTICAL-ACTION STEAM-DREDGER IN INDIA.

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The Dredger described in the present paper is one recently constructed by Mr. Charles Fouracres, Engineer in the service of the Government of Bengal. It was first put into regular work in the Patna Canal in Bengal under the direction of the author, who from time to time personally inspected the working of the machine, and verified the observations on which the facts given in this paper are based. Another dredger on the same principle is also working in the Arrah Canal in Shahabad, and one or two more are in course of construction, one for the Midnapore Canal near Calcutta, for the purpose of clearing out the silt which annually blocks the heads of most Indian canals.

Description.—The general arrangement of the dredger, as it has hitherto been constructed, is shown in Fig. 1, Plate 69. The peculiarity consists in the machinery, and in the arrangement of the parts which are there seen suspended from the head of the jib. The arrangement for working this machinery by means of a portable engine, crab-winch, and crane, as shown, is somewhat primitive, and would not of course be adhered to in large dredgers; it was adopted simply because those machines were the best means available, in the canal workshops, for fitting up the dredger. The engine used was one of 6 H.P. nominal; it drove the $1\frac{1}{2}$ -ton crab-winch direct by two straps, one of which was crossed and one straight; so that the man at the winch was able, with great facility, to wind up or unwind the chain, which was attached at one end to the drum of the winch, and at the other to the dredging apparatus. Six mud-punts, with flush decks and removable sides, accompanied the dredger.

Each punt was capable of carrying only about 18 cubic yards of material. It was found that these six punts were just sufficient to keep the dredger in full work, when the lead did not exceed three-quarters of a mile. All the mud was discharged from the punts into the river by labourers throwing it overboard; the material in each punt being levelled off and measured before it was discharged.

The crane, to which the dredging scoops were hung, was made to revolve on its vertical axis by a horizontal rack, which could be put into gear with a pinion on the outer extremity of the main shaft of the winch, by means of a pedal. This pedal the man driving the winch pressed with his foot whenever he wished to cause the dredging bucket to revolve, whether in order to come over the mud-punt and deposit its load, or to return to the centre line of the dredger. This arrangement, by which three machines—the engine, the winch, and the crane—were made to do the work of raising and lowering the dredging bucket, was rather an expensive one, as each machine required an attendant: whereas had a steam-crane, with rapid reversing and revolving gear, been available, one man might have done the work of these three.

The dredging apparatus, as shown in Figs. 2 to 6, Plates 70 and 71, consists of two segmental scoops *M*, hinged upon a cross-head which is firmly welded on the bottom of a wrought-iron spear *L*; this latter being attached by a key to a light wooden spear *C*. The scoops, when closed, form a bucket of the shape of about half a cylinder. Two metal collars, *W* and *X*, slide freely on the iron and wooden spears respectively; the upper one is connected to the scoops by the light iron rods *Y Y*, and the lower one by two chains *P P*. One end of each of these chains is connected to the lower collar *W*, Figs. 2 and 3, and the other, after passing through one of the sheaves *Q*, is attached to the end of one of the semi-circular angle-irons *J J*; the chain on the right-hand of the spear being attached to the angle-iron which is riveted to the right scoop, and the chain on the left-hand of the spear to the angle-iron which is riveted to the left scoop. These chains then cross each other, as it were, around the sheaves *Q*; and since the semi-circular angle-irons also cross one another at the same point,

the chains, when placed in tension, tend to close the scoops upon one another into the position shown in Figs. 3 and 5. The angle-iron which is riveted to the one scoop wraps itself round the other scoop, when the bucket is opened into the position shown in Figs. 2 and 6. Both of these angle-irons are carefully chipped and filed to a segment of a true circle on their upper edges; these edges bear against two friction rollers, which revolve on the same pin that carries the sheaves Q, and tend to preserve the angle-irons in their proper shape.

The sliding collar W carries a sheave, around which the main lifting chain B is rove. When working in soft soil, the chain B is attached directly to the collar W; but in hard soil power is gained by passing the chain round the sheave, and fastening the end of it to the spear, as shown in Figs. 2 and 6. This main chain is worked over the head of the crane, as shown in Figs. 5 and 6. Stops are provided on the scoops to prevent them from over-running themselves, and thus getting jammed.

One of the main features of the dredger is the float catch T, Figs. 3 and 5; this catch is hinged to the top of one of the scoops, and when the scoops are open, as in Figs. 2 and 6, it hooks on to a lug on the top of the other scoop. It thus ties the two scoops together at the top, and prevents them from closing as long as it remains in that position.

The hooks H, which are attached to the jib-head, are so counterbalanced by the weight K that they hang forwards in the position shown in Figs. 5 and 6, when the rope attached to them is slack. These hooks have their points made with faces sloping upwards, so that, when the clutch-collar X rises up to them, the projecting arms of this collar push back the hooks, and rise past them; when the arms are above the hooks, the latter fall forwards again and catch them, so as to prevent the collar from descending. When in this position the main lifting chain may be lowered, and the whole dredging apparatus remains hanging to the jib-head on the hooks H. The entire weight being thus thrown on the collar X, which is attached to the scoops by the rods Y, the scoops are drawn open into the position shown in Figs. 2 and 6.

The lever G is centered in the jib-head, Figs. 5 and 6, and has attached to it a lug or cam, which bears on a very shallow rack fixed to the spear C; on pulling the rope attached to the lever, this cam jams the spear in the guide E so that it cannot rise.

The two scoops forming the bucket are strengthened by stiffening bars N N, Fig. 4; and V V, Figs. 5 and 6, are leather flap-valves opening inwards, which allow water to escape if the bucket is not filled full with mud; but they are closed by any solid matter the scoops may cut into, which is thus retained within the bucket.

Mode of Working.—The action of the dredger is as follows:—

The main lifting chain B, Fig. 1, Plate 69, is attached to a winding engine, or to a crab-winch worked by a portable engine, or to any machine such that the man who regulates the machinery can wind up the chain, or unwind it, or hold it stationary at any moment he pleases. The bucket is first lowered into the water in the position shown in Figs. 2 and 6, Plates 70 and 71, by unwinding the main chain. While it is being lowered this chain is of course tight, as it bears the entire weight of all the movable parts of the dredger. The strain on the main chain tends to draw the travelling collar W upwards on the spear L; this tightens the closing chains P P, the strain on which, acting on the semi-circular angle-irons J J, tends to close the scoops of the bucket. The catch T however holds the two scoops together at the top, and prevents them from closing. In this manner the bucket descends, the wooden spear C sliding freely down in the guides D and E.

When the bucket reaches the bottom, which it generally does with somewhat of a blow if the engine be run quickly, the scoops rest on the surface of the mud, Fig. 2; they open slightly, and the strain is thereby taken off the catch T, which immediately rises out of gear by means of the flotation of the ball attached to it: thus the scoops are released and free to close. The stops on the scoops prevent them from opening more than is just sufficient to release the catch T. Immediately the scoops reach the bottom, the attendant reverses the machinery and winds up the main lifting chain; at the same moment

the lever G is pulled over by the rope attached to it, and jams the spear tightly in the guide E. As the main lifting chain ascends, it draws the collar W upwards on the spear L, and the collar draws up the closing chains P, which cause the semi-circular angle-irons J to press the scoops M into the material on which they were resting. The spear is meanwhile held fast in the jib-head by the gripping lever G, and cannot rise; thus the scoops are compelled to bite into the soil, Fig. 3. But if any very hard matter is met with, the upward thrust on the spear causes the cam on the gripping lever to jump out of the shallow rack, and no damage is done. As soon as the bucket is closed, which can be easily known by watching the point to which the collar X descends on the spear, the gripping lever is released, and the whole apparatus is drawn up to the surface by the continued action of the main lifting chain.

When the bucket with its charge of mud rises to the surface of the water, the crane A, Fig. 1, is revolved until the bucket hangs over the mud-punt, which is alongside the dredger. As the clutch collar X rises, its projecting arms push back the hooks H, Figs. 5 and 6, which immediately afterwards fall forwards again into position underneath the arms. As soon as the attendant sees that the hooks have thus caught the arms of the collar, he reverses the winding of the chain; the rods Y then take the whole weight of the apparatus, the spear and heavier parts descend, and the scoops M are pulled open, partly by the weight of the material they themselves contain, and partly by the weight of the descending parts, the whole of which presses upon the crosshead of the spear L, and thus tends to open the scoops. When the scoops are wide open, Figs. 2 and 6, the stops upon them bear against the spear L, and the catch T falling automatically into position catches the other scoop. The dredger is now ready for another bite. The slack of the main lifting chain is taken up, and the weight of the apparatus is lifted off the hooks H sufficiently to enable them to clear the arms of the clutch-collar. The hooks are then drawn back by the rope attached to them, the crane revolved, and the apparatus run down to the bottom again, as before.

The engine—or winch worked by the engine—has to be reversed

four times during each lift. Firstly, after lifting the clutch-collar from the hooks, it has to be reversed to lower the bucket; secondly, when the bucket reaches the bottom, it has to be reversed to lift it; thirdly, when the bucket is over the mud-punt, it has to be reversed to empty it; and fourthly, it has to be reversed for lifting the clutch-collar off the hooks.. In the dredgers which have already been constructed, the necessarily rapid reversal of the motion of the main chain has been effected by sliding-forks on the crab, by which direct and crossed straps are shifted alternately upon the tight pulley. It requires some practice to work the dredger quickly, but an intelligent labourer soon learns to do the work.

Figs. 9 and 10, Plate 73, show a modification of the dredging scoops, which is applicable for cutting very soft silt or light sand, where the weight of the scoops themselves is sufficient to press them into the ground, without their being held down by the spear. In this arrangement the spear is therefore dispensed with, and the sliding-collar X works on the lifting chain itself. The working of this arrangement is almost exactly similar to that of the one already described.

Results of Working.—The dredger has been at work for about eight months at the head of the Patna Canal. The canal at this point has 180 ft. base, 7 ft. general depth, and side slopes $1\frac{1}{2}$ to 1. There were 40,740 cubic yards of silt, partly sand and partly black alluvial deposit, in the first half mile of this canal. In some places there was as much as 4 ft. depth of silt, but in others only $1\frac{1}{2}$ or 2 ft. depth. The dredger of course worked to the greatest advantage in the deepest silt, as less manipulation of the boat itself was necessary. The depth to which the silt had to be dredged varied from 3 to 7 ft. below the surface of the water.

The dredger tried was an iron one of the following dimensions:—

Length	50 ft.
Breadth	15 ft.
Depth	4 ft.
Maximum draught of water	1 ft. 9 in.
Nominal horse-power	6 H.P.
Capacity of bucket	16 cubic ft.
Greatest depth to which dredger was designed to cut	8 ft.

2 R

The dredger was first started with the regulating apparatus designed by Mr. Fouracres. The dredger was secured in position, as shown in Fig. 7, Plate 72, by a T strut, the base of which was fastened to the bank at T by two pins. The further end of the strut was fitted with an eye, which worked on a pin attached to the stern of the dredger. This strut held the stern fixed, and the dredger was only able to revolve about that point as a centre. To the bow of the dredger a piece of quartering was attached, by another pivot similar to the one at the stern. This quartering was of sufficient length to allow the bow of the dredger to be moved a few feet beyond the centre of the canal. The quartering was marked into divisions of 4 feet each, which was the width of the bite of the bucket. After the bucket had taken its first bite, the bow was shoved off through the distance of one of these divisions of 4 feet by men on the bank working a small twofold tackle. Thus, each time the bucket was lifted, the bow of the dredger was moved out the distance of 4 feet, and the dredger was compelled to work in the arc of a circle. If it was found that one bite of the scoops was not sufficient to clear out the canal to the requisite depth, two or three bites were taken at the same spot, or the dredger was worked a second or third time over the same arc. When it was necessary to move the dredger forward to work on a new arc, the T strut at T was shifted about 2 ft. 6 in. along the bank, that being the length of the bucket used; and the dredger was thus set to cut another arc parallel to the last.

This arrangement, though an excellent one when working near a bank, or in a narrow canal where there is much traffic, was not found suitable for dredging a channel of 50 ft. width down the centre of the canal, which was the work required to be done. Indeed it seems doubtful whether a well-arranged system of anchors would not always be more convenient for working this dredger. The arrangement shown in Fig. 8, Plate 72, was therefore adopted. A small gipsy winch A was fitted on two uprights at the edge of the dredger. A small capstan would have been more suitable, since the regulating chain B would not have jammed on a capstan as it did sometimes on the winch. By turning the winch A, it was easy to regulate the movements of the dredger, causing it to oscillate in the arc indicated. Two anchors,

attached by $\frac{1}{2}$ -inch chains to a bollard on the stern of the dredger, kept the stern very nearly stationary: the action of the current tending of course to keep the anchor-chains tight. Occasionally, as the stream varied, the dredger would perhaps float slightly out of its proper course, in which case the bucket might come up very nearly empty; but this did not occur very frequently. When the dredger had worked up to the end of its arc, the anchor-chains were slackened and the dredger was moved forward about 2 ft. 6 in., the length of the bucket; the man regulating the dredger then reversed the winding on the winch A, and the dredger gradually worked back along the fresh arc to the other end, and so on continually. Occasionally, when the anchor-chains became long and the dredger was perhaps somewhat swept off her course by the action of the current, or when the anchor chains had been slackened by more than the proper amount, a ridge of silt would be left which the dredger had to be brought back to cut. But generally speaking the channel was dredged very cleanly.

Some difficulty was at first found in managing the mud-punt in the stream: the silt generally came up so hard and dry that it would not spread itself over the deck, and it was necessary to move the punt frequently, so that the silt might be uniformly deposited. An arrangement of hooks on the punt and small bollards on the dredger was therefore adopted; by this the labourers were able to draw the punt by hand into any required position, and fasten it to the bollards on the dredger by small pieces of rope. Two pairs of bullocks towed the full punts out to the river, and brought back the empty ones.

The silt dredged up varied from pure sand to soft black mud; the heavier particles (*i.e.* the sand) were of course deposited near the head sluice of the canal, and the silt gradually became less and less sandy, and more and more muddy, the further the dredger worked from the sluices. One of the greatest advantages of this dredger is that it brings up the silt quite hard and dry. The greater portion of the silt excavated could have been at once carried on coolies' heads in baskets if necessary. It is also remarkable how little the dredger

stirs up the mud when working ; it works most cleanly, taking its proper bite without disturbing the silt near it, and in this respect is much superior to other dredgers, which often plough up the silt into a thin slush as they lift it. The leather valves on the scoops acted capitally ; whenever the bucket came up partly empty, most of the surplus water had already fallen out into the canal, before the bucket was swung over the mud-punt.

It was noticed that in pure sand the scoops frequently failed to cut properly, and that the bucket came up only half full. This was due to the fact that at first the shallow rack arrangement, which has been described, had not been fitted on the dredger spear, but the lever G, Figs. 5 and 6, Plate 71, pressed upon the spear by a simple cam only. The consequence of this was that when cutting into pure sand, which is of course much harder than silt, the spear slipped up in the guides, and the bucket did not get its full bite ; the shallow rack arrangement however cured this defect. When the dredger is used for cutting into very hard soil, Mr. Fouracres proposes to make the scoops of somewhat greater radius, but each forming only one-sixth or one-eighth of a cylinder, instead of a quarter as they do at present ; he also proposes to fix steel teeth on the edge of the bucket, so as to catch the ground more readily. The effect of this arrangement would be that the scoops would drag more along the ground, and not cut into it so deeply as they do at present.

It will be manifest that this dredger possesses considerable advantages when working where there are waves or a swell. For when the scoops are resting on the bed of the river or harbour to be dredged, they will cut into any soft soil, without jamming as the buckets of an ordinary dredger are apt to do. It will be seen that the lever G, Plate 71, only holds the spear down, so as to stop its rising ; if the dredger rose on a wave, the lever would not lift the spear, which would slip down in the guides ; and if the dredger fell on a wave, the lever would give way when the pressure became too great for it to hold. The dredger is also very handy for working in corners

and near wharves or piers, where an ordinary dredger cannot sometimes find room to work. Again the author believes that in the old form of dredger the buckets rarely bring up on the average more than half the quantity which they could contain; this is chiefly due to the fact that it is almost impossible to regulate the forward motion of the dredger so exactly that the cut taken by each bucket is just sufficient to fill it. If the feed is too great, the front buckets churn up the extra mud which they cut into slush, and this is brought up by the following buckets. It is very probable too that if the buckets come up with a good load of heavy sticky mud, it will adhere to the bucket, and the whole will not fall out into the shoot. These difficulties are entirely overcome by the new dredger, which can never cut more than it can contain, and must necessarily empty the whole of its contents into the mud-punt, inasmuch as it opens entirely and the whole contents must drop out. When working in the most sticky stuff the bucket entirely clears itself, with the exception of some small lumps on the edge and in the corners of the scoops.

This dredger is also peculiarly suitable for working in tidal waters, where the varying depth causes trouble in the ordinary ladder dredger, necessitating the constant alteration of the ladder. Moreover as this gradually gets more horizontal, the ordinary dredger works at a greater and greater disadvantage, as more mud drops out of the buckets on their way up to the shoot. In Fouracres' dredger the efficiency increases as the tide falls; for the work to be done and the friction on the parts are directly proportional to the height of lift. The dredger will work to advantage as long as it will float.

During the first ten weeks of the working of the dredger in the Patna Canal, an accurate account was kept, showing the engine-hours, number of buckets lifted, &c. This account is tabulated in Table I. appended. After those ten weeks, only sufficient information was taken to give the cost per yard excavated. In Table I. the cost of repairs is not given, partly because the accounts were not ready at the time the Table was made out, and partly because the dredger was quite new, and needed of course but little repair during the

first ten weeks it was at work. The results of the ten weeks' trial give:—

Maximum quantity excavated in a day of $9\frac{1}{2}$ hours	172 cubic yards.
Average quantity per day of $8\frac{3}{4}$ hours	137 cubic yards.
Maximum quantity per nominal horse-power per hour	3·82 cubic yards.
Average quantity per nominal horse-power per hour	3·51 cubic yards.
Average number of buckets lifted per engine-hour	$45\frac{1}{2}$ bucketfuls.
Average quantity lifted each lift (full bucket being 16 cubic feet).	11·8 cubic feet.

The amount lifted per bucket is disappointing ; for, when working in soft soil or in a mixture of light marl and sand, the bucket frequently came up containing as much as 18 or 20 cubic ft., the material being heaped up above the crosshead. The comparatively small average per bucket must be attributed partly to the want of the rack arrangement which has since been introduced, and partly to the fact that, when cutting only a shallow layer of silt, it is not possible always to fill the bucket, as the material is not there to fill it. It will be seen that, although the lead of the punts increased with the increasing distance of the dredger from the river, yet the cost of discharging decreased during the ten weeks ; this was due to improvements in the discharging arrangements.

It is not easy to compare with real accuracy the performances of different machines, unless the observations are conducted by the same person, or at any rate under the same system, and unless the circumstances are thoroughly known. Through the kindness of the chief engineer of Bengal the author has obtained statistics of the performances of various dredgers now in use in Bengal ; these statistics are embodied in Table II. The information is the best the author could get, but he must express his regret that he has not been able to obtain the facts in sufficient detail to enable him to fill up all the columns. This Table gives the cost of dredging by seven different dredgers, working generally in silt or sandy river deposits of a very similar nature to the material excavated by the

new dredger. These seven dredgers were all working under somewhat different conditions, and cutting to different depths; some of them were only working for a short time during the year, and some were working in tidal waters, where they were placed at the disadvantage of being hindered at low tide; so that the columns which contain the charges for interest and depreciation are not really comparable; but those which show the actual cost of dredging, discharging, and repairs are as fairly comparable as the circumstances will allow.

From this Table it is clearly evident that the new dredger works at a much lower cost than any other in Bengal. During the five months for which the working of this dredger is shown, she worked 125 days, was idle 23 Sundays and 1 Christmas Day, and was laid up 5 days for repairs. She excavated on the average 134·7 cubic yards per day at a cost of 2·18 pence per yard, including dredging, discharging, repairs, and interest and depreciation on prime cost.

One of the greatest advantages which the dredger offers is the small cost of repairs. It will be noticed that during the five months she was working the cost of repairs was only 139 rupees (£13 18s. 0d.). Supposing that this figure was doubled, or even trebled, in an older dredger, the cost of the work done would still be very low. It has been found that there is very little wear except on the cutting edges of the bucket scoops. These get very blunt when working in sharp sand. The first bucket was made of iron and wore away very quickly. The later ones with steel edges have worked much better. As one bucket can be detached from the spear and another substituted in about twenty minutes, ordinary repairs do not delay the working of this dredger, whereas in the ladder and bucket dredger the removal and renewal of the links and pins is a troublesome and lengthy business. Again, the wear of the links in the latter class of dredgers interferes with their efficiency; for it sometimes becomes necessary to lift the ladder slightly, as the chain of buckets sags, otherwise they are apt to foul the edge of the well. In the new dredger this difficulty can never occur; and there is nothing to interfere with the depth to which the dredger will cut, except the length of the spear and main chain.

The comparison of the cost of working of the new dredger with that of others working in England is rendered less satisfactory than the comparison just made, by the fact that the values of labour and materials differ in the two countries. The establishment employed on the dredger in India was more numerous than would be required in England, but the pay of the men was less. Again, coals cost in India about 30s. to 40s. a ton, while on the Clyde and Tees they cost from 5s. to 10s. only. If it is supposed that the cost of labour here would be double or treble what it is in India, the cost of the work done by the dredger now described would still compare favourably with dredgers working here; and it must not be forgotten that it is comparatively much more expensive, as far as establishment is concerned, to work a dredger of 6 horse-power than one of five or six times the size; also that in a dredger properly constructed with a winding engine the establishment would be still further reduced. There were in India no less than fourteen hands employed on the dredger.

The following is the cost of dredging on the Clyde, as deduced from Mr. Deas's paper read before the Institution of Civil Engineers in 1873 (Proceedings, vol. xxxvi. pp. 157 and 160-161):—

Cost of dredging only	pence per cubic yard	1·31
Cost of dredging and repairs	„ „	2·54
Cost of dredging, repairs, and 10 per cent. interest and depreciation on prime cost.	„ „	3·86
Quantity dredged per nominal horse power per hour	cubic yards	1·73

Mr. John Fowler has kindly informed the author that the following is the cost of dredging on the Tees, allowing 10 per cent. for interest and depreciation, which however he considers too high:—

Cost of dredging only	pence per cubic yard	1·35
Cost of dredging and repairs	„ „	2·09
Cost of dredging, repairs, and 10 per cent. interest and depreciation on prime cost.	„ „	3·17
Quantity dredged per nominal horse power per hour	cubic yards	1·59

Design for large Dredger.—Mr. Fouracres' dredger was designed, and is most suitable, for working in soft deposits and in comparatively shallow water. It has never as yet been worked to a depth greater than 10 feet; but it is believed by the author that for such depths it is the most handy, cheap, and effective dredger yet in use. When intended for deeper cutting it is proposed to alter the arrangement to some extent, and to substitute two spears for the one at present employed. It is proposed to make these spears of iron or steel pipes, and telescopic, so that when raised they should not extend to an unreasonable height above the dredger.

Figs. 11 and 12, Plate 74, show the general arrangement proposed for a dredger capable of dredging 150 cubic yards per engine-hour at a depth of 20 feet. The details of the dredging apparatus itself are shown in Figs. 13 to 15, Plate 75. There are two revolving cranes at the bow of the dredger, which carry the dredging scoops; these cranes can be worked either together or separately. The drawings show them designed for working separately, but it would be easy so to arrange the regulating handles that one man could regulate both; in that case of course both cranes would revolve simultaneously, and the dredger would not then heel over as it does when only one crane is used.

The scoops of the bucket, which contains about $3\frac{1}{2}$ cubic yards, are similar to those previously described, except that they have double spears L and double closing chains P, Plate 75; the sliding collar W is also differently constructed, to carry the extra pulleys which are rendered necessary by the doubling of the chain P; by means of this doubling, the run of the collar W is reduced by one-half, and the apparatus is consequently more compact. The extra force necessary to close the scoops is gained by the double pulleys in which the main chain B runs. In order to enable one man to do the work which in the dredger now working is done by three men, it is proposed to work the hooks H by means of a spiral spring placed above a small steam or compressed-air cylinder K. By means of the spiral spring, the hooks H are kept constantly in readiness to catch the clutch-collar X; but when the hooks have caught the collar and are bearing the weight of the apparatus, the

man regulating the machinery admits the steam into the cylinder K ; so that as soon as the scoops are empty and the main chain has been sufficiently lifted to take the weight off the hooks, these are opened by the descent of the piston in the cylinder overcoming the force of the spring ; and the apparatus is then lowered. The pressure on the spears C is put on in the same manner, by admitting steam or compressed air to the cylinder G ; this presses the blocks J against the racks in the spears. While the scoops are being closed, the attendant keeps his hand on the regulator which controls the valve of the cylinder G ; thus he can at any moment release the spears by allowing the steam or air to escape from the cylinder, when the spiral spring N immediately draws back the blocks J out of contact with the racks on the spears. The teeth on these racks are so constructed that the blocks J would run back in the event of any extreme pressure coming on them, even against the pressure in the cylinder G. Friction blocks might no doubt be substituted for the rack and block J. The tubes C, which play the part of the wooden spears at present in use, are lightly braced together by iron rods. They are steadied above the jib-head by a light guide D, Plate 74, attached to the head of the crane.

It is estimated that a dredger constructed on this plan would dredge from a depth of 20 feet about 1000 cubic yards a day of soft material, at a cost of about $1\frac{1}{2}d.$ per cubic yard, including establishment, materials, repairs, and an allowance of 10 per cent. for depreciation and interest on first cost. The prime cost of such a dredger would not exceed £2,500.

APPENDIX.

TABLE I.—FOURACRES' DREDGER.
Abstract of Weekly Averages and Totals of Working.

1878-79.	Items.	1878.	Week ending Saturday									1879.	Total.	Average.
		2 Nov.	9 Nov.	16 Nov.	23 Nov.	30 Nov.	7 Dec.	14 Dec.	21 Dec.	28 Dec.	4 Jan.			
Weekly Averages.	Quantity lifted by } Bucket each time ... } cub. ft.	12·0	12·4	12·2	12·0	11·8	11·2	11·6	11·9	11·8	11·4	118·3	11·8	
	No. of Bucketfuls per } hour } ...	42·5	40·1	42·1	47·6	47·7	49·0	...	44·4	50·5	...	363·9	45·5	
	Daily Time of Dredger } working } hrs. mins.	5 31	6 36	6 27	6 39	6 20	7 27	...	6 41	6 53	...	52 34	6 34	
	Daily Time of Men em- } ployed } hrs. mins.	...	9 17	8 32	7 58	8 33	9 6	...	8 54	8 25	...	60 45	8 40	
	Daily Quantity exca- } vated } cub. ft.	3210	3135	3604	3762	3625	4172	3839	3622	3991	3953	36913	3691	
	Time of loading each } Puntful } mins.	51	53	53	49	50	50	...	53	49	...	408	51	
	No. of Bucketfuls in } Punt } ...	39·3	36·1	37·1	39·4	39·6	41·3	39·6	40·5	41·1	40·6	394·6	39·4	
	Quantity in loaded Punt cub. ft.	467	426	454	465	468	466	475	483	486	483	4673	467	
Lead of Punt feet	1200	1300	1400	1500	1600	1800	1900	2000	2100	2200	...	...		

Weekly Averages.		2 Nov.	9 Nov.	16 Nov.	23 Nov.	30 Nov.	7 Dec.	14 Dec.	21 Dec.	28 Dec.	4 Jan.				
Cost per 1000 cub. ft. as under:															
Dredging and Deliver- ing into Punt... ..		* r. a. p.													
Leading Punts and Dis- charging into River }		r. a. p.													
Total per 1000 cub. ft. ...		r. a. p. £ s. d.													
Weekly Totals.		Weekly Quantity exca- vated	cub. ft.	22,474	15,677	18,022	22,572	21,752	25,033	19,194	21,732	19,956	23,720	210,132	21,013
Weekly Expenditure															
Dredging and Deliver- ing into Punt... ..		* r. a. p.	28 12	124 11	929 7	934 10	330 6	630 10	1128 3	031 2	028 3	031 1	5297 4	829 11	8
Leading Punts and Dis- charging into River }		r. a. p.	22 11	017 10	015 8	619 3	319 14	018 11	616 14	616 6	015 3	616 12	0178 14	317 14	3
Total Weekly Expendi- ture		r. a. p. £ s. d.	51 7	142 5	945 0	353 13	650 4	649 6	545 1	647 8	043 6	647 13	5476 2	1147 9	11
			5 2	114 4	94 10	05 7	85 0	74 18	94 10	24 15	04 6	104 15	847 12	44 15	3
Average Cost per Cubic Yard.		Dredging, pence	0·84	1·03	1·06	0·99	0·90	0·80	0·94	0·93	0·90	0·86	9·25	0·93	
		Discharging, pence	0·65	0·73	0·56	0·55	0·61	0·50	0·57	0·50	0·50	0·44	5·61	0·56	
		Total ... pence	1·49	1·76	1·62	1·54	1·51	1·30	1·51	1·43	1·40	1·30	14·86	1·49	

* 1 Rupee = 16 annas = 2 shillings.

1 Anna = 12 pies = 1½ penny.

1 Pie = ⅓ penny.

TABLE II.

Cost of Dredging by different machines in Bengal.

Items.		Dredger A (See opposite page.)	B	C	C	C	D	D	E	E	E	E	F
				1875-6	1876-7	1877-8	Victoria.	Princess Louise.	1874-5.	1875-6.	1876-7.	1877-8.	Four- acres'.
Cost of Dredger £		4200	...	5358	5358	5358	5524	2841	21,000	21,000	21,000	21,000	800
Nominal Horse-Power H.-P.		24	6	15	15	15	60	35	60	60	60	60	6
Greatest Depth to which Dredger will excavate ... } feet.		5	5	10	10	10	10	12	27	27	27	27	8
Total Period of Working ... days.		84	187	...	...	...	...	...	214	190	192	221	125
Total Quantity Excavated ... cub. yds.		13,333	7,838	40,639	10,370	15,896	...	...	63,579	97,611	91,537	113,926	16,838
Working Cost.	Dredging alone *	Rupees.	Rupees.	Rupees.	Rupees.	Rupees.	Rupees.	Rupees.	Rupees.	Rupees.	Rupees.	Rupees.	Rupees.
	Dredging alone	...	...	7,083	2,957	3,444	...	...	...	...	...	...	691
	Dredging and Discharging Dredging, Discharging, and Repairs	1,932	1,807	11,807	4,851	4,880	...	...	28,960	27,462	25,536	28,775	1,063
	Dredging, Discharging, Re- pairs, and 10% Int. &c. }	...	...	14,198	8,351	5,937	...	...	34,934	35,401	37,175	40,858	1,202
		...	...	19,556	13,709	11,295	...	...	55,934	56,401	58,175	61,858	1,535
Average Cost per cubic yard.	Dredging alone	Pence.	Pence.	Pence.	Pence.	Pence.	Pence.	Pence.	Pence.	Pence.	Pence.	Pence.	Pence.
	Dredging alone	...	...	4.18	6.84	5.19	2.62	3.72	...	...	...	...	0.98
	Dredging and Discharging Dredging, Discharging, and Repairs	3.47	5.53	6.97	11.22	7.36	6.42	7.60	10.92	6.75	6.69	6.04	1.50
	Dredging, Discharging, Re- pairs, and 10% Int. &c. }	...	...	8.38	19.32	8.96	...	...	13.18	8.70	9.74	8.60	1.71
		...	...	11.54	31.72	17.00	...	...	21.11	13.86	15.25	13.03	2.18

* 1 Rupee = 2 shillings.

Particulars of Dredgers included in Table II.

- A. Ladder and Bucket Steam-Dredger, 94 ft. long,
15½ ft. beam, 6½ ft. deep. Sixteen buckets of
4 cubic feet each.
- B. Single Scoop Steam-Dredger, 50 ft. long, 13 ft.
beam, 6¾ ft. deep. Scoop working on a
vertically oscillating arm.
- C. Ladder and Bucket Steam-Dredger, 120 ft. long, 18 ft. beam, 6 ft. deep. This dredger worked part of its time in tidal water, and was therefore hindered. It never actually did 120 cubic yards in a day, and generally excavated to about 7 ft. depth below water level.
- D. Ladder and Bucket Steam-Dredgers. These work pretty constantly in the Calcutta circular canals. The cost of repairs is not stated by the engineer.
- E. Ladder and Bucket Steam-Dredger "Octopus." This belongs to the Calcutta Port Trust, and has been chiefly employed in clearing out silt near the jetties: depth dredged about 24 ft. The lead of the discharging hopper-barges was short.
- F. Fouracres' Steam-Dredger, with single vertical-acting bucket, 50 ft. long, 15 ft. beam, 4 ft. deep. This dredger has been working for five months in the Patna canal. The lead of the punts averaged about 500 yards.

These dredgers were employed in clearing silt and sand from the heads of the High Level and Kendraparab canals. The lead of the punts was not more than ¾ mile.

Discussion.

MR. BUCKLEY showed a model of the dredger described in the paper, and explained its operation, stating that the average number of lifts was 45 per hour, but that 60 per hour could be done easily at hard work. In addition to the wear on the cutting edges (as stated on p. 545) he had lately learnt that a good deal of wear took place on the pivot of the bucket (Fig. 5, Plate 71), and that it was found necessary to put hardened steel bushes upon the ends of the cross-head, and also upon the eyes. The cross-head originally used had had to be renewed after five months.

He had just received some information as to dredging on the Thames, which had been supplied to him by Mr. Leach, the Engineer of the Thames Conservancy. The cost of dredging was 4·405*d.* per cubic yard; repairs 0·988*d.*; 10 per cent. interest and depreciation 2·37*d.*; total 7·76*d.*, which was nearly double the amount on the Clyde and the Tees. Mr. Leach stated that on the Thames the dredgers worked only for a little while now and then; so that the cost ought not to be compared with continuous work. In one particular dredging operation now being carried on, the cost was stated by Mr. Leach to be a trifle less than that given on p. 546 for the Clyde and the Tees.

MR. C. J. APPLEBY said the members were indebted to Mr. Buckley for bringing before them a very important question—more important he thought than it was often considered to be: because, as remarked in the paper, dredging of the kind described could be done under conditions where an ordinary dredger could not be used at all. The apparatus used by Mr. Buckley was certainly very ingenious, but it bore evidence of having been schemed a good deal without reference to what had been done before. He fancied that, if the originator of this apparatus had seen what had been done by his predecessors, his ideas might have been modified. With regard to the form of the dredging bucket, he thought there could be

no doubt that the hemispherical form had decided advantages over the semi-cylindrical form of the dredger described in the paper. The latter was first used by Woodford, during the construction of the Grand Trunk Railway, for lifting materials from a ship; it was then developed by American engineers into an apparatus of the character described in the paper; but the arrangements for lifting, closing, and opening were in a simpler form than those shown in the drawings exhibited. Very similar arrangements had also been adopted by Mr. Bull, who had brought the invention to bear in India, as Mr. Fouracres had: Mr. Bull came to much the same design as the Americans; still in a simpler form than that described in the paper. But the objection to all semi-cylindrical scoops was that there must be something to push them down into the ground, otherwise they would not fill themselves properly. Later Mr. Bruce had hit upon the idea of the hemispherical form, and it certainly made a very excellent dredge. The hemisphere in his design was cut into three parts, each of course having a sharp point. The three points had a tendency to enter the ground when they came down upon it, and the arms were very ingeniously arranged in such a manner that there was no tendency for the bucket to rise, as Mr. Buckley had just shown his would rise unless it was forcibly kept down.

He might mention that he was at present using a Bruce's excavator under the following circumstances. There was a mud bank at Plymouth to be dredged just inside the harbour, which was dry at low water and had about 4 ft. of water over it at high water. Of course a ladder dredger could not be got to work there. His advice having been asked by the contractor, Mr. Laing, who felt himself under some difficulty, he had advised him to use Bruce's excavator, and this was now being employed. The apparatus altogether was simply a good, handy steam crane, and a Bruce's excavator of 5 ft. in diameter, holding about 32 cubic feet. The crane was mounted on a barge, and sent out to do its work. When the tide went down, it left the barge on the mud still working. At the present moment they could only do about 300 cubic yards per day, because they had not barges to convey more than that away; but as soon as they had more barges

it was proposed to do about 600 yards per day. He had just received a letter from the contractor, in which he grumbled very much at the idea of doing only 600 yards a day; he wanted to remove 1200 yards, and said that the machine would do it well, and that they must work day and night for the purpose. The cost of the whole of the mechanical appliances would be about £600, the craft about £600 more, sundries say £300, making a total of £1500 as the cost of the working apparatus, which he was told would do 1200 yards per day of 24 hours, or 600 yards in an ordinary day. That appeared, so far as capital went, to compare very closely with Mr. Buckley's figures on page 548.

The advantage of the hemispherical scoop was so great that it was worth while to refer to it again. In working at a great depth there would be considerable disadvantage in using the heavy spear shown in the drawings; whereas with the hemispherical bucket there was only a lifting chain, as in a crane, and it was perfectly immaterial at what depth the bucket worked. He was able to give some facts respecting the bucket used at Plymouth, which was much larger than Mr. Buckley's; indeed the bigger it was the better. The man in charge of the excavator wrote as follows:—"Both the crane and the excavator are working very well indeed. In the top mud the excavator brings up a brimful load, so that on reaching the surface of the water some of the mud falls over again; in the harder mud it brings up a full load, except when we pick up baulks of timber and other refuse, which, getting between the jaws of the excavator, causes us to lose the mud through the opening; there is a quantity of such large stuff about the part where we are excavating." As a matter of fact, with the hemispherical form of bucket, when the spades or points got hold of anything too hard or heavy, something was bound to give way; and for that reason he used a very light chain, because he would rather see the chain break and leave the bucket at the bottom than pull everything over or break the crane. Another advantage was that the buckets could be made of almost any size.

Dredges of the type described by Mr. Buckley had been first made by Mr. Bull for dredging out the inside of cylinders, and

a large number of them had been used for that purpose in India. He had himself made Bull's and also Bruce's excavators for that purpose. The smallest Bruce's excavator he had made was 3 ft. 6 in. in diameter, and the largest he had heard of was 20 ft. in diameter. The smallest contained about 15 cub. ft. or 14 cwt., and the largest about 270 cub. ft. or 13 tons. As he had already said, the larger the apparatus was, the better the duty that was got from it; because naturally the time occupied in going down and coming up was much the same for both sizes, and the extra weight of the larger bucket had a tendency to propel it further into the ground. In the case of very hard substances, it might be necessary sometimes to use a hydraulic cylinder actuating a beam, to force the excavator into the ground; but in that case, whatever the form was, spherical or cylindrical, there was the objection of the use of the spears.

Professor JAMES THOMSON, F.R.S., asked if there was a prospect of dredgers of this kind answering in the shallow water upon the sugar estates in Demerara, instead of the ordinary dredgers now used. There were many estates in Demerara which were suffering from mud flats extending out to sea, and thrown up by the waves or by the action of sea and drift; these interrupted the outflow of the drainage and compelled the estates to be drained by pumping. Many estate owners had been keeping open the outlet to the sea by various means, and were anxious to get further information as to any improvement that might be adopted.

Mr. ANDREW BROWN (Renfrew) observed that in giving the cost of dredging on the Clyde and Tees Mr. Buckley had not included the cost of the lead, or taking away of the spoil; if that were added to the cost of dredging on those rivers it would add materially to the cost per ton. The style of dredger described in the paper was certainly very valuable, especially in rivers, canals, and places where there was a limited depth of water, and where the stuff was not very tenacious or hard. If the buckets or scoops were fitted with steel teeth, as proposed by Mr. Buckley, they would enter better into the soil, although in that case the work would not be done quite so

quickly ; longer time would have to be allowed for the bucket to fill properly. As to larger machines of the same kind, he should be a little doubtful whether the benefits would be so great, or whether the result would be so successful, considering the greater quantity of work now done by marine dredging machines of the ladder type with their recent improvements. On the Clyde, on the Tees, and on the Tyne, those large machines would lift at least 500 tons of soft material in an hour. Now 4000 or 5000 tons a day was a large quantity of stuff to raise. He did not say that the style of machine now described ought to be compared with those great dredgers ; but taking that quantity of stuff, and taking the cost of doing the work with the larger and more costly machines, he believed it would be found that the difference per ton or per yard would not be so great. In some of the latest machines that had been built, the cost did not exceed what Mr. Buckley had given. In one instance he had been informed that the cost was under $1\frac{1}{2}d.$ a ton : of course that did not include repairs, but it did include removing the spoil a couple of miles out to sea, and working in a tidal harbour where the dredgers (which carried their own spoil) could not get out regularly. In that instance, if the dredgers were able to get out as often as they could load, it would double the amount of work accomplished, and consequently reduce the cost by one half.

He merely mentioned this matter to show that the cost which had been given in the paper for doing work on the Clyde and on the Tees was hardly comparable with the working of a small machine, especially on the Thames where the soil was generally soft and easily lifted. In many parts of the Thames he understood that if a hole was dug anywhere the soil would flow in from all round, and consequently the buckets would lift any quantity, if they were merely allowed to run down to the bottom. Some of the powerful dredgers on the Clyde, when lifting a soft kind of soil, and running the buckets at a good speed, would lift nearly 500 tons an hour. The appliances described by Mr. Buckley were however no doubt very valuable in many cases, and would do work in some places where ordinary machines would not be able to do it.

Mr. JOHN M. EASTON had used Bull's excavators on the Oude and Rohileund Railway in sinking wells. The cylindrical form of bucket was there used, but the depths were of course much greater than any mentioned by Mr. Buckley. He had used Bull's excavators to a depth of 40, 50, 60, and even 70 feet. They were worked by a chain, and were found to answer admirably. As to the defect that had been pointed out by Mr. Appleby, that the lips might pitch on a stone and the chain would then have to break, that was not his own experience. He had found that a stone, or large nodule of kunker or limestone, was brought up by the excavator; at the same time of course, as the lips of the scoop were prevented by the stone from closing, all the rest of the earth ran out in that lift. At other times when working in the ordinary silty deposits of those rivers, the bucket was brought up full every time, and the work was done well and economically. The chain was used without any spear, the weight of the apparatus itself being sufficient to penetrate the soil.

Mr. BUCKLEY said in reply that Mr. Appleby had recommended the hemispherical form of bucket, as being much superior to the semi-cylindrical, on account of its power of cutting more easily into the ground. The hemispherical bucket of course acted entirely by weight. There was no spear, nothing to keep the bucket down; it worked entirely by its own weight, and he must confess, although there might be some trifling advantages in the hemispherical form, he did not understand how a machine which worked simply by its own weight could cut more deeply into the ground if it was spherical than if cylindrical. Of course if the implement was held down, two or three cutters cutting into the ground would cut more easily if in the spherical form; but when it was a simple question of the bucket's own weight, he did not see why one should be more easy than the other.

Mr. Appleby had also said, in mentioning Mr. Bruce's dredger, that the larger the buckets were, the better they worked. Of course that was so in every case where the bucket worked simply by its weight; for the heavier it was, the more it would press into the material to be cut. In the dredger shown in Figs. 9 and 10, Plate 73,

working without any spear, the bucket did cut by its own weight, and of course in some respects was similar to the one described by Mr. Appleby. When working with its own weight alone, it would cut as much and hold as much, if made of the same size, as the bucket of Mr. Bruce's dredger. The particular advantage of the Fouracres dredger was the spear, by means of which the bucket could cut material that could not be cut by any bucket with its own weight alone. If a machine were wanted which would cut with its own weight alone, that shown in Figs. 9 and 10, Plate 73, could be used; for soft material, into which the bucket would sink by its own weight, the spear arrangement described in the paper would be worse than useless and would be very cumbrous. That would answer Mr. Appleby's remark about the cost of the working at Plymouth, where the bucket had been stated by him to come up brimful each time; if that were so, the soil must be very soft. He had frequently seen the dredger described in the paper working in soft stuff without the lever for holding down the spear, and the bucket coming up full, containing stuff heaped right up to the top of the angle-irons of the scoop, so that as it rose above the water some of the stuff fell off. What he had wished to bring before the meeting was not a dredger that would merely work by its own weight and cut soft stuff, but a dredger that would cut into harder stuff, which others would not touch.

Professor Thomson had asked whether the dredger would be suitable for working in shallow water in Demerara, where silt accumulated. He thought there could be nothing better for working in stuff that was tolerably soft, but yet harder than could be worked by a dredger acting simply by its own weight. He knew of no machine which would work in these cases with such advantage. The cost of working in India of course could not be compared with the cost of working on the Clyde, on account of the difference in the price of coal. The fairest comparison would be made with other dredgers working in India. It would be seen by the Tables that the cost of dredging alone, in the cheapest case in India, was 3·72*d.*, or three times the price of the work done by the Fouracres dredger; and in many cases the cost of other dredgers came to eight or ten times that of the Fouracres. Nothing could be better for Demerara

than a dredger something like that shown in Plate 69, if working at a reasonable depth.

Mr. Andrew Brown had referred to the question of steel teeth for the buckets. It was only proposed by Mr. Fouracres to put steel teeth on a bucket requiring to cut into very hard stuff. A tool called a "spider" had been designed by him and supplied to the Ravi Bridge works on the Punjaub Northern State Railway some years ago; * it was a machine very much of the same kind as Bruce's dredger, but instead of having only three diggers cutting into the soil it had half-a-dozen or more. The spider would cut into solid hard ground, and several wells were sunk by that instrument. It was in that way that Mr. Fouracres proposed to use steel teeth for his bucket; to have the bucket much larger, and to let the teeth scrape along the ground, and so cut hard material, clay or kunker, which the other sort of bucket would not touch.

With reference to making the dredgers on a large scale, the only real difficulty was in the revolving of the crane over the mud punt, as it tipped the dredger over considerably. With a small dredger a sort of outrigger was put on the stern, formed of an iron pontoon and two timber beams, so that when the crane revolved the dredger did not tip over more than was reasonable. That method might be employed in very large dredgers, where the overhanging weight would have a tendency to upset the barge. There was then no limit to the size the dredgers could be made, and the depth to which they could cut. Certainly the spear would be cumbersome if very long; but it could be made telescopic, so that it would close up. Mr. Easton had referred to the great depths that had been cut by Mr. Bull's excavator. He himself knew that dredger very well indeed, and had seen it in India. It would no doubt cut into soft material without a spear; but the best instrument to work in that way was the one shown in Figs. 9 and 10, Plate 73, with which it would be possible to work to any depth. As to sinking wells, the dredger described in the paper was not designed for that purpose, but of course it could be used for it; and a design somewhat similar to this

* See Proceedings of the Institution of Civil Engineers, 1878, vol. liv., p. 67.

had been used in Glasgow, he believed by Mr. Milroy, for the sinking of large cylinders for a railway bridge. There were two rods passed down, one on each side of the well; the excavating apparatus slid down the rods, and when it got to the bottom it clutched them and cut into the ground.

The great advantage he wished to point out in the dredger described in the paper was not with reference to cutting soft material, which many machines could do; but the bringing up of the material dry, and the cutting into harder material than could be cut by means of a simple insistent weight; the principle being that of a spear to keep the apparatus down, and a float catch which acted automatically to liberate the two halves of the scoop as soon as it reached the bottom of the river.

The PRESIDENT said he was sure the members would thank Mr. Buckley for the careful way in which his paper had been prepared; and also for the Tables given, which would be found useful in comparing the amount of work done by different modes of dredging.

The vote of thanks was passed.

The PRESIDENT said it was now his duty to move some resolutions of thanks, which he was sure would be received with the cordial approbation of the meeting, and which were as follows :—

To the Lord Provost and the Corporation of the City of Glasgow, for their kindness in granting the use of the Corporation Galleries for the purpose of the present Meeting, and for the facilities afforded by them in connection with the Meeting.

To Mr. Robert Mansel, President of the Institution of Engineers and Shipbuilders in Scotland; to Mr. Jamieson, Chairman of the Executive Committee; to the Council of that Institution; and to the General Committee; for their cordial invitation, and their very obliging and hospitable arrangements for the reception and entertainment of the Members of the Institution of Mechanical Engineers.

To the Proprietors of the various Works in Glasgow and the neighbourhood, open to the visit of the Members, for their kindness in inviting the Members to visit their Works, and for the arrangements made for their visit.

To the authorities of the Caledonian, the North British, and the Glasgow and South Western Railways, for their kindness in arranging special facilities for enabling the Members to visit the Works open in the excursions.

To the Honorary Local Secretary, Mr. W. J. Millar, for the very valuable services rendered by him in maturing all the arrangements and promoting the success of the Meeting.

Bailie HAMILTON, City Treasurer, said that, in the absence of the Lord Provost, who he had no doubt was detained by other duties that required his presence elsewhere, he had to state on behalf of the Corporation of the City of Glasgow that they considered themselves honoured by the visit of the Members of the Institution of Mechanical Engineers on that occasion; and he had no doubt that if they should again find it convenient to visit Glasgow, the Corporation would be most happy to render them every assistance and to make them as

comfortable as possible. He was sure that the papers which had been read on that occasion would be interesting to every one who had heard them. He himself had been much interested in the paper on dredging, because in Glasgow they well knew the advantages their river had derived from dredging operations. That river, which at one time could be waded across at Govan, was now capable of allowing vessels drawing 21 feet of water to pass up and down at that same place. That had been done even by the old-fashioned dredging machines; and if the improvements of which they had heard so much could be carried out, there was no knowing what might be done in other rivers.

Mr. J. L. K. JAMIESON regretted very much that Mr. Mansel, the President of the Institution of Engineers and Shipbuilders in Scotland, was not present to reply on behalf of that Institution; but he would take upon himself to do so in a very few words. As Chairman of the Executive Committee in Glasgow, and also as a Member of the Institution of Mechanical Engineers, it afforded him great pleasure to see the Members of that Institution in Glasgow; and he was also glad to find that the meeting, so far as he could judge, had been a very great success. The attendance had been very large, much larger he believed than had been anticipated in the north. It had afforded the Council and Members of the Institution of Engineers and Shipbuilders in Scotland very great pleasure to see their friends upon that occasion. The papers had been very interesting, and would well bear reading in future. That was one of the points, he thought, to which they should always look in meetings of that kind—to get papers that would bear fruit in time to come. He thanked the Members very much for coming to Glasgow. It was a long time since they had visited them before—a period of fifteen years—and it might be a long time before they came again; but he had no hesitation in saying, not only on his own behalf but on behalf of the young men who were coming up, that the sooner they returned the better the Glasgow engineers would like it; and he had no doubt that they would have as good a reception in the future as they had had in the past.

Mr. WALTER MACFARLANE said as a member of both Institutions he felt very proud in receiving his friends from the south to visit his works, along with the other works in the city. There was no doubt that an exchange of views on both sides of the Tweed was beneficial, as they could compare notes with advantage. They might have some little to show in the north, but certainly there was a great deal to be seen in the south. Those who lived in the north never felt more proud than when they crossed the border, because they felt that they could see in London and the other large English towns something fresh that they could take away with them, and which would be profitable to them in future. He was happy, on behalf of the manufacturing interests of the city of Glasgow, to express the very great pleasure they felt in being honoured with this visit of the Members of the Institution of Mechanical Engineers; and he hoped that, when they were honoured with another visit, they would be in a better position to receive the Institution. They were all aware that the trade of Glasgow had been depressed in a very exceptional way; clouds had been hanging over them, such as their friends in the south could scarcely realise; but he hoped those were now passing away. He had very great pleasure in thanking the meeting for their appreciation of the manufacturing industries of the city.

Mr. JAMIESON, in responding as a railway director to the vote of thanks to the railway authorities, said he knew that those who had acted on behalf of the railway interest had taken considerable trouble for the purpose of doing honour to the Institution; and on their behalf he begged to thank the meeting for this kind recognition of their labours.

Mr. MILLAR said it was very gratifying to him to hear the resolution moved by the President, which had been echoed so heartily by the Members of the Institution, as to the satisfactory nature of the arrangements that had been made by the Local Committee and carried out by himself and his assistants. That expression was deeply gratifying to him, because in looking forward to such a large

meeting and the various arrangements connected with it there was always a fear of some hitch occurring. He was glad to know that so far everything had passed off satisfactorily to the Members; and he trusted that the remaining part of the proceedings, which would be more a matter of pleasure than of business, would also have a happy termination.

Mr. JAMIESON said there was one duty which, as Members of the Institution of Mechanical Engineers, and also as Members of the Institution of Engineers and Shipbuilders in Scotland, they had still to perform; and he had no hesitation in saying that that was one of the most pleasant duties which they could discharge. No one could have noticed the great tact, skill, and judgment, with which the President had conducted himself in the chair, without seeing that he had manifested all the attributes which contributed to make a gentleman; and that they were greatly indebted for the success of their meeting to the manner in which he had occupied the chair. He therefore asked the Members to vote cordially by acclamation their best thanks to Mr. Robinson.

The motion was passed by acclamation.

The PRESIDENT said he would only detain them, after the expression of so much cordiality on their part, to thank Mr. Jamieson for his proposal and the meeting for the way in which they had accepted it when placed before them. He was very glad if he had been able at all to minister in any way to the success of the meeting.

The Meeting then terminated.

VERTICAL-ACTION STEAM DREDGER.

Plate 69.

Fig. 1. *General Arrangement of Fouracres' Dredger,
on Patna Canal, Bengal.*

Dredging Bucket with Spear.

Fig. 2.

Fig. 3.

Fig. 4.
Plan of Bucket.

Fig 7. *Dredging from either bank to centre of narrow canal.*

Fig 8. *Dredging centre channel in canal.*

*Dredging Bucket without Spear,
for very soft silt.*

Fig. 9.

Fig. 10.

VERTICAL-ACTION STEAM DREDGER.

Plate 74.

Fig 11.

Design for Large Dredger.

Fig 12.

(Proceedings Inst. M. E. 1879.)

Scale $\frac{1}{150}^{\text{th}}$

Plate 74

VERTICAL-ACTION STEAM DREDGER. *Plate 75.*

Details of Design for Large Dredger.