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Description of a Dredging Machine Invented and Patented by D. S. Howard, *of Lewis County, N. Y., with some Notes made at a trial of it at Whitehall, Washington County, N. Y.; accompanied by some formulæ and rules for calculating the effect of Dredging Machinery.* By John W. Nystrom.

The dredging machinery represented in the accompanying plates, is worked by a pair of horizontal high pressure steam engines.

Plate I. represents a side elevation of the machine, showing the buckets drawn up on one side to the full height above the water line, and those on the other side let down to the full depth of excavation.

Plate II. is an end view of the same, showing the buckets down on the starboard side, and up on the port side above the water line.

Plate III. is a plan of the dredge, showing the steam engines and the method of transmitting the motion from them to the dredging machinery.

The power from the steam engine is transmitted through the main shaft *e*, and chain wheel *s*, over which is placed the joint chain I, passing over a second chain wheel *l*, by which the motion is transmitted to the pinion H, and cog-wheel J. The bucket chain *t*, passes over a pair of chain wheels fitted on the same shaft with the cog-wheel J, by which motion is given to the buckets.

The two engines are connected by a link *r*, so that the cranks G G, are at right angles. The dredging machinery is the same on each side of the boat.

The driving chain I, and bucket chain *t*, are composed of alternate links of wrought and cast iron riveted together by steel bolts, so that the pitch of the chain is equal to the pitch of the studs on the chain wheels, which studs fit into the *wrought* iron links of the chain. The buckets and bucket chain pass from the driving chain wheels K K, over a pair of flanch wheels M M, situated on a car movable on the inclined plane X; the buckets and bucket chain then pass down to the place of excavation, under another pair of chain wheels Q, where the buckets dig their loads, and are drawn up by the driving chain wheels K K, over which the buckets with their excavated material pass to the place where it is unloaded.

The buckets have the side nearest to the chain made like a door, latched to the bucket, when full; on the chain wheel shaft K K, is a latch wheel which unlatches the door, and the excavated material, of its own weight, falls into the spout N, and passes off into a scow placed underneath for the purpose, while the empty bucket, with its door open, continues its motion over the flanch wheel M M, where the door is closed by the wheel P, and the bucket goes down for another load.

The lower chain wheel under which the buckets excavate are supported by a wooden framing called ways. Those ways are guided by friction rollers at the top, and by the rack arm S, at the lower end. The buckets and ways are raised or lowered by moving the car U, up or down on the inclined plane X, which motion is either operated by hand or steam power. For hand, the windlass *u* is worked by the crank T, pinion and wheel V; when worked by steam power, the pinion is thrown into gear with both the wheels U and V, the wheel U, which is fast on the flanch wheel shaft, transmits the motion through the pinion to the wheel V, and windlass *u*, by which the car is wound up or lowered on the inclined plane X, and the buckets with the ways are raised or lowered to suit the depth of excavation, or can be raised up above the water line when required.

The dredge can be fed (moved ahead) in three different manners while excavating. *First*, by a kedge anchor placed at a suitable distance ahead of the dredge; in this anchor is fastened the hemp cable *g*, extended to and wound up on the windlass *f*, which is worked either by hand, by the crank *v* and pinion *w*, or by steam power working the pall *y* in the cog-wheel *w*. The pall receives its motion from the eccentric and lever *x*. This is the most general mode of feeding the dredge when long distances are to be excavated. For short distances, the feeding is done (*secondly*) by the rack arm S, which receives its motion from the crank *c*, connecting rod *d*, and lever *b*, on which latter is a double pall working into the wheel *a*, and by a pinion gearing into the rack arm S; the ways R, with the lower chain wheel Q, can be pushed forward, while the dredge boat is at anchor; and, *thirdly*, the dredge can be fed by the ropes *b' b'*, attached to the bow and stern anchors *h h*.

The bow and stern anchors *h h*, are secured sideways above the deck of the boat and at the lower guards, but are allowed to move at the bottom fore and aft about fifteen feet, which allows the dredge to move that distance towards the kedge anchor by feeding in the cable *g*, and the dredge will be confined in a lateral direction, as the anchors are guided sideways.

The anchors *h h*, are raised either by a hand lever or by steam power, the ropes *o o*, passing round pulleys to bring them in a right direction for the capstans *p p*, by which the anchors are raised.

United States Dredge Machine at Whitehall, N. Y.

In March, 1853, the Bureau of Topographical Engineers contracted with Mr. Howard for the construction of four dredge boats for service in Lakes Champlain, Ontario, Erie, and Michigan.

These boats, in addition to the dredging machine, were required to be provided with locomotive power, in order that they might be transferred from harbor to harbor, as the necessity of the service might require.

The one for Lake Champlain was prepared for inspection and delivery by November, 1853, and the Bureau assigned this duty to Lieut. George G. Meade of the Corps of Topographical Engineers.

This officer has furnished a report of the performance of the dredge under inspection to the Bureau.

The following is a summary of my notes made under the same inspection.

Dimensions of the Dredge Boat.

Length in clear,		123 feet.
Length from centre of rudder to outer side of stem,		109 " 6 inches.
Breadth of beam,		26 " 1 "
" " over all,		41 " 1 "
Draft of water forward,		2 " 7 "
" " aft,		3 " 1 "
Mean draft,		2 " 10 "
Greatest immersed section,		68 square feet.
Tonnage of displacement,	141 tons.	
" Custom house measurement,	157 "	

Two horizontal high pressure engines.

Diameter of cylinders,	12½ inches.
Stroke of piston,	4 feet.

Two cylindrical boilers placed side by side half surrounded by brickwork forming the first flues.

Length of boilers,	20 feet 3 inches.
Outside diameter,	3 " 4½ "
Two flues in each boiler. Inside diameter,	14⅜ "
Total heating surface in both boilers,	617 square feet.
" fire grate " "	37 " "
Area of draft to fire grate,	6 " "

The boat was provided with paddle wheels to move her from place to place, the paddle wheel shaft being connected to the main shaft by couplings, so that the wheels could be worked together or separately.

Extreme diameter of paddle wheels,		15 feet.
Number of floats in each,	14.	
Each float 5 feet wide by 15 inches deep,		= 6·25 square feet.

Dredging Machinery.

There are two sets of buckets, one on each side of the boat, as represented on the accompanying plates. The buckets are connected by two chains of alternate wrought and cast iron links; the wrought iron links are 8 inches between the centres, by ½-inch thick, forming the space for the studs on the chain wheels, while the cast iron links are 6 inches between the centres, by 2½ inches thick, fitting between the studs. The wrought iron links are riveted, one on each side, by steel pins, to the ends of the cast iron links, making the pitch of the chain $8+6=14$ inches, and five pitches $=5$ feet 10 inches between each bucket.

The buckets are made of ¼-inch boiler iron, 2 feet 6 inches by 1 foot 3 inches at the top and 2 feet deep, making the capacity of each bucket 6¼ cubic feet.

The following TABLE contains the result of a day's work of the dredging machine in South Bay, Whitehall, New York, November 12, 1853.

No. of operations.	Time by watch. Commenced. H. M.	Time by watch. Stopped. H. M.	Operating time in minutes. Excavating.	Operating time in minutes. Emptying scows.	Operating time in minutes. Total.	Cubic yards per Operation.	Cubic yards per Minute.	Depth in feet of Excavating.	Depth in feet of Water.	Depth in feet of Excavated channel.	Feeded feet per Operation.	Feeded feet per Minute.	Steam Engine. Revolutions.	Steam Engine. Steam. lbs.	Steam Engine. Horse power.	Excavated materials in tons per hour.	Remarks.
1	9 20	9 35	15	4	19	40	2·85	11	8	3	70	4·65	38	30	21·6	139	Soft clay.
2	9 39	9 53	14	3	17	35	2·50	11	8	3	51	3·64	37	20	14·7	122	Do.
3	9 56	10 10	14	4	18	42	3·00	11	7 9	3 3	76	5·42	40	25	20·	146	Do.
4	10 14	10 27	13	4	17	42	3·23	11	7 9	3 3	60	4·61	40	25	20·	158	Do.
5	10 31	10 46	15	3	18	42	2·80	11	7 6	3 6	56	3·73	37	25	18·5	137	Do. softer.
6	10 49	11 02	13	2	15	44	3·38	11	7 6	3 6	53	4·07	38	20	15·2	155	Do. and vegetable matter.
7	11 04	11 17	13	3	16	47	3·61	11	7 3	3 9	52	4·00	39	20	15·6	106	Mud and very soft.
8	11 20	11 35	15	3	18	41	2·73	11	7 3	3 9	42	2·80	40	25	20·	125	
			1 h. 52 m.	36	2 h. 18 m.	333	2·97				460	4·10					Shifted the boat for a new start 30 min. Dinner 1 h. The two scows on one side.
	H. M.	H. M.	M.											lbs.			
9	1 05	1 16	11	2	13	44	4·00	11	8	3	50	4·53	48	25	24·	195	Common clay.
10	1 18	1 27	9	2	11	44	4·87	11	8	3	56	6·20	47	25	23·5	238	Do.
11	1 29	1 40	11	1	12	32	4·91	11	7 9	3 3	66	6·00	48	30	28·8	142	Some hard clay mixed with vegetable matter.
12	1 41	1 50	9	2	11	44	4·88	11	7 9	3 3	78	8·64	50	35	35·	237	
13	1 52	2 04	12	1	13	44	3.67	11	7 6	3 6	80	6·65	48	30	28·8	179	Found a log; raised up the buckets on one side, Clay and vegetable matter.
14	2 05	2 15	10	1	11	42	4·20	11	7 6	3 6	81	8·10	47	30	28·1	204	
15	2 16	2 28	12	2	14	42	3·50	10, 11,	7 3	3 9	66	5·50	44	40	35·2	165	
16	2 30	2 41	11	2	13	46	4·17	11	7 3	2 9	57	5·17	44	30	26·4	197	A crooked log about 3 feet long by 7 inches diameter came up in a bucket.
17	2 43	2 55	12	1	13	44	3·66	9, 10, 11,	7	4	50	4·16	40	30	24·	173	
18	2 56	3 15	19	2	21	46	2·42	11	7	4	67	3·52	38	30	22·8	114	Raised up the buckets on one side.
			1 h. 56 m.	16	2 h. 12 m.	428	3·68				651	5·60					Shifted the boat for a new start.
	H. M.	H. M.												lbs.			
19	3 57	4 08	11	1	12	46	4·18	11	8	3	60	5·45	39	25	19·5	203	Soft clay.
20	4 09	4 22	13	2	15	44	3·38	11	8	3	70	5·37	38	20	15·2	165	Do.
21	4 24	4 37	15	2	17	44	2·93	11	7 9	3 3	72	4·80	40	25	20.	143	Some harder clay.
22	4 39	4 50	11	1	12	46	4·18	10	7 9	3 3	69	6·26	46	25	23·	263	Do.
23	4 51	5 00	9	1	10	44	4·88	11	7 6	3 6	64	7·10	48	25	21·	238	Do
24	5 01	5 15	14	5	19	44	3·14	11	7 6	3 6	84	6·00	47	25	21·5	153	
25	5 20	5 33	13	3	16	46	3·53	11	7 3	3 9	54	4·15	40	20	16·	172	
			1 26	15	1 41	314	3·65				473	5·50		Steam valve only ¼ open.			
			1 56	16	2 12	428	3·68				651	5·60					
			1 52	26	2 18	333	2·97				460	4·10					
Averages.			5 14	57	6 11	1075	3·42				1584	5·04	42		22	170	

In the first eight operations, two scows were used, one on each side of the dredge, to receive the excavated materials, and for each operation received the cubic yards noted in the 7th column. In the fifth column is noted the time occupied in moving and emptying the scows and replacing them for the next operation. The dredge is provided with four scows capable of carrying forty tons each, of which we had only two at South Bay. In order to occupy as little time as possible in conveying the excavated material away, both the scows were placed on the port side of the dredge, so that one could be emptied while the other one was being filled, and the excavated material on the starboard side was dropped into the Bay, supposing it to be the same quantity as on the port side, where it was measured by the scows, and its specific gravity noted.

Lieutenant Meade considered this day's work to have been a satisfactory test, and that the dredging machinery was capable of doing more than double the duty that the contract called for. The locomotive power of the boat still remained to be tried.

The locomotive power of the dredge boat was tested on Lake Champlain, November 16th, 1853. Started from Benson at 7 o'clock in the morning against a brisk wind, current about one-quarter of a mile an hour in our favor. Arrived at Barber's Point at 2 hours 7 minutes P. M., a distance from Benson of 39 miles. From Barber's Point we returned to Benson, where we arrived at 7 h. 56 m. the same evening.

The whole time from Benson to Barber's Point and back was	12 h. 56 m.
Of which time the engine was stopped, . .	0 54
Actual running time, . . .	12 h. 2 m.

A distance of 78 miles, making nearly $6\frac{1}{2}$ miles per hour.

The average pressure in the boilers was 100 lbs. per square inch. Cut off at half stroke. Paddle wheels made 20 revolutions per minute.

Diameter of the centre of pressure of the floats in the paddle wheels,	=13·75 feet.
Circumference of the same, . . .	=43·19 "

Distance moved through by centre of pressure $\frac{20\times43\cdot19\times722}{5280}=118\cdot1$ miles nearly.

$$\text{Slip of paddles } \frac{78}{118}=66\cdot04 \quad 100-66\cdot04=33\cdot96.$$

Slip = 34 per cent. nearly.

Formulæ and Rules for Dredging Machinery.

The following formulæ and rules were deduced by me from the performances of a number of dredging machines built in Motala, Sweden, some of which have since been published in my Pocket Book of Mechanics and Engineering.

Letters Denote

T. = tons of materials excavated per hour.

h. = height in feet, to which the excavated material is raised above the bottom of the excavated channel.

H. = horse power required to excavate T. tons of material per hour.

k. = coefficient for the different kinds of materials, which have been found by actual performance.

Very hard clay mixed with gravel, .	$k = 0{\cdot}1$
Hard pure clay, .	$k = 0{\cdot}07$
Common clay or sand, .	$k = 0{\cdot}05$
Soft clay or loose sand, .	$k = 0{\cdot}04$
Very soft and loose sand, .	$k = 0{\cdot}03$

$$H = T\left(\frac{h}{700} + k\right) \qquad - \; - \; - \; - \; 1$$

This is the formula for finding the horse power required to excavate T. tons of material per hour, and raise it to feet.

Example 1.—A harbor of hard pure clay is to be excavated to 15 feet of water, the material to be raised 11 feet above the water line, making the height $h = 15 + 11 = 26$ feet; it is desired to raise $T = 250$ tons of clay per hour. Required the horse power necessary for the excavation?

$$H = 250\left(\frac{26}{700} + 0{\cdot}07\right) = 26{\cdot}785 \text{ Horses.}$$

Given the horse power, to find the quantity of materials that can be excavated per hour.

$$T = \frac{700\,H}{h + 700\,k} \qquad - \; - \; - \; - \; - \; 2$$

Example 2.—A steam engine of 20 horses is to be used for a dredging machine to excavate a dock of common clay to 10 feet, the material is to be raised 9 feet above water line, making the height $h = 10 + 9 = 19$ feet. Required how many tons of clay can be excavated and raised per hour, $T = ?$

$$T = \frac{700 \times 20}{19 + 700 \times 0.05} = 259 \text{ tons.}$$

To find the power necessary to loosen the material without raising it. This will be found by the insertion of the height, $h = o$ in the formula 1, and will appear simply—

$$H = Tk \qquad - \; - \; - \; - \; - \; 3$$

Example 3.—What power is required to dig loose, $T = 300$ tons of soft clay per hour, $H = ?$

$$H = 300 \times 0{\cdot}04 = 12 \text{ Horses.}$$

Example 4.—How many tons (T) of hard pure clay can be dug loose per hour by an engine of $H = 18$ horses, $T = ?$

$$T = \frac{18}{0{\cdot}07} = 257 \text{ tons.}$$

To find the resistance opposed to feeding the dredge by excavation. Let v = velocity of the buckets in feet per second, and

F = the force in pounds resisting the feed motion of the dredge, we shall have the force—

$$F = \frac{550\,H}{v} = \frac{550\,Tk}{v} \qquad - \; - \; - \; 4, 5$$

C. S. Howard's Dredging-Machine.

Plate 1.