ON THE BAZIN SYSTEM OF DREDGING.

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The following paper contains a brief description of the construction and working of a Dredger, designed on the system invented by M. Bazin, the well-known hydraulic engineer, and used by the author for the past three years in dredging sand and other material in Lowestoft Harbour.

Construction.—The dredger is represented in its general features in Figs. 1 and 3, Plates 8 and 9. The total length of the hull is 60 ft., with 20 ft. beam. In the after part of the hold is placed a horizontal boiler A, Fig. 1, which supplies steam to a pair of inverted vertical engines B, Fig. 3. These engines drive, through belts and overhead pulleys, a centrifugal pump C. The suction pipe D of this pump passes through the side of the dredger, and then forms an elbow bent downwards at an angle of 45° . To this elbow is attached a flexible pipe E, 12 in. diameter and 25 ft. long, made of india-rubber, with a coil of iron wire inside to help it to keep its shape. At the lower end of this pipe is an elbow-shaped copper nozzle which rests on the bottom, and is fitted with a grating to prevent stones getting into the pump, and stopping the work.

The flexible tube E is supported by chains that pass over the head of a derrick F, mounted at the stern of the dredger, and then round the barrel of a steam winch G, Fig. 1. By this means the depth of the nozzle is altered, as required to suit the depth of water. A man stands at the winch, and lifts or lowers the pipe as is required, judging by the character of the discharge from the pump. If the liquid

discharged is very dark and thick, he knows that the nozzle is too deep in the sand or gravel, and he therefore raises the pipe; but when the discharge is of a light colour, he lowers the pipe, since the proportion of water to sand or gravel is thus seen to be too great. The best proportion of water to sand, according to actual experience, is 5 to 1. When loose sand is the only material to be dealt with, it can be easily sucked up, even if the nozzle is deeply buried; but at other times stones interfere with the work, and the man in charge of the flexible tube has to be very careful as to the depth to which the nozzle may be buried in the sand.

The action of the apparatus will be at once understood. The pump, being worked by the engine, draws up the water and sand from the bottom through the flexible pipe E, and discharges it into the wooden trough H; from thence it falls into hopper barges, Fig. 3, placed at either side as convenient. So powerful is the action that at Lowestoft, before the grating was fixed to the nozzle, large stones and iron bucket-pins, in some cases over 3 lbs. in weight, were sucked up and passed through the pump.

The pump itself is shown, in longitudinal and horizontal section, in Figs. 4 and 5, Plate 9. The fan is 2 ft. diameter, and has only two blades. Originally it had four blades, but on one of these getting accidentally broken, the action was found to be improved, and eventually it was found to work best with the two only. The faces of the blades, where they come in contact with the sand, are covered with flaps of india-rubber. Small doors are provided at the sides of the pump, for cleaning it out, extracting stones, &c. The fan makes 350 revolutions per minute, and at that speed is capable of raising 400 tons of sand, gravel, and stones per hour, but the average in actual work may be taken at 200 tons per hour. This is with a 10 HP. engine, and working in a depth of water varying from 7 to 25 ft.

Applications.—The great advantage of this dredger is its capability of working in disturbed water, where the frames of a bucket-dredger would be injured by the rise and fall of the vessel. Thus at Lowestoft bucket-dredgers are used inside the harbour, and the Bazin dredger at the entrance, where there is sand and gravel, and where the water is more disturbed. The dredger does not succeed

very well in soft silt, because it runs over the sides of the hopper barges without settling. Nor is it good for dredging solid clay, which is difficult to suck up. It gives however excellent results with sand and gravel, and for this work is much superior to the bucket dredger.

Experience in Working.—In May 1876 the author went to Angers, to see a dredger on the Bazin system, which was working there on the river Loire. It was roughly fixed in a barge, and was excavating sand for the foundations of a large bridge over the river—a work which it seemed to perform in a very satisfactory manner.

In consequence of the author's report, a contract was entered into by the Great Eastern Railway Company with Messrs. Charles Ball and Co. to supply a dredger of the same kind for Lowestoft, the terms being that it was to dredge 100 tons per hour before it was accepted. Between September 1877 and July 1878 many attempts were made to get this dredger to work satisfactorily, but all without success; and the contractors became so disheartened with their failures that they were disposed to abandon the contract altogether. The author was very reluctant that this should take place, as he felt persuaded that it only required perseverance to make the arrangement a success; and this has been justified by the result. One of the chief alterations which produced the final success was made by Mr. Charles Ball, managing director to the contractors, and consisted in the introduction of india-rubber flaps attached to the blades of the fan. This enabled stones, gravel, &c. to be dredged without damage to the pump. Before this, although cast iron, wrought iron, and steel were all tried for the blades, it was found that in a very short time both the blades and cheeks became so cut and abraded by the gravel passing between them as to be unfit for use: but the soft india-rubber yields to the cutting action, and thus escapes much injury itself, while it prevents all injury to the cheeks. The india-rubber used is of a tough description, $\frac{1}{2}$ in. thick, and is cut into pieces 5 in. by 10 in. Slotted holes are cut in each piece, and bolts passing through these hold it down to the blade. When the outer edge of a piece is much worn, it can be pared off, and the piece

moved outwards on the blade by shifting the holes, thus exposing a fresh edge. This operation is performed every fourteen days at a cost of only about four shillings. It is this feature which gives the Bazin dredger its special capability of dredging with economy in rough stony ground. Sand pumps were used for dredging in the construction of the Suez and Amsterdam canals; but the author believes the dredger now described to be the only one that will effectively dredge gravel or large stones.

Apart from the wear of the fan, the chief difficulties which were experienced were as follows :—

1st. The difficulty in keeping the dredged material from flowing over the sides of the barges. When dredging in alluvial silt, it took more than an hour to dredge about half a barge load, or 30 tons; since, owing to the disturbed state of the water, the material would not settle to the bottom of the barge, but ran over the sides. Several methods were adopted to avoid this, such as dividing off the barge by partitions into settling chambers, directing the shoot into different parts of the barge at stated times, &c., but all to no avail. Finally it was concluded that the dredger was not suited for this light material, unless it could be thrown on to a large area, as over a bank into a field or vacant space, where sufficient area could be allowed for settling. Such cases would often occur in the dredging of rivers; but for harbour work the dredger is only available for shingle and sand.

2nd. The choking of the nozzle and suction pipe, owing to pieces of canvas, old bags, timber, baskets, &c., being drawn in with the sand. This was provided against by fixing iron bars across the face of the nozzle, thus forming a kind of gridiron and preventing the pipe from getting choked. Although these obstructions stick on the gridiron, yet, when the pump is stopped for a moment, they drop off into the water.

3rd. The fact of having to force the sand and shingle, after being pumped, along a horizontal 12-in. pipe which led along the top of the dredger into the shoots. If the sand came too fast, and not sufficiently mixed with water, it was a case of forcing a solid block of sand through the pipe, which thus became choked and stopped the engine. This was remedied by replacing the 12-in. pipe by an open

wooden trough 16 in. square, as shown in Fig. 1, Plate 8, thus giving twice the area, and preventing the possibility of choking.

There were several minor difficulties experienced through the imperfections of the machinery. For example, the smoke-box of the boiler was not sufficiently large, and frequently got red hot, and the boiler also primed considerably. These were remedied in the best way available, as they arose.

Cost of Working.—The vessel or barge for carrying the machinery and pump cost £600, and the contract price of the machinery and pump was £1,200. But before the dredger was taken over by the Company the alterations before enumerated had cost about £300, bringing the total for barge and dredger up to £2,100. In building a second dredger this might of course be greatly reduced. The cost of repairs for one month's working has been only £5.

The contractor receives for labour alone $2\frac{1}{8}d.$ per ton, being at the rate of about $1\frac{3}{4}d.$ for the dredging and $\frac{3}{8}d.$ for taking to sea (a lead of two miles), all materials being supplied to him. The consumption of coal is at the rate of about 1 ton for 1000 tons of sand dredged. At Lowestoft harbour the total amount of dredging has been about 200,000 tons yearly, but this is now much reduced in consequence of the pier extension recently constructed by the Author, which now prevents the sand and shingle from the sea blocking the mouth of the harbour. The services of the Bazin dredger are in consequence not so necessary.

The figures for cost, with this dredger, are as follows:—

Cost of dredger, say	...	...	...	...	...	£2000
Nominal horse-power	...	...	...	...	...	HP. 10
Depth at which it excavates	...	...	...	...	...	ft. 25
Quantity excavated, per annum	...	...	...	...	tons	200,000
Labour for dredging, lead (2 miles), and discharging, per ton	...	...	...	...	...	$2\cdot125d.$
Coal and other stores, say per ton	...	...	...	...	...	$0\cdot375d.$
Repairs (total £60)	...	...	...	...	...	$0\cdot072d.$
Total working cost per ton	...	...	...	...	...	$2\cdot572d.$
Add 10 per cent. interest on capital	...	...	...	...	...	$210d.$
Total cost per ton, including interest on capital	...	...	...	...	...	$2\cdot812d.$

The total repairs to the steam-tug, hopper barges, and dredger, have averaged about 2*d.* per ton.

Since 1 ton of the liquid dredged will very approximately occupy 1 cubic yard, these figures may be at once compared with those given by Mr. Buckley, *Proceedings* 1879, p. 552. It will be seen that the cost is far below that given for bucket-dredgers, and will compare favourably even with that given for Mr. Fouracres' dredgers, when the greater lead, and the high cost of labour in England as compared with Bengal, are taken into account.

Discussion on the Bazin Dredger.

Mr. LANGLEY wished to add that several attempts had been made to put the engine directly on to the fan of the pump, but without success. The present arrangement was to drive from a belt, and that acted as a sort of safety-valve. Directly the pump showed a tendency to choke, instead of the machinery breaking (as it would do if the pump were attached direct to the engine), the belt slipped; and therefore he thought this was the best arrangement that could be adopted.

He had used the dredger very successfully to pump water. A short time ago he had had to reconstruct a lock at Mutford, near Lowestoft; and having made a cofferdam at each end of the lock, he put the nozzle of the suction pipe through the dam, and used the pump to suck out the water from the lock. Some of the men put a net in front of the delivery pipe, and managed to secure nearly a cartload of fish of one kind or other; amongst others, a crab about seven inches across the back, and also many eels.

He had frequently been asked whether the Bazin dredger compared favourably with the bucket dredger. That was very much like asking a carpenter which was the most useful tool he had in his basket. He would naturally ask, "What do you want it for?" It was the same with the dredger. To dredge clay, it was no use putting in a suction pump, for it would not suck it up; if it was mud, it would be of no use, because the mud would flow over the sides of the barge; but for gravel or sand he believed there was no better dredger when it was properly worked; it would do very much more work, and at a very much less rate, than the ordinary form. If any gentleman desired to ask him any questions on the subject, he should be happy to afford any information in his power, either there or afterwards at his office.

Mr. C. P. SKERRETT, having been in charge of the dredging for the Great Eastern Railway both at Lowestoft and at Harwich for five years, hoped to be allowed to make a few remarks on the interesting paper of Mr. Langley. For many years dredging had been carried on at Lowestoft by means of three large bucket-dredgers; but it was with the greatest difficulty that they were able to overcome the accumulation of sand and shingle, which the north and north-easterly winds brought in in large quantities between the pier heads. The Bazin dredger however came to their assistance; and with that, and the extension of one of the piers seawards, they had been able to overcome the difficulty.

The details of the dredger had been gone into minutely in the paper, but he had made a few further notes on that subject. The boiler was of the usual multitubular kind, 11 ft. long and 4 ft. in diameter, with a working pressure of 60 or 70 lbs., and consuming about 5 tons of coal per week, when working on an average about eight hours a day. The engines consisted of two inverted cylinders, 9 in. diameter and 10 in. stroke, making about 120 revolutions per minute. The higher velocity of the pump was obtained by means of a leather belt on a counter-shaft. As mentioned by the author, the engines were frequently pulled up in the first trials in consequence of a large block of sand forming in the vertical pipe above the pump.

That they had remedied by doing away with the horizontal portion of the 12-in. delivery pipe, and substituting the open wooden trough H, Fig. 1, Plate 8, about 16 in. square. The flexible pipe which they were now using at Lowestoft was not quite so long as mentioned in the paper. Although the suction pipe was 25 ft. long altogether, it was now divided into two portions, one of galvanised iron 12-in. pipe, 15 ft. long, and only the remaining portion, about 10 ft., of india-rubber flexible pipe. That was owing to the great difficulty experienced in getting a good flexible india-rubber pipe. Owing to the knocking against the soil at the bottom, against sand and stones, and against the dredger, the flexible pipe was liable to be broken; they therefore used it as short as possible, of course long enough to allow working in different depths of water.

The hopper barges that had been mentioned had a capacity of about 65 tons each. They were square-nosed, and cost from £180 to £200 each. They were towed out to sea by a tug, and to empty them a trigger was knocked upwards, to which was attached the chain holding up the doors in the bottom. A short time ago one of their men, in knocking up the trigger, slipped, and went with the mud through the bottom of the barge. He was however none the worse for his experience.

With regard to the fan, they at first had a four-bladed fan, but, as the paper said, one of the blades got broken, and then they had a new fan made of two blades. They were however now using one with three blades, and equally good results were obtained with it. Dredging in solid clay certainly had not succeeded at Lowestoft; they could dredge mud, but solid clay would not come up. An arrangement existed by means of which a species of plough was set to work in advance of the suction pipe, to break up the soil so that it could be dredged. If the spoil could be discharged from the dredger over a bank or a dam, or upon a large surface, so as to give time to settle, he had no doubt the dredger would be equally efficient with broken clay or mud. Besides the blades and cheeks being worn at first, as the paper had stated, by the grinding action of the sand and shingle, they also found it so with the spindle of the pump; and they had to renew it four or five times, which was rather costly, and

occasioned considerable loss of time. They managed to avoid this difficulty by using conical brass bushes, which could be moved inwards on the spindle as required, and which were very easily renewed. The india-rubber flaps which they bolted on to the blades of the fan were at first made each in one piece, but they were now cut longitudinally down the centre, and fixed in two portions; so that, when the outer edges were worn, instead of having to renew the entire piece, they merely moved the two portions laterally outwards on the blade and then screwed them down again, thus leaving a fresh edge projecting beyond the edge of the blade.

With regard to the cost of the barge which contained the pumping machinery, it was put down as £600; but that, he thought, was scarcely a fair criterion, as it was the first of the kind made at Lowestoft, and he believed the second of the kind ever made in England. With their present experience no doubt the cost could be reduced to one half. The paper stated that 200,000 tons of sand had been dredged at Lowestoft. That was not by the Bazin machine exclusively, but by two bucket dredgers and one Bazin dredger. In one case they had used the dredger with the greatest advantage. The Lowestoft Water and Gas Company, under the supervision of Mr. Hawksley, were laying some gas and water pipes across the harbour, and for that purpose they had to cut out rectangular pockets, 9 ft. by 5 ft., from the sides of the quay wall. These had to be dredged in order to admit the vertical portions of the gas and water pipes. In such a case the bucket dredger would have been useless; but they directed the nozzle of the suction pipe of the Bazin dredger into the pocket itself, and in a very short time took out the necessary quantity of sand. Mr. Langley had mentioned the case of a lock gate at Oulton Broad near Mutford. There they passed the suction pipe of the dredger through the cofferdam, which they had to drive on either side, and then vertically downwards almost to the bottom of the lock. The dredger acted as a first-rate centrifugal pump, pumping out water at the rate of 2,000 gallons a minute. In that case it had a vertical suction of about 14 ft.; whereas when working as a dredger it had no suction, because the centrifugal pump itself was under the water-level outside. He at first feared that

it would not work well with the 14 ft. suction; but by fixing a foot-valve on the bottom of the suction pipe, and so always keeping the suction pipe filled, it answered very well indeed.

Mr. CHARLES BALL said his experience with this form of dredger had been extensive, there being twenty or thirty of that class at work in different parts of the world. He was much obliged to Mr. Langley for the kind mention of his name in connection with the invention which had made the pumping dredger practicable; and he would take the liberty of explaining the difference which existed between the Bazin dredger, as he had supplied it at first to the Great Eastern Railway, and the Ball dredger which they were now using. M. Bazin's idea was that by placing what he called a rotary elevator of any kind at a certain distance below the surface of the water, the hydraulic pressure outside the vessel would produce an immense inrush of water, which he called a gratuitous advantage; but he (Mr. Ball) supposed that if the water rushed into the boat it still had to be pumped out, and therefore the inflow would not be gratuitous, the expenditure of mechanical power being about the same when employing the centrifugal pump for forcing as for suction. That was the form of dredger he first sent to Lowestoft; and one of the difficulties of the system was that, in order to obtain any head of water worth the name, it was necessary to sink the pump far below the surface; it therefore required specially constructed dredging plant, drawing much water. In the case of Lowestoft, after scheming a great deal, with the assistance of the engineers of the railway, he managed to get the centre of the pump about 2 ft. below the level of the water. The results were not very satisfactory. In twelve months they dredged 738 tons, they spent £340, and they replaced the pump, or at least the inner parts of the pump, two or three times. When the face of the fan blades was made of india-rubber, the difficulty of wear disappeared. The practice which he had acquired then and since had proved that the position of the pump was absolutely of no importance whatever; but that what was required was a special pump, capable of passing thousands of tons of material per day without wearing at all. It was particularly inconvenient to put the pump

below the surface of the water for several reasons; first, because it necessitated special craft, which generally had to be built for the purpose, and secondly, because it necessitated an opening in the side of the boat, communicating with the interior. Then, if they had to open the pump, the water would rush into the boat and swamp it immediately. It was therefore necessary to interpose a sluice-valve between the pump and the water. But the sluice-valve was very difficult to manage, and when pumping stones or pieces of metal it often would not shut. Anyhow, he had found it possible to place the pump above the water level; in fact his usual practice now was to place the pump 3 or 4 ft. above, and under those conditions he required no special craft. He could take a fishing smack, and as long as it would carry a boiler and engine his pump could be put upon the top, the whole thing weighing 12 tons, for a dredger that could raise 100 tons of material an hour.

In placing the pump above the surface of the water, he met at once with a difficulty, which was that the centrifugal pump would not start, as they all knew, unless it was filled beforehand; and being above the level of the water, it was impossible to fill it unless there was a foot-valve. The same objection which applied to a sluice-valve between the water and the pump applied equally to the foot-valve, which would never work when sucking stones, gravel, &c. But he had succeeded in arranging so that the pump, though placed 3 or 4 ft. above the surface of the water, could be filled almost instantly, and when once filled it would remain full for weeks, and would start whenever required, without there being a foot-valve or any impediment to the passage of materials. With the pump first tried at Lowestoft, the delivery pipe was vertical, and there was another difficulty: whenever the pump stopped, a whole column of gravel fell back into it, the result being that, when the engine started again, the strap slipped, and it could not start. At Lowestoft this was altered by fitting a horizontal length of delivery pipe next the pump, and then turning it upwards further on. If the gravel then settled it obstructed the pipe a little, but it did not reach the vital part of the pump. To get the pump started without filling he had gone further in the same direction, and had bent the pipe first down and then up

again. If the bottom of this bend was below the external water-level, then there were evidently two columns acting against one another. If the column in the bend was the longest, naturally the air could not come in, and the pump could be stopped for any time, and would always be ready. In order to start the pump he used a simple ejector, putting for the moment a flap of india-rubber on the end of the delivery pipe until the vacuum was produced. As soon as the pump was partially filled by the action of the ejector, the machinery was started. It took about 30 to 45 seconds to start the pump; the only point was to make the ejector sufficiently large.

One of the great advantages of this pump was its power not only of dredging, but of conveying materials through long pipes. In one case at Langenbrugge in Holland the spoil was carried 1,200 yards through pipes, thereby doing away entirely with all loading into barges and a great amount of labour. But to do that it was necessary first to avoid choking. Now the remedy which had been adopted at Lowestoft would not apply to that case, because, if it was desired to force material a great distance, it was impossible to use, as at Lowestoft, an open channel. It was also necessary to make sure that too much material was not taken at one time. The arrangement that was employed very successfully was to use a simple vacuum gauge on the suction pipe, brought under the eye of the man who was in charge of the nozzle; because, though one could see the nature of the material and the quantity which was coming by looking at the delivery, that was no longer possible when the delivery was 400 yards away. Suppose that the pump had a tendency to choke, then the vacuum inside the pipe would increase; therefore by placing a common vacuum gauge on the pipe, and giving it a sufficiently large dial, the man could see the hand moving towards the vacuum, and would know that he ought to lift the nozzle, so as to suck more water in with the sand. On one occasion, when dredging ballast for the Orleans Railway on the River Loire, he had the misfortune of seeing the whole of the delivery pipes disappear under water. The pump had taken too much sand; the men were not quick enough in relieving it, and the delivery pipes completely filled with sand; the buoyancy which they received from some empty barrels was not sufficient to keep them

afloat, and they sank, and had all to be unbolted under 4 ft. of water. He had afterwards thought of making the vacuum itself remedy the evil automatically, and had done so with success, by means of the contrivance shown in Fig. 2, Plate 8. Just above the mouth of the nozzle a number of large openings were made all the way round, and then for simplicity these were covered with a ring of india-rubber having a slit opposite each of the openings. If the thickness of the india-rubber was properly proportioned, the result was that, as soon as the nozzle began to choke, sufficient vacuum was produced to make the slits open inwards, and a stream of water then entered, and prevented any further choking.

Another very great difficulty was in dredging foul ground, *i.e.* ground filled with various obstructions, as inside harbours, where sails and straw and things of that kind had accumulated. The grating of the nozzle then got completely filled up, and nothing could enter it. The remedy was to take up the nozzle and clear it; but in so doing the engine had to be stopped, and it took some few minutes to pull away the obstructions. After trying a great many devices on a dredger at Smyrna, dredging the harbour for Messrs. Dussaud, he hit upon a very simple expedient. The iron suction pipe was made to end in a fork, and to each of the two branches was applied a separate flexible pipe and nozzle, lifted and lowered by two separate ropes, running on the same barrel of the steam winch but on opposite sides; at the junction of the branches was placed a valve, which could be moved so as to shut off one side or the other, according to the will of the dredger foreman. As soon as one nozzle began to get foul, he shifted the valve so as to draw from the other, while the first was lifted up and cleaned; and by the time the second was foul the other was clean. The result was that, although the obstructions were continual, yet the work of the dredger was also continual, with only the additional expense of the wages of one man, a labourer occupied with an iron hook in cleaning the nozzles. He had saved thereby 35 to 40 per cent. in the working of the dredger.

As to the price of these dredgers, of course it varied according to what they were intended to do. A dredger of that class, not floating but mounted on wheels, to cut ditches through salt pans in the south

of France, near Marseilles, cost £480. When tested it dredged 750 cubic metres, or 1,500 tons, in two days. He had also worked on the Loire, where there was a peculiar difficulty from the exceeding shallowness of the river, and the occasional sudden fall of the water. Contractors had to be exceedingly careful with their dredgers, but even then they were sometimes caught and stranded high and dry on the banks of the river, where they remained four or five weeks or more until a freshet came and took them away; and that was of course very expensive to the contractors. But the simplicity of the Ball arrangement was such that he was able to use a local boat made to carry cargo, exceedingly long and wide, and drawing only 2 ft. In the case of Angers, with the engine fixed and ready to work, the boat only drew 1 ft. 4 in.; and that engine, with only a 9-in. suction pipe, raised 195 tons, on the average, per hour.

Mr. T. R. CRAMPTON asked if Mr. Ball could state through what lengths of pipe he had carried the mixture of sand and water; and what quantity of water in proportion to the solid material he found the best, according to the length of pipe passed through. It was easy to pass the stuff through open channels; but in some cases it might have to be sent a great distance, and if the flow was not regular and sufficiently fast, of course it would soon choke up. He should like to know also what was the indicated horse-power under given conditions, and the percentage of actual work done. That would give the loss by friction, which he fancied must be very great for long distances, if the pipe was small.

Mr. BALL said that the longest distance to which he had carried material through a pipe was the 1,200 yards already mentioned; but he had done that in two relays. After it reached 600 yards the back-pressure seemed to become too great—that was to say, the friction increased the resistance to the passage of the material so much that the pump was no longer able to force it through. He therefore established a second pump on a floating pontoon or barge, with a special engine; the delivery from the first pump entered into the suction of the second, and the two working

conjointly soon built up a very large mound on the banks of the canal that was being cut. In that case it was very fine sand. There was so much uncertainty with the different materials that these points could only be settled by practice in each case. Evidently, if there were heavy stones and so on, they did not roll easily, whereas very fine sand seemed to keep in suspension, and the friction was less. He had used a little device to prevent the material from settling at the bottom of the pipe, when running horizontally for long distances. He had formed a spiral rib in the pipe by means of a small angle-iron riveted along the inside, so as to make a long helix. The result was that the water in rushing through the pipe took up a rotary motion, and so kept the material from settling.

Mr. CRAMPTON said there must still be a minimum velocity, at which, if the material was sent, it would all settle. What was that minimum velocity as compared with the proportion of water to sand?

Mr. BALL said that was a question which he was not able to answer exactly, notwithstanding the numerous dredgers he had worked, because the circumstances varied continually. The same bottom did not work alike during half an hour. He might say generally that there were three elements in the problem: l the length of pipe; k the coefficient of friction, which for any given material could be made to vary by admitting more or less water; and P the engine power. There was a connection between these three quantities, which might be roughly expressed by the equation $P = k \times l$. Now if l were a fixed quantity, say 600 yards, and P also a fixed quantity, being the limit of the engine power, this equation could still be maintained, because k could be controlled by admitting a little more or less water. Supposing that in the progress of the work the distance l became doubled, it simply meant taking more water; and if the nature of the material changed, that affected k , but it could always be modified again by increasing or diminishing the admission of water, so as to satisfy the equation. Of course in practice the engine

power P could also be varied; for the engine was not supposed to be worked always to its very maximum, but to have at least a good third of its power in reserve. To give a single example, his so-called one-foot plant, that is, the plant of which the piping was 1 ft. diameter internally, delivered a maximum of 15 tons of water per minute; this gave a maximum velocity in the pipes of about 12 ft. per second, which he had found capable of carrying heavy stones, and even pieces of iron that got in by accident, as easily as so many straws.

Mr. LANGLEY thought Mr. Crampton's question was partially answered at page 101; viz., that the best proportion of water to sand, according to actual experience, was 5 to 1. Of course that applied only to the case shown in Plate 8—a total lift of about 25 ft., of which the suction pipe drew about 12 ft., and then a horizontal travel of about 50 ft. further to the hopper barge. They found that 5 to 1 with that material answered best under those circumstances; but the proportion was sure to vary with the length of pipe, the distance to be carried, the material to be dredged, and the velocity. Very fine mud was held in suspension in water, and of course would go as far as the water went; but with sand it was different, as it continually sank downwards. Therefore water would carry with it a greater proportion of clay than of sand.

The PRESIDENT asked if there was not something peculiar in the form of the fan blades, which seemed to be very much curved at the ends. He should like also to ask how much space there was between the outside of the fan and the inside of the casing, and what clearance there was allowed beyond the edge of the india-rubber at each side.

Mr. LANGLEY said the sides of the casing came very close to the metal blades, the clearance being $\frac{1}{2}$ inch; the india-rubber nearly touched, or did touch. The clearance between the front of the blades and the casing was about $4\frac{1}{2}$ to 9 in., the pump not being concentric.

Mr. CHARLES HAWKSLEY said that, having had the advantage of seeing the dredger at work at Lowestoft on the occasion referred to by Mr. Skerrett, he could bear witness to the facility with which the dredger did its work, especially in the difficult position of having to dredge out of a pocket made in the side of the upright wall of the harbour, and also when dredging close to the foot of the piles which sustained the retaining wall. With regard to the difficulty experienced when dredging mud, in getting the mud to settle, it might perhaps be obviated by having three or four barges into which to discharge the delivery of the pump, dividing it equally among them, and not putting it into one barge at one point only, but say at a dozen points. The contents of each barge would then have time to subside, and allow the water to flow over the edge without carrying the mud with it.

Mr. LANGLEY said they had tried a scheme which to some extent had answered the same purpose, by placing boards lengthwise in the barge, so as to cause the water to go from one end to the other several times, before finally it went over the side; but they found that, even with these precautions, about half the mud was lost.

Mr. CHARLES HAWKSLEY said that plan would not have quite the same effect, because the water would be passing through narrow channels, and therefore its velocity would be retained; whereas if they passed it across and across the barge, letting it travel the whole length of the barge before going over, the velocity would be very much reduced; and if instead of employing one barge they employed four, of course they would again reduce the velocity to one-fourth of what it would be with a single barge.

Mr. LANGLEY said no doubt something of that kind would prevent the loss; but to use so many barges together would cause such complications, that it would be better to use the ordinary bucket dredger.

Mr. E. A. COWPER thought it was due to the memory of Dr. Potts to say that he had been the first, he believed, who had proposed to excavate by vacuum. Many cylinder foundations for bridge piers had been excavated on his plan, which consisted chiefly in making a vacuum in a large reservoir, and then *suddenly* opening a large pipe connecting the reservoir with the cylinder to be excavated, when the great rush of water into the bottom of the cylinder brought in with it gravel, stones, sand, and mud, and allowed the cylinder to go down. He had himself sunk such a cylinder through 5 ft. 0½ in. at one suck by such means, and stones the size of one's two fists were often drawn in. Dr. Potts had also proposed using a pipe from a vacuum reservoir to suck up stuff from the bottom into the reservoir.*

* The following note, on other attempts of the same kind, has been communicated to the Secretary by Mr. William Anderson:—

“The principle of sucking up mud, sand, and gravel by means of centrifugal pumps has been familiar to me since 1864, when I saw, at the Chatham Dockyard Extension Works, a vertical-spindle centrifugal pump, by Messrs. Gwynne, fitted up as a mud dredger. Mr. Bernays, the resident engineer, writes to me that it was an entire failure, owing to the difficulty of getting the pump to the mud or the mud to the pump. When the pump was dropped down into a mud bank, a few revolutions brought up a wonderful stream of mud; but after it had brought up, in about half a minute, all the mud within range of the fan, it pumped nothing but water. The mud would not pull to the pump, and the pump could not be got to follow up the mud. The working was therefore quite spasmodic; and as the dredging lay in a tide way, where the bottom could be seen at low water, there was abundant opportunity of observing the action of the pump. The mud was removed in holes or trenches, and there was no symptom of any possibility of removing the mud from any given surface with the slightest regard to uniformity. At the best, the ground, after the pump had passed over it, looked like a celery bed. Mr. Bernays concludes by saying that he has often thought that the pump might be useful in pumping out of hopper barges on to land, the mud being fed up by hand. Some years ago I made a dredger for Demarara which acted on this principle; the mud was dredged up by an ordinary ladder, the buckets shot their contents into a centrifugal pump which was also supplied with water, and the mixture of mud and water was pumped over the canal banks. I have recently heard that this system has succeeded; certainly it worked very well in the Thames.

“Mr. H. Lee commenced experiments on sand pumps in 1872 or 1873, with the view of dredging the sand out of the North Sea entrance to the Amsterdam

NOTE.—Messrs. Gwynne and Co. wish the insertion of a note to remove the impression which might be produced by the note on a mud dredger, published p. 117 of the present volume, that they had only made one dredger, and that that had been a failure. As a matter of fact they have made several such dredgers for dredging mud, which have been generally successful.

Canal. He finally adopted a Woodford two-bladed fan about 4 ft. diam., working on an inclined or vertical spindle and always kept submerged. The pump consumed about 70 I.H.P. and raised 145 cubic metres of sand per hour; but the action was uncertain, and the bottom had to be finished with an ordinary dredger. The same effect appears to have been produced as that described by Mr. Bernays; the pump made holes and trenches. Mr. Lee would not use the pump again for large works, but thinks that in canals and narrow estuaries it might be useful, especially if the pump could deliver its contents over a bank; but even then the lead must be very short, as the power consumed increased rapidly with the length of the pipes. He found the same difficulty in filling the hopper barges as the author of the paper describes. Sand and gravel filled very well, but silt, mud, and peat would not subside fast enough.

“Mr. Lee did not encounter any of the difficulties Mr. Ball seems to have met with, probably because his pump was completely submerged, and hence all difficulties of charging and regulation were much diminished.”

BAZIN DREDGER:

Plate 8.

Fig. 1.

*Longitudinal Section
of Dredger.*

Fig. 2.

Scale 1 to 128

BAZIN DREDGER.

Plate 9.

Fig. 3.
Transverse Section of Dredger.

Fig. 4. Section of Pump through YY.

Fig. 5. Section through XX.

Scale 1 to 20.