CHAPTER 21

THE HYDRAULIC DREDGING AND PUMPING OF LAKE AREA DEPOSITS

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First let me say that it is a sincere pleasure and an honor to address such a distinguished audience. More people should be made aware of the work that you are doing in the protection of our shores and coastline. It is a great satisfaction to me to be associated with an industry that is instrumental in rebuilding our shores along the lines of your extensive studies and recommendations. I recall laboring over the trochoidal wave theory in my study of naval architecture quite a few years ago. Frankly, it is not used very much in dredge design except in the larger molded form sea going hopper dredges. There is no doubt that you have made great strides in the theory of wave motion and transmitted energy since that time.

When Professor Hamilton first called upon me to speak to you regarding hydraulic dredging, he felt that you would be interested in a description of various types of hydraulic dredges and their fields of application. It occurred to me then that you would also be interested in a brief description of the modern dredge pump which actually constitutes the heart of the dredge.

While my talk is principally confined to dredging operations in this lake area, the various fields and the scope for the application of the hydraulic dredge is so interesting that with your permission, I should first like to cover the subject in a general way.

Since about 1870, the hydraulic method of excavation and transportation of solids has proven itself a necessary adjunct to our economic and cultural life - - - indeed an important factor to our existence.

In peace time, hydraulic dredging makes possible the continued flow of maritime commerce by the maintenance of our navigable channels. It makes possible the beautification of our parks, our lakes and cities, the elimination of insect ridden swamps and lowlands, the building of levies to protect our homes and property, the digging of channels for proper run-off in flooded areas, the restoration of our shores.

It makes possible the depositing and building up of hydraulic fills as a base for highways, airports, industrial sites and homes. It has contributed to the successful completion of some of our earth-filled dams. It deepens our lakes for the better propagation of marine life. It is one of the most economical methods of excavating for pipeline river crossings. It excavates and often transports in one operation oyster shell for the manufacture of cement and the building of roads, sand and gravel for the production of the screen classified and washed product, it reclaims coal from coal refuse areas, it procures our lake sands from depths sometimes exceeding 100 feet for the production of core and foundry sands for our automotive industry. It excavates ores and minerals for the production of gold, tin and other metals.

THE HYDRAULIC DREDGING AND PUMPING OF LAKE AREA DEPOSITS

Hydraulic dredges are in use for the commercial dredging of peat and humus. One of the most unusual applications of the dredging method occurs in off-shore fishing operations where fish such as menhaden are pumped from the purse seines into the holds of fishing boats and then dredged out of the holds as soon as the vessels are moored to the dock.

In time of war, hydraulic dredging has been indispensable as a fighting tool. Portable dredges are designed which can be shipped in knocked-down condition to almost any part of the world and then reassembled for strategic purposes.

DREDGE CLASSIFICATIONS

It is customary to classify hydraulic dredges broadly into two groups; first, those that are self propelled similar to many of the dredges operated by the U. S. Engineers; secondly, those that are not.

SELF PROPELLED DREDGES:

Hopper Dredges - An interesting example of a self-propelled dredge is the U. S. Engineer twin screw Hopper Dredge Hains now engaged in widening the channel in the Detroit River. A rather light silt is being dredged from a depth of 30 feet and pumped directly into built-in hoppers. The dredge is equipped with a single 18" dredge pump directly connected to a 400 Horsepower electric motor. The main power plant is diesel electric developing 1400 HP. The hopper capacity in this dredge is 730 cubic yards. The Hains maintains a speed of two to four miles an hour while dredging and is capable of a speed of 14 miles per hour in fully loaded condition.

This type of dredge is equipped with two suction drags, one on each side of the hull. The drags are shaped much like a shoe and the bottom of the drag is equipped with a cellular bar screen to exclude oversized foreign matter. The drag is also equipped with a flap valve on its upper surface to admit water at times when it may become clogged.

The Hains is arranged so that the pump can either discharge into the hoppers on board or ashore as the operation may dictate. It is equipped with a bin pump out system in which the dredge pump is used to pump out the eight hoppers. The most common means of unloading the hopper, of course, is to dump the material through hopper gates at the bottom. Under favorable dredging conditions, this dredge has pumped solids into the hoppers at a rate as high as 2160 cubic yards per hour. This is exceptionally good performance for a pump of this size.

Another interesting feature about the design of the Hains and for that matter, most other self-propelled hopper dredges, is the twin rudder design. Each of the screws has a rudder located immediately behind it. The twin rudders are necessary to maintain steerage-way while dredging at the extremely low speeds.

The dredge pump is equipped with a degassifier and it might be well to dwell for a few moments on this rather important device. The function of the degassifier is to remove the entrained gases in the dredging mixture from the suction nozzle of the dredge pump. The output of the dredge pump is reduced considerably with air, vapor or gas present in the mixture. A dredge pump is highly efficient as an air separator -- in fact, too much so in many instances for profitable operation. The entrained air entering the suction of the pump separates immediately and remains in the eye of the impeller until it is removed. The heavier dredging mixture swirles around the periphery of the pump casing. If a sufficient volume of air is permitted to accumulate, the pump will stop functioning, the flow will cease, the solids will drop out of suspension, often causing clogging.

In general, the degassifying system consists of a surge tank, the bottom of which is connected as close to the eye of the impeller as possible. Either a vacuum pump with a priming valve or an educator connected to the top of the tank is then used to exhaust the air from the tank and as a result, from the eye of the impeller. In many instances, the use of the degassifier has resulted in the success of a dredging operation which otherwise might have been a complete failure. This is particularly true in the more gaseous deposits found in marsh lands and sewage sludges.

While the Hains is now engaged in widening the channel of the Detroit River, it has been used in a variety of dredging work here on the lakes. This same type of dredge performs all of the U. S. Engineer harbor maintenance work in the lake area and often is called upon to remove bars at harbor mouths occasioned by storm. The Hains has also aided in the restoration of the lake shore in Rochester, Erie and Ashtabula by dumping sand through the hopper bottom gates into currents on the down-drift side which eventually deposit the sand in the needed location on the shore.

When we speak of self-propelled dredges, we think mostly in terms of molded form hulls such as the dredge just mentioned.

Cutter Dredges - There are only a few self-propelled cutter type dredges in this country. Usually, the expense connected with the propulsion unit is not warranted, unless the dredge is a large one operating and travelling in open waters.

NON-PROPELLED DREDGES:

Non-propelled dredges are of the following types:

1. Pipeline dredges, used either in general contracting service or for the production of sand and gravel and other mineral products.

2. Dredges discharging directly overboard into barges used mostly in the production of sand and gravel.

3. Dredges with complete or partial screening and classifying equipment on board used mostly in the production of sand and gravel.

All three types can be equipped with or without agitating equipment. The most common mechanical agitators are:

1. The rotating basket type cutter.

2. The travelling suction screen.

Hydraulic agitation is sometimes resorted to in the form of high pressure jets at the suction mouth. However, jet agitation has not proven very successful, and is entirely ineffectual in clay or hard pan deposits.

Pipeline Dredges - The most common type of pipeline dredge is the hydraulic cutter dredge consisting essentially of a box-shaped floating hull with rotating cutter, cutter shafting, bearings, reduction gears and, in most cases, the driving electric motor located on a structural steel ladder hinged on trunnions at the bow of the dredge. It is customary to provide a wound rotor motor with variable speed control. The most efficient dredging angle of the cutter ladder is 45°. This type of dredge is usually equipped with a 5-drum dredge hoist. In the larger sizes, dredge hoist brakes and frictions are controlled by pneumatic or hydraulic controls. The center drum on the hoist serves the purpose of raising and lowering the cutter ladder. Two of the drums are used for swinging the dredge to either side and the two remaining drums for raising and lowering each of the two spuds at the stern. The swing lines are usually anchored at a considerable distance each side of the dredge and pass through swing sheaves located at the bottom end of the ladder. Dredge hoists are designed to swing the dredge at speeds varying from 50 to 80 feet per minute.

The usual method of operating a cutter dredge after the cut has been established is to start near the top of the face with cutter projecting into the deposit for approximately its own length, then swinging the dredge from side to side, with the working spud acting as a pivot. The cutter itself rotates only in one direction. The ladder is lowered at each swing on a radius about the working spud until the dredging depth has been reached. The operator then "steps ahead" by dropping the auxiliary spud, and again lowering the working spud when the dredge has been advanced into the cut by approximately the length of the cutter.

Often the operator will undercut the bank to produce caveins for higher production.

When the dredge has advanced to a point where the swingline anchors at each side are so far aft of the ladder that the swinging motion of the dredge is impaired, the anchors are moved again to a point somewhat ahead of and sufficiently outboard of the dredge to permit full freedom in swinging.

The modern pipeline cutter dredge used in general contracting service usually has a main dredge pump directly driven by a diesel engine or it is diesel driven through reduction gears. All dredge auxiliaries such as the raw water circulating pumps, service pumps, hoist, cutters are usually driven by electric motors with current supplied by a diesel engine driven generator.

One of the many interesting hydraulic cutter dredge projects performed on the Great Lakes is the 2500 ft. long cellular steel sheeting break-water built by The Great Lakes Dredge and Dock Company in 1950 for the Youngstown Sheet and Tube Company at the West entrance to the Indiana Harbor Basin here on Lake Michigan. This breakwater extends Northwest from the entrance to the harbor, and is 2500 ft. long. The breakwater was built as a retaining wall for a fill which was being made at the time. It consists of partially intersecting circular steel cells which were filled very nearly to the top with sand dredged and discharged through about 1000 ft. of pipeline from the dredge.

The radius of each cell is about 25 ft. The sheeting used was 50 ft. long. The depth of the water varied from 23 to 29 ft. and the bottom was found to be soft clay. The sheeting was driven to a penetration depth of 15 to 21 ft. After the cells were filled and the sand allowed to settle, a reinforced concrete cap was poured to prevent the washing out of sand cores.

There is an interesting side light regarding this breakwater. After completion, it was found that it deflected currents toward the channel which interferred with the navigation of ships approaching the basin from the north. As a result, the U. S. Engineers, after careful study, required the Youngstown Sheet and Tube Company to riprap the lake side of the cells completely from top to bottom at an angle to deflect these currents clear of the channel.

Some pipeline dredges are entirely electric motor driven with current supplied through a cable from the shore. As you can surmise, this type of dredge is suitable only in locations where the operation is permanent or of long duration. An electrically driven dredge is usually lower in price than one that is diesel driven. It is also more maneuverable because of its smaller physical dimensions.

Striking examples of this type of all electric pipeline cutter dredge are the two dredges which will be built by Construction Aggregates Corporation for operation at Steep Rock Lake, Atikokan, Canada.

As you probably know, a high quality iron ore lies beneath the lake bottom.

The purpose of these dredges is to remove the lake bottom and to expose the ore body. The entire lake was drained several years ago to uncover the bottom. Dredge design data are as follows:

Size 36 inches
Hull - 165 ft. x 30 ft. x 10 ft. deep
Expected output about 6000 cubic yards per hour
Main dredge pump motor 10,000 horsepower
Length of pontoon piping 5,000 feet
Length of shore piping 24,000 feet
Static discharge head about 600 feet

Each dredge will have two 36" booster pumps in the pipeline, one afloat, the other ashore. Each booster will be directly connected to a 10,000 HP motor making a total of 60,000 connected HP for the two dredges and the two sets of boosters.

160,000,000 yards of material will have to be removed and this will be one of the largest dredging operations ever attempted.

<u>The Overboard Discharge Dredge</u> - This type is used principally for sand and gravel production and is found mostly in the rivers.

The dredged material is discharged directly into barges alongside. Since there is no floating pontoon line, there is less interference with navigation. But the most important reason for operating a dredge of this type is to reduce maintenance costs.

The river deposits in this area are, as you know, of glacial origin, containing high percentages of gravel. It is not uncommon to find deposits containing as much as 50 to 60% gravel.

It is not economical to pump this destructive and heavy material through long lengths of pipeline and against high static heads. Abrasion of the pump parts and pipeline is so rapid that costs skyrocket and shutdowns are frequent.

Pumping directly overboard to the barges increases the solids output and by reason of the low pump head and speed greatly lengthens the life of the pump parts.

Most of these glacial deposits are semi-compacted requiring an agitator to obtain reasonable production.

<u>Sand and Gravel Dredges with Screening Plants on Board</u> - This type of dredge is used where it is impractical to locate the screening and classifying plant ashore. It is a completely self contained unit and is designed for operation in glacial gravel deposits.

The dredge pump discharges to a head box containing a scalping screen which separates the oversized stones and discharges them overboard.

The material then passes over the screens needed to produce the desired sizes of gravel. The sand also is separated and both gravel and sand are discharged through chutes into barges along side.

Often the dredge will discharge to four barges simultaneously. While the static discharge head on the pump is 40 ft. to 50 ft., the pipeline is short and pump speeds and maintenance costs low.

METHODS OF AGITATION

Rotating Cutters - Different designs of cutters are used to suit the type of deposit. For sand and gravel, the basket type cutter is used. Cutting edges of the blades may be plain, serrated or toothed.

For clay, a modification of the basket type cutter is used. The blades are narrower, the cutter is more open. Serrated cutting edges are needed to break up the clay.

For conglomerate or soft rock, the cutter is equipped with heavy teeth.

Manganese steel has been found to be the best for cutters operating in gravel or rock.

The Travelling Suction Screen - Many sand and gravel dredges are equipped with a travelling suction screen which, in effect, is a double moving chain connecte by cross links which pass the suction mouth over its full width. It is endless - - - moving upwards toward the bow of the dredge over the suction pipe and downwards toward the nozzle under the suction piping. The travelling screen is fitted with hooks or lugs which remove oversized stones or boulders from the suction nozzle and act as a conveyor to carry the stones upward and away from the digging operation.

The Plain Suction Nozzle - The plain suotion pipeline dredge as the name implies, has no means of agitating the material. It is not recommended for cemented, compacted or semi-compacted deposits, and it economical only in deposits of a free flowing nature.

DREDGE PUMPS

Characteristics and Performance - The design and performance of the dredge pump is the most important factor in the success of the dredge. It must be designed for extremely high suction lifts with a minimum of cavitation. Clearances through the impeller must be large to pass stones of maximum size. It is essential that the vane curvature be correct to produce a smooth flow through the passages, free from excessive eddying and turbulence. We find that overlapping of the vanes definitely improves hydraulic efficiency and that when we turn down the impellers destroying the overlapping feature, we greatly reduce the pump efficiency.

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One of the few patent claims allowed in centrifugal pumps in recent years is the pressure balancing feature in our impeller design which tends to reduce circulation of the abrasive solids from the pressure passages in the shell, past the suction disc liner and into the eye of the impeller. This is accomplished by making the suction shroud of the impeller larger in diameter than the vanes. The outer surface of the impeller also has integrally cast vanes which are quite narrow but take the same curvature and position as the main vane inside. These vanes being longer develop a counteracting pressure at the periphery of the suction shroud to balance as nearly as possible the pressure in the volute. By retarding this internal circulation, we are obtaining a notable increase in the life of the pump wearing parts.

An important factor in providing long life of the dredge pump is the speed of operation. Low speeds and low angular velocity means lesser impact of the solids against the surfaces of the vanes and consequently longer life of the parts.

The modern dredge pump is designed with extremely heavy casings or volutes, the periphery uniformly increasing in thickness from the cutwater to the point of discharge. The casing is definitely considered as an expendable part and our object in varying the thickness at the periphery of the volute is to place the metal where, in our experience, we have found the wear is greatest. The ideal design is such as to have the least amount of weight and scrap left when shell finally wears through. All modern dredge pumps have casings of volute design. When we first started the manufacture of dredge pumps in 1870, our casings were circular. Through succeeding years of research and development, we have found that volute casings definitely increases the hydraulic efficiency and the wear characteristics. We take the position that it is just as important to keep on with this development as it is to continually improve the design of our water pumps.

You may be interested in knowing that before we start the manufacture of a new line of dredge pumps, we build a homologous model which is usually an 8" unit. The design of our latest line of heavy duty dredge pumps is based upon exhaustive model tests which extended over a period of one year. Various combinations of impellers and casings were tested. Each combination required six complete tests, each with different diameter impeller. We were extremely fortunate as a result of these model tests to obtain efficiencies with full diameter impellers as high as 75%. This is not much lower than accepted efficiencies for water pumps where there is unlimited freedom in design.

Basically, the dredge pump differs from a water pump in the following ways:

The dredge pump has heavier and more rugged parts. It has internal liner protection and lower operating speeds.

In many cases, a dredge pump, developing the same head and capacity as a water pump, will operate only at 1/4 its speed.

On the suction side of the pump, the sealing or wearing surfaces are structly in a vertical plane. Adjusting features are provided on most dredge pumps to move the impeller toward the suction disc liner of the pump at times when the clearance between the wearing surfaces becomes excessive. This clearance between the impeller and the liners on the suction side should be maintained at 1/32" for best performance.

Bearings of any kind in contact with the dredging mixture cannot be tolerated. The dredge pump shafts, therefore, are supported by heavy bearings entirely external of the water end itself. The shaft must be heavy enough and the center distance between the bearings great enough to provide rigidity and negligible deflection of the overhanging shaft under the worst operating conditions.

You may be interested in the size boulders which these pumps will pass:

36" Pump --------- Will pass stones approximately 26" in diameter.

20" Pump --------- 14" in diameter.

15" Pump --------- 11" in diameter.

12" Pump --------- 9½" in diameter.

The pump must be designed for this severe service without danger of bending or breaking the shaft, pump parts, or damaging the bearings.

The size of the dredge is usually designated by the size of the pump discharge nozzle. You may like to know what output can be expected from various sizes of hydraulic dredges provided that agitators will excavate the solids at the rate of which the pump is capable.

Let us assume first, that the dredges are operating in ideal deposit such as a fine beach sand. The approximate maximum output, when operating at reasonable dredging depth, based upon the mixture containing 30% solids by apparent volume with pipeline velocity 20 ft. per second, is:

36" dredge ---------------6000 yards per hour.
24" dredge ---------------3000 yards per hour.
20" dredge ---------------2100 yards per hour.
15" dredge --------------- 800 yards per hour.
12" dredge --------------- 600 yards per hour.

We are considering here a free-flowing deposit with particles well rounded and not exceeding, say 50 mesh in size. Naturally, this output would be considerably reduced in the presence of clay.

Let us assume next that these same cutter dredges are operating in a compacted gravel deposit with few stones exceeding the size which will pass through the pump, the deposit containing 50% gravel and 50% sand - pipeline velocity the same as before. The maximum output that could then be expected would be only about one third of the output in free-flowing sand. Output is often further reduced by the presence of oversized stones and boulders. Where a high percentage of oversized stones is contained in the deposit, the dredge will remove smaller stones and the sand leaving the oversized material at the bottom. It is not uncommon to eventually pave the bottom with oversized material to a point where the dredge is no longer able to penetrate the layer. Often times, harbor bottoms are covered with trash such as old tires, scrap iron, water-logged timbers, long branches and roots. These too can be an enigma, often to the extent of abandoning hydraulic dredge operation.

CONCLUSION

It is obvious that each dredge must be specifically designed for the job it has to do. It should be placed in operation only after careful consideration has been given to the depth of dredging below water level, the length of the discharge piping, the type of deposit, whether loose, compacted, cemented or gaseous, the static discharge head, the maximum size of stones in the deposit, the amount of trash to be encountered.

In general, the dredge must be large enough to pass practically all of the material in the deposit to be really successful.