The Hydraulic Dredge J. Israel Tarte

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THE HYDRAULIC DREDGE "J. ISRAEL TARTE."

(By A. W. Robinson, M. Can. Soc. C. E.)

This dredge was placed in service in June, 1902, in deepening the channel through Lake St. Peter in the River St. Lawrence. As it involves some new features both in design and mode of operation, and has achieved a remarkable result, a detailed account of the dredge and of the work on which it is engaged will be of interest.

The author has purposely refrained from publishing an earlier account of it, preferring to wait until it has been thoroughly tested in service, and the results made available. The present paper will deal with the conditions leading up to the construction of this dredge, a description of the dredge itself, and a statement of the results accomplished.

The Lake St. Peter Channel is part of the improvement in navigation of the River St. Lawrence between Montreal and Quebec. This work has for its aim the passage of ocean vessels to Montreal, making that city the point of trans-shipment of the inland lake and rail traffic by the St. Lawrence route to the sea. This section of the river is 160 miles long between the cities named, of which about 60 miles is dredged channel in about 20 different places.

The kind of material met with, varies in the different localities from soft clay to slate rock and stones. The dredging machines, therefore, must be different in their character for the different sections of the work.

The original least depth of water in the channel was 10 ft., this being the nearly uniform depth on the flats of Lake St. Peter, which is a shallow expansion of the river about 9 miles wide by 18 miles long. The bottom here is of blue clay of a varying degree of softness, with some sand and stones in places.

For the information of those unfamiliar with the subject, the following table of the successive stages of water attained, and the dates of completion, is appended.

Original depth of water in channel..	10 ft.
Dredging commenced in 1832.	
Depth completed in 1853..	16 "
Depth completed in 1858..	18 "
Depth completed in 1865..	20 "
Depth completed in 1878..	22 "
Depth completed in 1882..	25 "
Depth completed in 1888..	27½ "
Depth now nearly completed...	30 "

The fact that this great work was commenced in 1832 and prosecuted with more or less continuity ever since, is eloquent testimony alike to the importance of the work and to the energy, pluck and perseverance of those early pioneers who so boldly faced a work of such stupendous magnitude with the primitive appliances and slender financial resources which they then possessed. It is indeed a fortunate fact that all this early work still remains to the good, and that the character of this noble river is such that its bed is practically unchangeable. In this respect it is unlike the alluvial Mississippi, which requires a fleet of ten powerful dredges to maintain the channel. It is strange that in the public mind, unacquainted with the facts, there exists a widespread impression that much of this dredging is of a temporary nature and that it must naturally fill in again. This is entirely erroneous. The geological formation is such that there is practically no erosion of the banks, and the bed of the river is composed of various kinds of material, some of which is very difficult to dredge, and all of which (with the exception of one or two unimportant places where sand occurs) remains in place. Surveys and soundings made sixty years ago correspond closely with those of the present day. The work, therefore, is permanent.

The size of ships using the St. Lawrence route has steadily increased and has at all times been fully up to the limit of the depth of water. In a paper on "The Economy of Large Ships," read by the author before the Society in 1902, he pointed out that when the 30 ft. channel of the St. Lawrence was completed, it could be navigated by a vessel 520 ft. long, 61 ft. beam and 12,000 tons dead weight carrying capacity (or about 20,000 tons displacement), and that the economy of such a vessel was nearly double that of a vessel of 5,000 tons dead weight. It follows that a larger vessel would be still more economical, the limitations being only depth of channels, capacity of harbours and facilities for furnishing and handling large cargoes.

In the same paper he pointed out that a greater degree of safety and immunity from accident would be obtained by a large vessel than several small ones of equal capacity. One of the reasons for this is that a large vessel, such as we have under consideration, will usually be commanded by higher salaried and more competent officers than a smaller ship or tramp vessel. This means that the accidents, due to ignorance or negligence, and which may be classed as avoidable, will be reduced. There are also risks of the sea, which may be classed as unavoidable. These will also be less with a large ship than with a small one, for the reason that the large ship does the work of, say, three small ones, or, in other words, carries as much cargo in one voyage as the smaller vessel will do in three. Consequently, the risk from unavoidable disasters is one-third in point of time of exposure to such disasters for a given amount of commerce, and furthermore the large ship is more staunch and seaworthy, and thus better able to withstand the stress of the sea.

The assertion that better paid and more skilful officers and crew of a vessel carries with it greater immunity from accident, is borne out by the history of the lines coming to Montreal, as comparatively few accidents happen to the large and well-appointed regular liners whose officers and crew are experienced in the service. The majority of the accidents are those which have happened to the smaller class of vessels, and are due either to inexperience or negligence.

In pursuit of great economy and money-making capacity, the size of vessels is ever on the increase. Hence the necessity for deeper channels and greater facilities for handling of cargoes. Many vessels are in use larger than the size above, and the limit of depth for a first-class ocean port is now from 35 to 40 feet.

The condition of the St. Lawrence ship-channel, in 1901, was that the much-to-be-desired 30-foot stage of water was still some distance off. There remained some 25 millions of cubic yards to be dredged, (*1) and the fleet of six large dredges were removing it at the rate of about 2½ million yards per season (*2). In order to meet the

(*1.) See Estimate 30 foot channel Dec., 1902; Annual Report Dept. Public Works, p. 146.

(*2.) The total number of cubic yards dredged in year ending June 30, 1901 was 2,479,385 cubic yards. See Annual Report 1901, p. 186.

demands of commerce and to complete the 30-foot stage as early as possible, it was evident that something must be done to hasten the work. A large part of the balance remaining to be done lay in the soft clay of Lake St. Peter.

The existing channel through the lake was 300 feet wide in the straight portion, and 27½ ft. deep (or 26.1 at new datum of extreme low water, See Note) and about 18 miles long. The immediate work to be done was deepening to 30 ft. and widening to 450 ft. To allow a little margin the actual cut taken out in the deepening was about 5 ft., and the thickness of cut in the widening was 18 ft. to 20 ft. In the bends the width increases to 700 ft. The total volume to be removed to accomplish the deepening and widening in Lake St. Peter alone was, therefore, in the neighborhood of 15,000,000 cubic yards. To remove this at a much more rapid rate than was heretofore possible, the then Minister of Public Works, the Hon. J. Israel Tarte, after investigating the subject, resolved on the adoption of the hydraulic type of dredge, and the writer was commissioned to design a dredge that would have a working rate of 2,000 cu. yards per hour.

These instructions were given in February, 1901, and it was desired, if possible, that the dredge should be in operation by the end of August of the same year.

The conditions which presented themselves were as follows:

A channel 26 ft. deep at low water, about 300 ft. wide in the straight part and 600 ft. in the bends, and 18 miles long, with 10 ft. to 12 ft. of water on the banks. The section to be removed was that due to deepening the present cut 5 ft. and widening it 150 ft., and material blue clay of a varying degree of softness with some sand and stones in places.

The dredge, therefore, must fulfil the following conditions :—

1. It must be able to make a cut 700 ft. wide at one time and 5 ft. to 10 ft. thick at one cut.

2. It must leave a clean and level bottom and cut mechanically the entire area, as the material is blue clay and will not run or wash like sand.

Note. This work to 1897 was done to ordinary low water datum. Since that date a new datum 1.4 ft. lower has been established, which corresponds to extreme low water a stage that has only once been reached in many years. The new channel of 30 ft. is therefore 3.9—or say 4 ft.—deeper than the 27½ ft. channel. In all ordinary seasons and except for a few weeks in the fall of the year the depth of water is 2 to 5 ft. above low water, so that a vessel of 30 ft. actual draft can safely navigate the 30 ft. channel except for a few weeks in the fall of the year if the season should be a dry one.

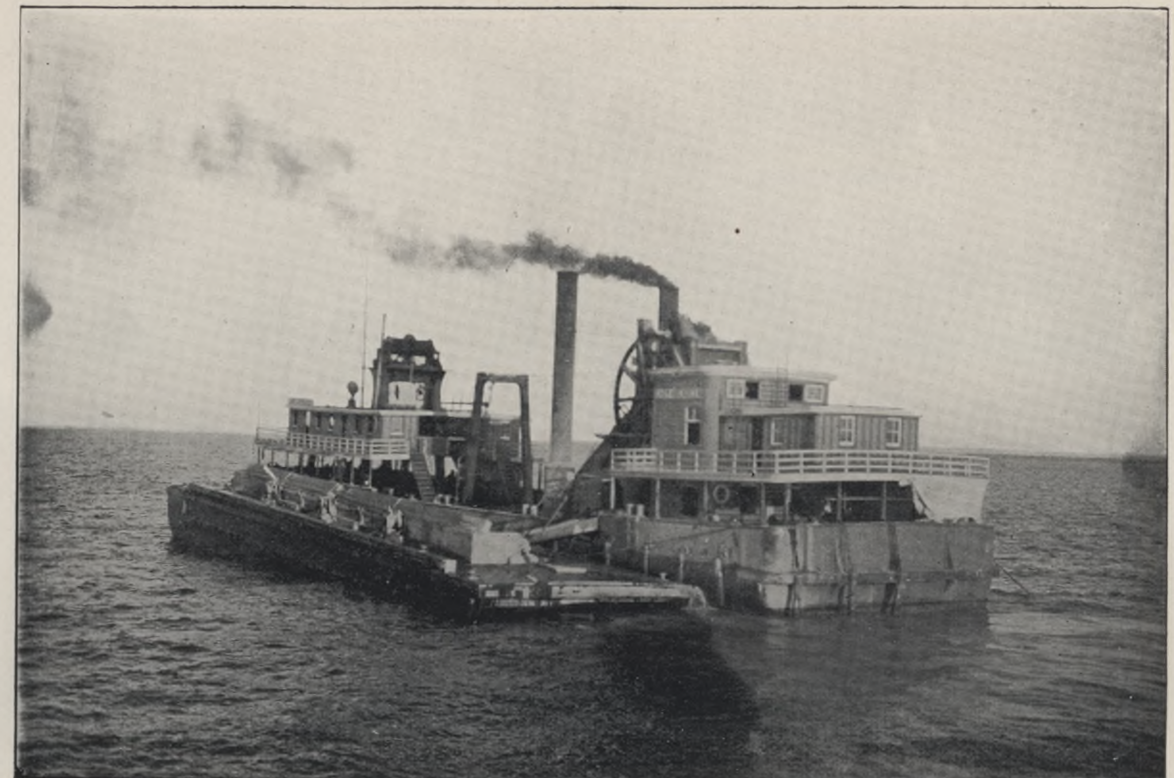


FIG. 1

ELEVATOR DREDGE ABERDEEN.

3. It must deliver the material sufficiently far to one side of the channel to avoid any risk of washing back again.

4. The floating pipe-line must be so arranged that it will freely permit of the movements of the dredge, and that it will withstand the winds and waves due to the locality, and which are severe at times.

5. The dredge must be so worked that it will not obstruct the channel for passing ships.

6. The anchorage and movements of the dredge must be so arranged that the feed will be continuous and uniform.

7. The capacity to be a working rate of 2,000 cu. yards per hour.

8. The dredge must have ample coal supply and provision for a double crew.

The dredge "J. Israel Tarte" was designed to fulfil the above requirements and was built by the Polson Iron Works, of Toronto, Ont., and delivered and tested in October, 1901. The contract price was $163,800. This price did not include the discharge-pipe nor winches, which at the time the contract was placed, were not designed. In point of fact, when the contract was placed, nothing of the detail shop drawings of the dredge were made, nor any patterns available. In order to save time the contract was based on a general specification and outline design, leaving the details to be supplied afterwards as the work progressed. All drawings and patterns of every detail of the dredge were specially prepared and all material specially ordered, and the time which elapsed between commencement of the drawings and patterns and the testing of the dredge under steam was eight months.

Before describing the new dredge, brief reference will be made to the existing fleet of dredges and a statement given of the record already established by them on Lake St. Peter.

The fleet of dredges previously existing and engaged on the ship-channel between Montreal and Quebec comprises six elevator dredges, which, taking hard and soft material together, took out 2,479,385 cubic yards in the fiscal year ending June 30, 1901, at a total cost of $128,259.17, or an average of 5.1c. per cubic yard.*

These dredges have been brought to a high state of efficiency, and are the improved development of the early dredges on the work, the first of which was imported from Scotland in 1832.

The work done on Lake St. Peter by the elevator dredges may be illustrated by the "Aberdeen." This dredge is illustrated in Fig. 1. The buckets have a capacity of one cubic yard each, and can work to a depth of 40 ft. Small wooden barges, holding 300 cu. yds. each,

*See Annual Reports, Department Public Works, 1901.

are used to take away the spoil, and one tug suffices to do the work, going out with one barge while the other is being filled, making a round trip of about 1 mile in about 15 minutes.

This dredge worked in Lake St. Peter for a short time in 1901, and dredged 120,600 cu. yards. in 21 days at a cost of $3,054.88, or 2.53 cts. per cu. yd. The actual working time was 246 hours, giving an average output of 490 cu. yds. per hour.

The new hydraulic dredge, having a proposed capacity of 2,000 cu. yds. per hour, would therefore be called upon to accomplish results much larger in quantity than anything that had been done before on the work.

As far back as 1886 one of the elevator dredges then in use made a record which stood alone. This was made by dredge "No. 9" which, while working in Lake St. Peter, accomplished 886,710 cu. yds. at a cost of $25,723, or 2.9 cts. per cu. yd. (*1.)

The excellent work already done by these dredges rendered the task of improving upon them, by the proposed hydraulic dredge, the more difficult. The records for economy already cited, which were made by dredges "No. 9" and "Aberdeen,' were indeed hard to surpass, and have been rarely surpassed by any dredges in the world. The new dredge would be more costly than its predecessors, and manifestly, unless it could show considerably better results, not only in quantity, but in economy, would not fulfil the expectations concerning it.

It was recognized that a hydraulic dredge of this type is a special tool, that is to say, it would not be capable of doing the variety of work that the elevator dredge can do, or work in very hard material. Nevertheless the magnitude of the work in Lake St. Peter alone, and other places where suitable material exists, was sufficient to justify the construction of the dredge.

The state of the art of building large hydraulic dredges at this time, showed that it was possible to employ pumps of large power and capacity, and to deliver material through floating pipe-lines to a distance sufficient to meet the conditions of the present case. The great dredges of the Mississippi River, (several of which were designed by the writer) contributed much useful data and experience. (*2).

There, dredges were able to maintain a capacity of 1500 to 2000

(*1.) See Reports Harbour Commissioners of Montreal 1886 p. 80. This cost includes operating expenses of every kind, scow and tug service and repairs, but not interest or depreciation.

(*2.) See Trans. Am. Soc. C. E., Dec. 1898. "Dredges and Dredging on the Mississippi," by J. A. Ockerson, C. E. for a full account of these dredges at that date. Much further development has taken place since that paper of which no full account has been published.

cu. yds. per hour deposited 1000 ft. The material was sand, the depth 10 to 18 ft., and the cut made was a shallow trench by straight forward feed. Sand, however, is easier to dredge than clay, and these Mississippi dredges only worked to half the depth and deposited the material at half the distance which would be required on St. Lawrence. Furthermore, the Mississippi dredges only made a cut 30 ft. wide at one time, whereas it was here required to make a cut 700 ft. wide. It was necessary, therefore, to adopt a lateral feed instead of a straight forward feed, and also to apply mechanical excavation which would cover the ground. No hydraulic dredges had done any successful work in clay, and attempts in this material had been abandoned on account of the clogging up of the apparatus. No examples existed of long distance pipe-line dredges of large size which made wide cuts. Large dredges in America which discharged through pipe-line either anchored by spuds making a radial cut, or by mooring lines, making a straight forward feed. Sand-pump hopper dredge practice of European designs offered no useful points. Here was, then, the necessity for a new application of the hydraulic principle of dredging, the points of novelty being, 1st, the lateral feed of 700 ft. width, while discharging to a long distance through a pipe-line adapted to such movement ; 2nd, cutting mechanically over every foot of the ground in blue clay, and to do this without clogging ; 3rd, the construction of a pipe-line that would be capable of standing some stress of weather and wave-action.

To this extent, therefore, this dredge was experimental, and the present paper will describe the result of the experiments and the methods adopted to improve the detail parts after testing. The writer's observation of the elevator dredges in Lake St. Peter led him to conclude that here was a clay deposit which could be worked successfully by the hydraulic method if the proper apparatus for cutting or digging it were employed. The clay is of a soft, unctuous nature, sometimes partly silicious, bluish in color and of a character suitable for brickmaking, or pottery. It dumps well from the buckets of a ladder dredge and slides readily down the chute into the barges in chunks, frequently the whole size of the bucket and showing the markings of the rivets. The problem in the new hydraulic dredge, therefore, was to cut this clay regularly and uniformly and feed it into the mouth of the suction pipe without clogging. Once there, it would slide freely along and be discharged without difficulty, and by making the pipe of large diameter and the pump with passages of large section, the clay could go through in lumps even more readily than sand or finely divided material of like nature, which would tend to precipitate. Thus the hydraulic apparatus is used, not for dredging, but for purposes of transportation only.

In considering the question of capacity, the dredge was designed to have a theoretical rate of 3,000 cu. yds. per hour, and it was deemed that this would be sufficient to give a working rate of 2,000 yards per hour, including the delays incident to regular work, but not counting delays from exceptional causes, storms or repairs. This rate required a section of cut 5 ft. by 6 ft. by a feed of 45 ft. per minute, equal to 3,000 cu. yards per hour. It was, therefore, necessary to provide a cutter capable of dealing with that section and with plenty of margin to spare, and to provide means for feeding it 450 to 700 ft. across the channel at the required rate. As this involved traversing the entire dredge broadside at that rate, and dragging the

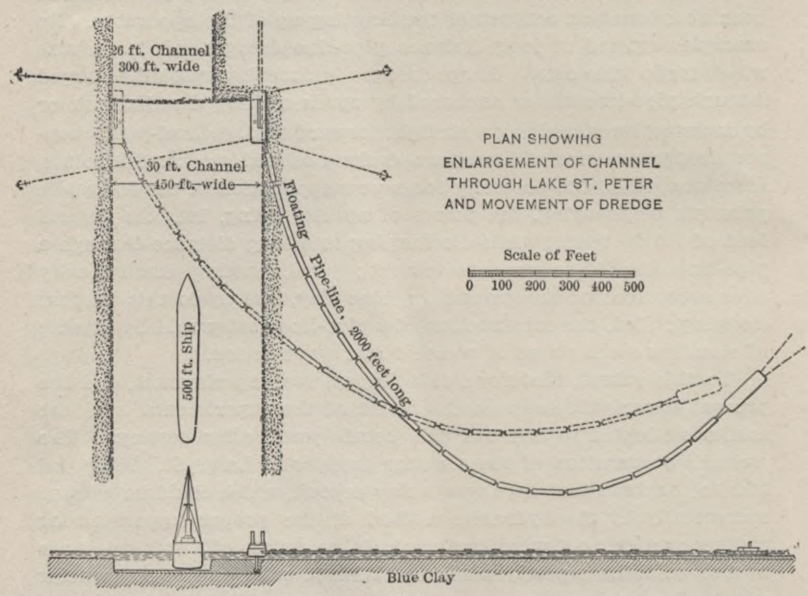


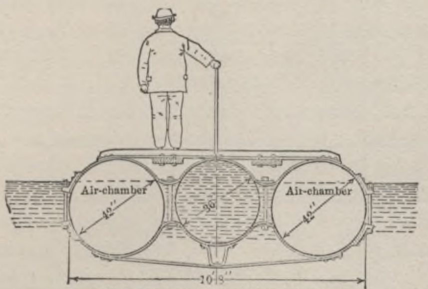
FIG. 2.

semi-submerged pipe-line after it, the power required for this purpose would be quite large, and produce a corresponding necessity of providing strong anchorage to the mooring lines, by which the traversing movement was to be effected.

In considering the movement of the pipe-line attached to the dredge, advantage was taken of the fact that there is a more or less constant current of ½ to ¾ mile per hour in the lake. This is due to the discharge of the river, and is modified by winds and sometimes by tides to a scarcely appreciable extent. The tidal variation at Quebec, 110 miles below, is 9 to 15 ft, but this gradually becomes less on ascending the river until it becomes lost at the lower end of the lake. The current, therefore, causes the pipe-line to assume a catenary curve of varying tightness according to the travel of the dredge. This is shown by Fig. 2, which is a diagram showing the movement of the dredge and the relative position of the pipe-line.

The current, therefore, was employed to deflect the pipe-line to the form of a loop having slack enough to permit the dredge to traverse 450 ft. In order to utilize the current for this purpose, and at the same time render the pipe-line less exposed to the wind and waves, it was designed to be two-thirds submerged. The weight of a large steel pipe filled with water and mud is very great and would require very large pontoons to carry it in the air, but by partially submerging it the buoyant power required is much reduced.

The form of pipe-line adopted is that of a central conduit, 36 in. diam., carried by two cylindrical pontoons or air chambers 42 in.



CROSS SECTION OF FLOATING PIPE LINE

FIG 3.

diam., the three being bound together by truss-frames clamped upon them as shown in Fig. 3. In this way no bolts or rivets are put into the air chambers, and they may be readily taken apart.

The pipes were made up in 100 ft. sections and four sections of 50 ft. were made with the idea of putting them in that part of the pipe where greater flexibility was required. It was found, however, that these 50 ft. pipes did not stand the sea as well as the 100 ft. sections, and that moreover sufficient flexibility could be had without them. They were accordingly joined together and converted into 100 ft. sections.

The joints connecting the 100 ft. sections were at first made by uniting them with a forged steel pin-connection over the rubber sleeve, thus relieving the rubber sleeve of all strain due to tension of the pipe and permitting the required angular movement. These joints were not strong enough and were found to be too rigid in wave action, and caused heavy strains to be set up, which broke some of the joints. They were temporarily repaired for the first season, and during the winter of 1902-3 new joints of special construction were devised by the writer designed on the ball-and-socket plan to permit of universal movement to a moderate degree, and also fitted with draw-bar springs to absorb the variations of length due to surging and pitching. The ball-and-socket principle was embodied, not in the pipe itself, but in a strong steel frame above the pipe, which was connected by rubber sleeves in the usual way. This has proved entirely successful and the practical result is that the dredge is capable of continuing at work in all but the heaviest weather. The general

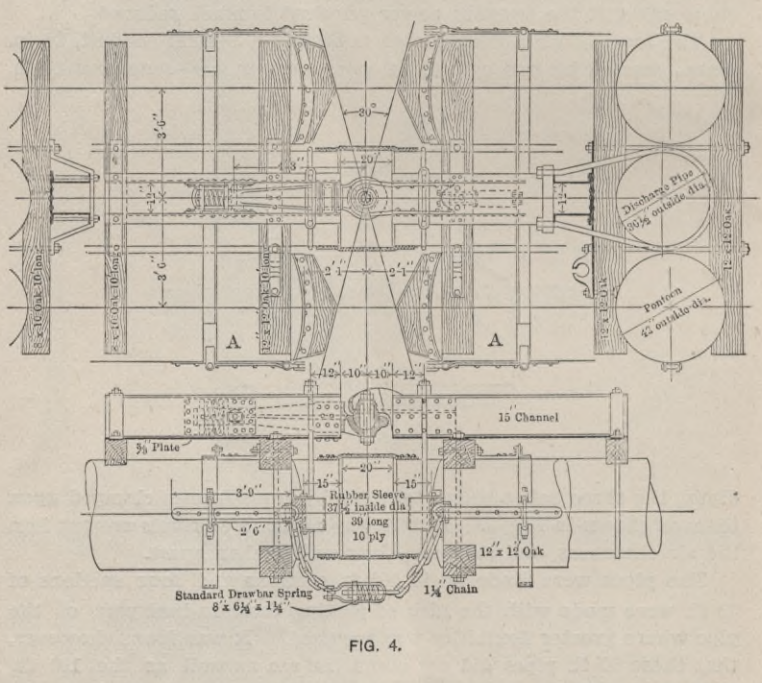


FIG. 4.

contruction of the pipe-line and joints are illustrated in Figs. 3 and 4. The ball end of the joint is solidly riveted to the frames on the pipe, while the socket end is fitted to slide in a casing or frame, and its movement is resisted by springs, as shown. These springs are two in number and are heavy car springs. They are 6¾ in. diam. and 8 in. long, and made of round steel, 1¼ in. diam. The springs are carried between spring-plates, resting against stops in such a way that the springs are compressed for either thrust or pull of the draw-bar, and the whole arrangement is built in the very strongest manner of steel, and each joint is strong enough vertically to carry half the entire weight of a pontoon upon it. In other words, should the entire buoyancy be removed from one pontoon for 50 ft. of its length by the trough of a wave, its weight could be rested upon the adjoining pontoon with safety.

This pipe-line has now been tested during the working season of 1903, and no breakage or failure of these joint connections has occurred, neither does the ball-and-socket arrangement show appreciable wear.

The elevator dredges which are used on the lake load into barges and can work in a moderate sea, but have to stop work when the surging of the barge against the dredge becomes too great. It was predicted that a flexible pipe-line could never be made a success in Lake St. Peter, as it would be impossible to maintain it in the waves and that more time would be lost on account of weather than is the case with the elevator dredges. As a matter of fact the position has been reversed, and with improved steel connections the dredge suffers less delays on account of the weather than the barge-loading dredges.

In order to provide flexibility of the pipe at the point of leaving the dredge a swivel elbow is employed, and the first length of pipe is short and connected to the elbow by a pair of hinges. The axis of the hinges is horizontal while that of the swivel elbow is vertical; thus the movement of the pipe is universal. The pipe leaves the dredge on the corner in order to permit the pipe to radiate from the dredge at any angle through three-fourths of a circle. The horizontal hinges at the swivel elbow will permit the main pontoons to have a vertical or wave-movement of 5 feet.

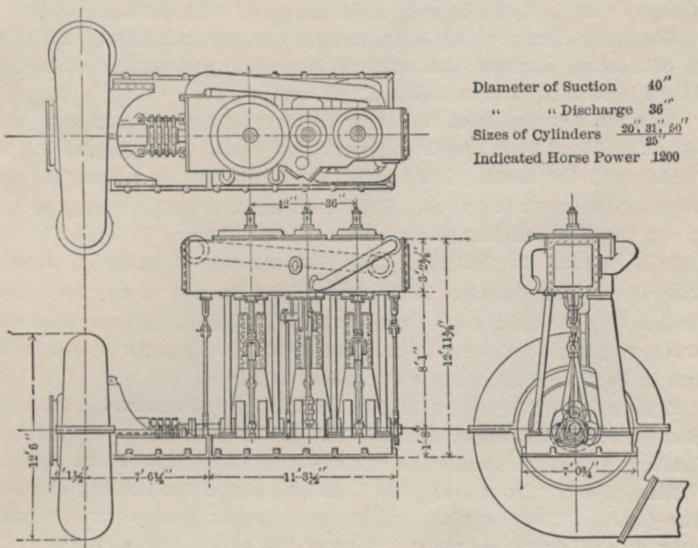
At first the discharge-pipe left the dredge through the stern near the centre of its width, it being supposed that the pipe would always drift downstream with the current, or could be anchored in that position. Such, however, proved not to be the case, as a strong wind astern would temporarily deaden the current and cause the pipe to drift upstream. The position of the point of leaving the dredge was therefore changed to that shown on the plans, with a swivel elbow which permits it to radiate at any angle through three quarters of a circle. This arrangement is entirely satisfactory. No anchorage is used at any intermediate point of the pipe. It is attached at one end to the dredge and at the other by a short cable to a scow, the entire 2,000 ft. being free to drift as it pleases. The scow is fitted with a steam winch, by which its own anchorage is controlled. It has two anchors with wire cables, 1¼ in. diam. and 2,000 ft. long. These can be hauled in and paid out as required, and this movement serves both to distribute the material, to avoid piling up above the surface of the water, and also to regulate the tension of the pipe when the dredge is making a very wide cut. In places when the cut is 750 ft. wide the pipe tightens up to almost a straight line when the dredge is at the far side. The scow anchorage permits considerable freedom of movement and when necessary the operator on the scow pays out on his anchorage to relieve the tension and permit the dredge to make the cut.

The anchors used for holding the dredge are of large size to hold well. The side anchors and the bow anchor are alike as the strain is fully as great on the side anchors as on the head line. There is also a stern anchor worked by a special winch which acts like a towing engine, in that it hauls in and pays out the line automatically as the dredge traverses its cut to suit the varying length and keep a constant tension.

Turning now to the dredge itself, the general form and arrangement will be seen by referring to Fig. 7. The hull is of steel and is 160 ft. long, 42 ft. beam, 12 ft. 6 deep. The plating is generally ½ in. thick on the bottom and ⅜ in. on the sides with 5-16 in. deck. The hull is rounded at the bilges but is rectangular in plan with rounded ends in side view. There is a central opening, or well, through which the suction-pipe works. This well is 8 ft. wide, except at the forward end where it is 10 ft. wide to admit the cutter, and it is of sufficient length to receive the pipe. The suction-pipe is formed of a rectangular steel box girder of great strength, and having its lower horizontal web extended in width so as to fit between the sides of the well. The flanges of this horizontal girder are formed of two angle irons, 5 in. x 5 in. x ½ in., covered with a plate 12 in. x ¾ in., which bears against the sides of the well. This is for the purpose of withstanding the great lateral strain due to feeding the dredge sideways and with the cutter in contact with the bottom. The dredge being designed to work at a depth of 50 ft., the suction-pipe forms a lever within the hull and both the hull and the attachments of the pipe thereto, are of great strength to withstand the stresses due to contact with the bottom in a seaway and due to the lateral feeding. The suction-pipe is hinged to the hull at the deck by means of massive steel hinge castings, and a steel bulkhead extends the entire width of the hull at this point. The sides of the hull are extended above the deck to form a solid steel bulwark entirely around the dredge, the hand rail being formed of an 8 in. bulb angle, finished on the outside with 2½ in. half round. These bulwarks form a protection against the seas which sometimes break over the dredge.

The suction-pipe is suspended from a double steel A-frame over the forward end of the well, and the lifting winch for raising and lowering the suction-pipe is carried on top of this frame. The suspension tackle is formed of two sets of heavy wire rope tackle; the diameter of the ropes being 1⅝ in. The sheaves are of cast steel with turned grooves and brass bushings. The hauling parts of this tackle in this way pass direct to the drum of the winch without the intervention of any idler sheaves as would be the case if the winch were located below the deck. This arrangement has the further advantage of getting this winch out of the hull where it would occupy valuable space.

The main engines are of the triple expansion marine type, having cylinders 20 in., 31 in. and 50 in. diam., by 25 in. stroke. They are adapted to run at 150 revolutions per minute, with 150 lbs. of steam. The engine room is provided with a complete outfit of all the usual



MAIN ENGINES AND PUMP.

FIG 5.

accessories including air pump, feed pump, surface condenser, heater, bilge pumps, etc.

The material is excavated by an improved rotary cutter, 9 ft. 6in. diam., by 9 ft. long, the weight of which is 10 tons. It is formed of steel blades with specially designed clearance spaces between them, so as to avoid clogging with the material and the suction-pipe and passages through the pump are made very large for the same reason. The cutter is driven by a pair of engines placed on top of the suction-pipe at the upper end. These engines are of the double tandem type of 300 I. H. P. They are of the most substantial description with all bearing surfaces extra large for continuous heavy duty. The gearing and power transmission for these engines is of exceptional strength and capable at all times of encountering immovable resistances with full head of steam on the engines without risk of breakage. The main gearing driving the cutter is of cast steel 5 in. pitch and 15 in. face. It is worthy of note that during the whole two seasons that this dredge has been in service no breakage, or failure of any kind, has occurred to any part of the suction-pipe, cutter, or cutter-driving apparatus. This is due to the exceedingly substantial character of the design and construction, and the direct manner in which the strains are met ; also to the fact that the engines are the weakest part and can be stalled at any time with safety.

Steam is furnished by four boilers, having collectively 8,500 sq. ft. of heating surface, and adapted for working pressure of 160 lbs. There is coal bunker capacity of 200 tons.

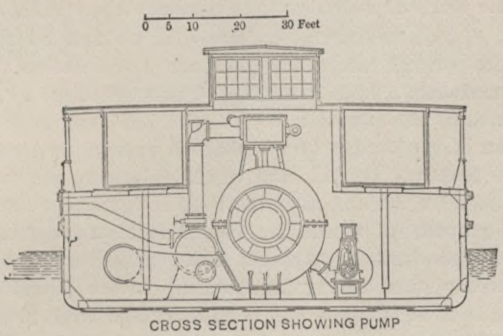
The main pump is of the centrifugal type, having cast steel runner of enclosed type and heavy cast iron shell. The blades of the runner and the heads of the pump are protected by renewable steel wearing plates in the shell. This shell is exceedingly heavy so that it can stand a considerable amount of wear before it begins to fail, and it is also so designed that the stream of material issuing from the runner does not strongly impinge upon it at any one point. In this way the tendency to wear is greatly reduced as compared with ordinary pumps. The original pump with all its parts is still in use and in good condition, after two years of service.

The whole of the operations of the dredge are controlled from the pilot-house on the upper deck. Here are located the levers for both the bow and stern anchorage winches and the lifting winch for the suction-pipe ; also a system of bells and signals to the engine room. The pilot-house is so placed that the operator has an unobstructed view up and down the river ; also of the entire discharge-pipe. It is necessary for the dredge to get out of the channel to enable vessels to pass. For this purpose the operator causes the dredge to remain on that side of the channel on which the discharge-pipe is situated and slackens out the breasting lines on the opposite side so that they rest upon the bottom.

The dredge is fitted with complete quarters for a double crew of 36 men, or 18 men on each shift. The dredge works continuously from Sunday night till Saturday night each week, without stopping, except when necessary. Several runs have been made of five or six days without a stop of the main pumping engines, the only interruption being the pause in feeding due to the passage of a ship.

The dredge is attended by a powerful light draft twin-screw tug. The principal duty of this tug is to fleet the anchors as the dredge moves ahead. The side lines of the channel to be made are marked at night by temporary range lights.

Turning now to the results accomplished, the work done during the month of June, 1902, when the dredge began work, was only 93,750 cubic yards. This was accomplished in 41¼ hours, or 14.3 per cent. of the total working time. It naturally occupied some time to get everything in good working order, to make minor improvements and to train the crew for their work, none of whom had ever operated a dredge of this type before. The output month by month steadily increased until in September, 1902, the quantity was 580,000 cubic yards; in October 600,000 cubic yards,—this notwithstanding the defects to which reference has already been made, and which were remedied during the following winter. The length of channel deepened in September was 7,800 lineal ft., 325 ft. wide by 5 ft. average thickness cut, and in October, 8,000 lineal ft. The dredge thus demonstrated her ability to deepen the channel to 30 ft. at the rate of a mile and a half per month.



CROSS SECTION SHOWING PUMP

FIG. 6.

Owing to lateness in starting in the spring and to early stoppage in the fall on account of accident to the boilers, the season of 1903 was very short, being 126 working days. During this time the work accomplished was 2,671,750 cubic yards, scow measurement, equal to an average of 21,200 cubic yards per day for the season. This includes all delays from whatever source. The best month was September, 1903, when the output reached the phenomenal figure of 757,100 cubic yards. This was accomplished in 25 days of 552 working hours, giving an average rate of 1,646 cu. yds. per hour, or 30,280 cu. yds. per day for the month. Of this time 460 hours was actual dredging, being 83¼ per cent. of the possible time. The work done was widening and deepening, at one time, the average thickness of the cut in the deepening being 4 ft., and of the widening, 14 to 17 ft. These figures show what can be done with this dredge when the working time can be kept up to a high average.

No special short time tests were made although log records show rates as high as 2,600 cubic yards per hour maintained for several hours. The average cost per cubic yard for the year is about 1¾c.

Unfortunately, the season was cut short by explosion of one of the boilers, due to low water, and causing the loss of two lives. But for this untoward accident the work of the season would have been much greater.

The work of the month of September, 1903, is believed to be greater than that ever before accomplished in one month by any dredge. Larger outputs have been claimed for shorter periods of time and in dredging free sand from shallow depths and delivered to shorter distances. The writer believes that the only proper way to estimate the work of a dredge is to measure the results obtained by the month. A high record may be made for a single hour, or a single day, but the general results may be poor if the dredge has not the ability to maintain a high average. The work done by this dredge is determined by the engineer in charge of the river works who takes the position of the dredge in the channel at a given time, say, the first of the month. On the first of the following month he again takes the position, having also observed its progress from time to time. The quantity of material removed is then determined by the area of the cross-section of the cut made, multiplied by the advance actually accomplished during the month. In the quantities as given the volume thus determined has been increased from place measurement to scow measurement, place measurement being 80 per cent. of scow measurement. This ratio is based on actual experiment and is for the purpose of comparing the work of this dredge with the other dredges on the river, all of which work by scow measurement. As the material is blue clay, which remains in place and leaves a cleanly defined bank, the cross-section of the cut can be determined with reasonable accuracy, and in a ship-channel 18 miles long, through level flats, it is very uniform and there is no chance for any considerable errors to be made.

The table on page 18 gives a comparative statement of the results of short time tests of the "Tarte" and two of the great dredges on the Mississippi. By short time tests is meant 12 to 24 hours. Many official tests of dredges on the Mississippi were made by pumping into barges so that the volume of sand and water could be accurately measured. Much useful data was secured in this way, but as the duration of such tests was only two or three minutes, the writer does not regard them as a valuable index of the working capacity of the dredge. The data given for the "Tarte" was derived from the daily log of the dredge, giving hours worked, distance covered and volume dredged. It does not therefore represent a "test" strictly so-called, but is one sample among many similar ones of what may be considered a good day's run under working conditions. The data for the "Delta" and "Epsilon" is taken from a special test recorded in Annual Reports, Chief of Engineers, U.S.A., 1899, Part V, p. 3495, for the purpose of ascertaining the performance under working conditions. These results likewise do not represent the utmost rate of which the dredges were capable, and it is recorded of the "Delta" that for a short time the capacity reached 2,550 cu. yds. per hour. The other dredges also would probably show a higher rate for a short time under the most favourable conditions.

Comparative Statement of Short Time Tests of Dredges.

"J. Israel Tarte" and Dredges of similar size on the Mississippi.

Name.	Cu. yds. per hour.	Distance Deposited.	Diam. of Discharge Pipe.	Indicated Horse Power.	Steel Hull.			Cu. yds. per H. P. per hour.	Depth of Dredging.	Kind of Material.
					Length.	Beam.	Depth.			
Delta	1,259	1,000 ft.	34 in.	1,050	175 ft.	38 ft.	8ft. 4in.	1.19	16 to 18	Sand
Epsilon	1,305	1,000 ft.	32 in.	748	157 ft.	40 ft.	7ft. 9in.	1.74	16 to 18	Sand
J. Israel Tarte.	2,106	2,000 ft.	36 in.	980	160 ft.	42 ft.	12ft. 6in.	2.15	35	Soft Blue Clay

Note.—The "Delta" was tested on October 30th, 1898, and Dredged 34,560 cu. yds. in 27h. 25m.

The "Epsilon" was tested on November 26th, 1898, and Dredged 32,407 cu. yds. in 24h. 50m.

The "Tarte" was tested on October 20th, 1902, and Dredged 25,280 cu. yds. in 12h. 0m.

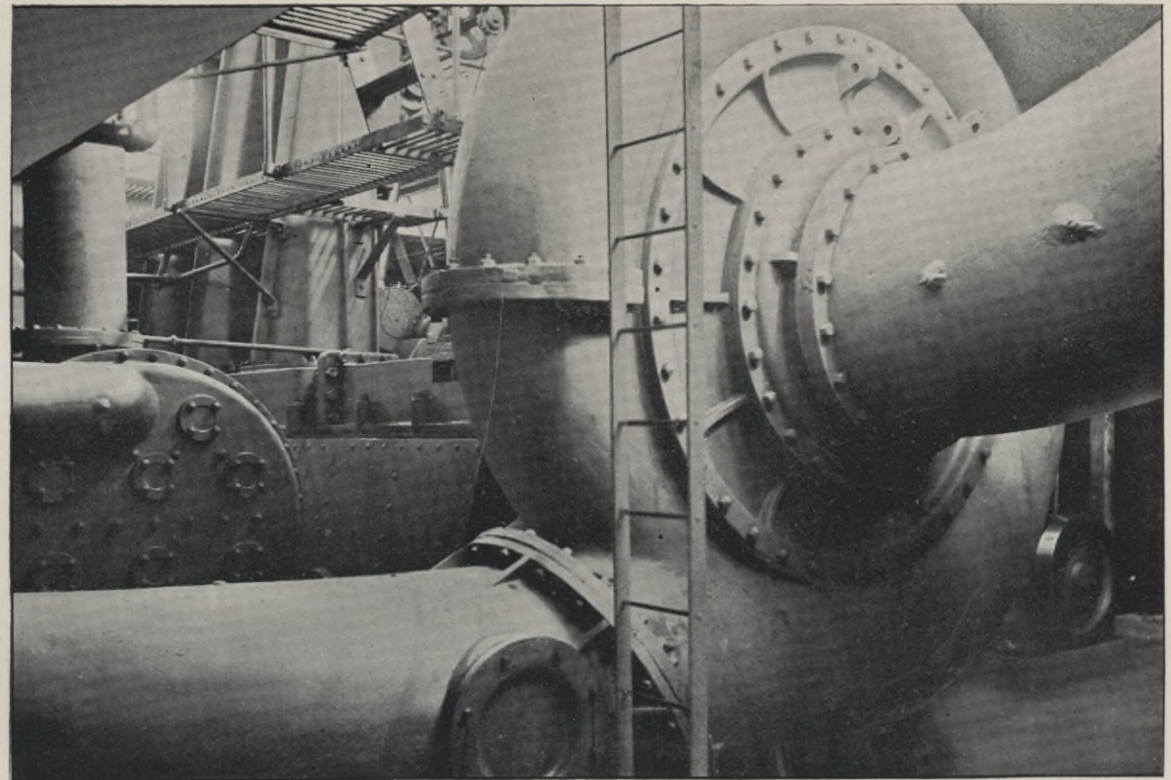


FIG. 10.

VIEW OF MAIN PUMP