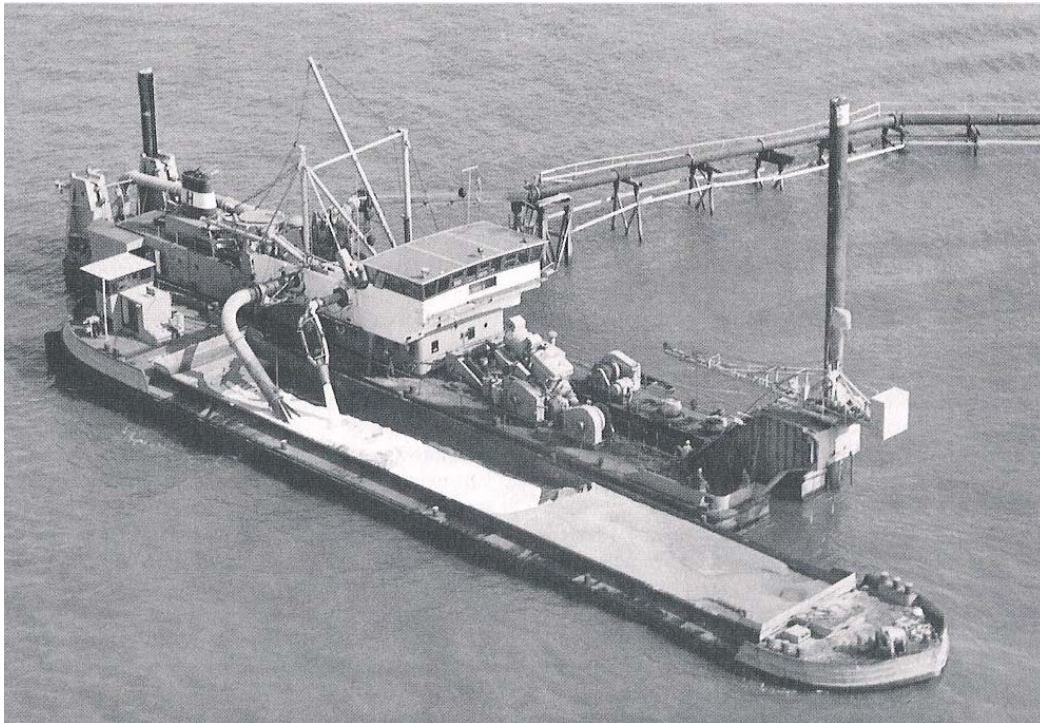# 5. The barge unloading/reclamation Dredger

Figure 5-1 Barge unlading dredger "HOLLAND"

A specialized dredging tool that can be categorized in the section of stationary plane suction dredgers is the barge unloading/reclamation suction dredger.

5.1.   General considerations

Barges that are used for the transport of dredged material can be divided in self-unloading and non-self-unloading. The self-unloading barges, called hopper dump barges or bottom unloaders, are usually equipped with doors (valves) that one way or the other can be opened to dump the dredged material under water.
Non-self-unloading barges need to be unloaded either mechanically or hydraulically. Mechanical unloading can be done with a grab, backhoe, excavating wheel or bucket elevator. Non-self-unloading barges are therefore often called elevator barges.

Figure 5-2 A Japanese BUD with backhoe's and belt conveyors.

Hydraulic unloading can be done using a shore pump discharge system, usually installed in trailing suction hopper dredgers or by means of a barge unloading suction dredger.
For the last 20 years the transport with barges is strongly reduced and because, as mentioned, the barge unloader is a specialized dredge tool, it is hard to use the tool for other purposes. Hence the amount of barge unloading suction dredgers has decreased considerably in this period. At present many barge unloading suction dredgers are in service that can also be used as plain suction dredger or cutter suction dredger.
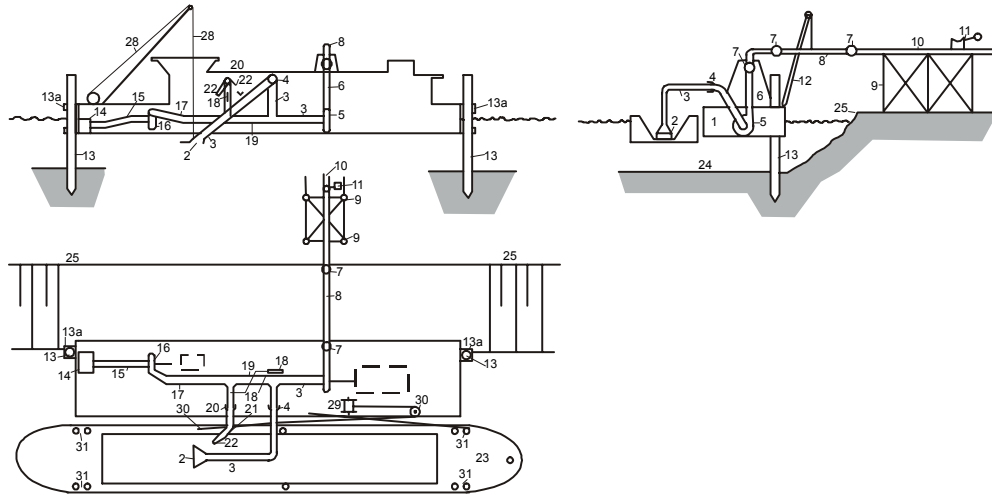
5.1.1. Characteristics

Figure 5-3

The barge unloading suction dredger is a stationary dredge tool, moored along mooring piles or anchored with spuds. (***Figure 5-3***) The barges are moored along the tool for unloading. The tool is equipped with one or more sand pumps and a jet pump. The suction pipe sticks out at the side of the tool and can be lowered in the barge lying next to the dredger. The water needed for the mixture and the transport is jetted into the barge using one or more nozzles.

5.1.2. The areas of application

The barge unloading suction dredger is able to unload barges hydraulically. These barges are filled one way or the other, for instance with a plain suction dredger or a bucket ladder dredger. The material in the barge is diluted with water and sucked up (figure 5.1). This immediately implies that the barge unloading suction dredger can only handle materials that fluidize quickly like silt and sand. Cohesive materials, of which the forming of a mixture is too slow, will cause the barge unloading suction dredger a lot of problems.

5.1.3. The history

The barge unloading suction dredger is a Dutch development. During the excavation of the North Sea Canal a stationary plain suction dredger was transformed to a barge unloading suction dredger (± 1875). Before the barges were unloaded using a bucket elevator. Next the material was transported to the dump with small sand trains. With the arrival of the barge unloading suction dredger these trains, which were very labor-extensive became redundant. Besides it was now possible to transport weak soils simply. The first pressure pipes were mad of wood but soon these were replaced by iron pipes.
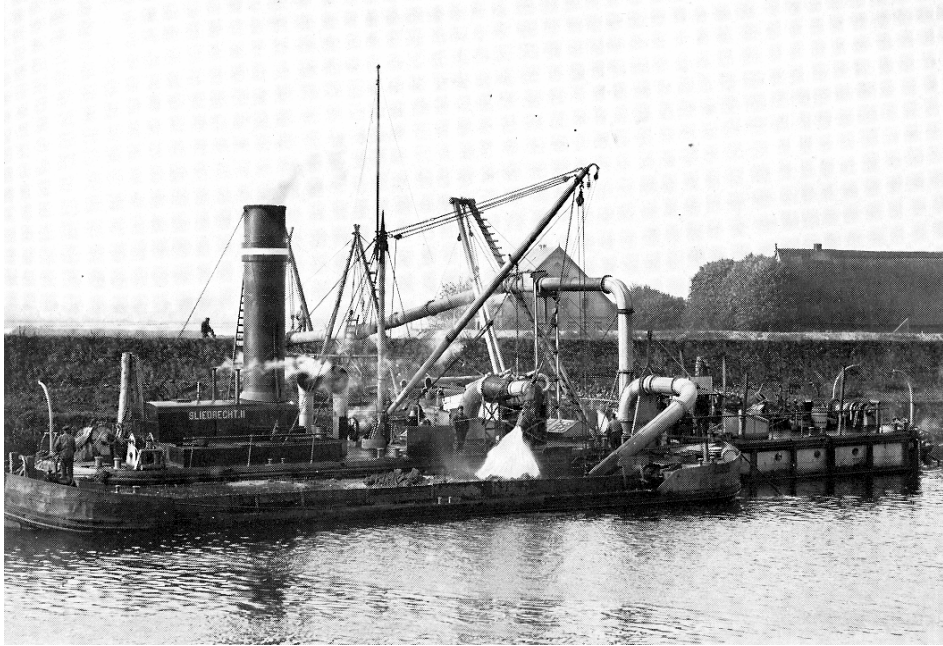
Figure 5-4 The steam driven BUD "Sliedrecht I"

5.1.4.   Work method

In ***Figure 5-1*** the working method is schematically explained

At the start of unloading process, the suction pipe is lowered to the sand level in the barge, while the jet pump is connected to the suction pipe. The speed of the dredge pump on board of the dredgers is reduced in such away that the jet water flows via the suction tube on the sand in the barge, where its erodes a pit under the suction mouth. The dredge master lowers the suction mouth below the water level in this pit. When no air is released via the suction mouth, the butterfly valve between the jet pump and suction pipeline is slowly closed, causing an outflow of jet water via the jet nozzle. (***Figure 5-5***.A.). Meanwhile the speed of the dredge pump is increased

When the dredging process is running well, the jet nozzle erodes the breach while the sand is removed via the suction mouth. During this process the pit under the suction mouth becomes larger and the suction mouth is lowering until she reaches the bottom of the barge. (***Figure 5-5***.B). Sand flowed behind the suction mouth has to be jetted back to the suction mouth regularly (***Figure 5-5***.C). Therefore modern BUD"s have either a jet installation around the suction mouth or additional jet pipe to overcome this problem The concentration in the discharge line is controlled by hauling the barge (***Figure 5-5***.D).
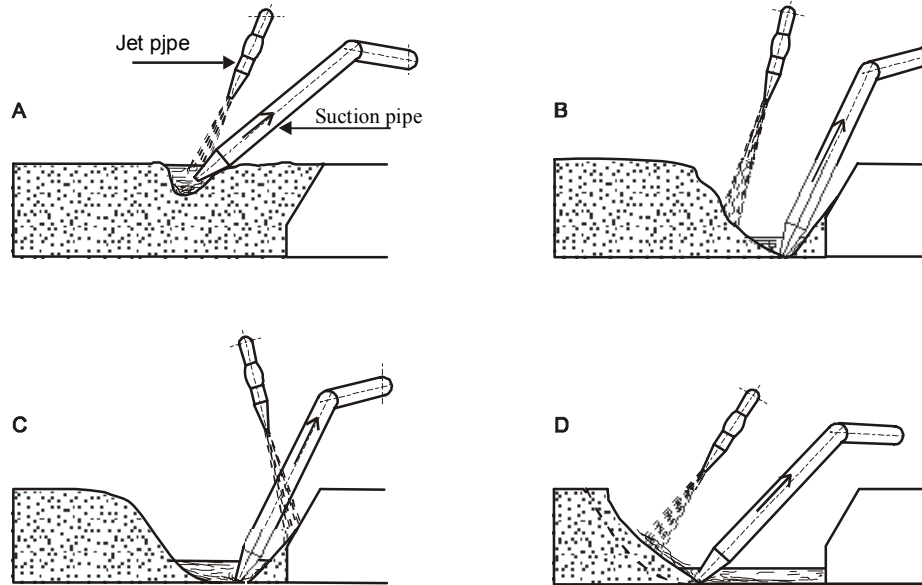
Figure 5-5 Working method of barge unloading

During the exchange of the barges the pressure side of the jet pump is connected with the suction side of the sand pump. This keeps the sand pump moving in the discharge line. The more the sand-water mixture is exchanged for clean water in the discharge pipeline, the velocity increases and if necessary the number of revolutions of the sand pump can be reduced. Apart from the continuation of the dredging process, this construction is necessary to prevent the suction in of air through the suction mouth of the suction pipe, with all consequences (think of submerged pipelines).

When the next barge is moored along the barge unloading suction dredger, the number of revolutions of the sand pump is decreased such that it just can handle the flow rate of the jet pump. The surplus water is run away through the jet piping and the suction pipe and a new dredge cycle can start.

Figure 5-6 Unloading a barge

5.2.   The design

The barge unloading suction dredger has to fulfill in principal two functions:
1. the material in the barges must be diluted such that a mixture develops that can be sucked up in high concentrations.
2. the dredge pumps in the dredger have to take care that the sucked up material can be pumped to the reclamation area with enough velocity and production.

5.2.1.   The production capacity

Like with the other tools the required production capacity plays a crucial role in the design. The production capacity is however determined by the supply of the sand by barges and therefore by the tool that loads the barges. This can be, for instance, a barge loading plain suction dredger, a backhoe dredger or a bucket dredger.

For the design of the barge unloading suction dredger the required production for each barge is the criterion, so the required discharge time for each barge. After all the non-presence of barges by external causes has nothing to do with the required production capacity. Besides that the size of the barges is of course of influence on the required production capacity.

5.2.2.   The transport distance

The transport distance gives requirements for the installed dredge pump power and the necessity for the installation of one or more pumps. For further details with regard to the choice of the pumps see Chapter 4 Plain suction dredgers.

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5.2.3. The dredge installation.

5.1.1.1 General

When the dredge capacity is known, this requirement, like with the plain suction dredger, is translated in:

1. a sand flow rate Q

2. a sand concentration C_{vd}

After all: $P = Q \cdot \dfrac{C_{vd}}{1-n}$

with:
P	=	production	[m³/s]
Q	=	flow rate	[m³/s]
C_{vd}	=	transport concentration	[-]
n	=	porosity	[-]

The minimum flow rate is determined by the critical velocity that is required to keep the material in motion. So $v_{critical} = F_{l,h}\sqrt{2g\left(S_s-1\right)D}$ in which the value of $F_{l,h}$ is determined by the to be pumped material (see wb3414, Dredging processes).

The maximum concentration that can be sucked depends on many factors, like:

- the breach behavior of the soil.
- the design of the suction mouth in comparison with the width of the barge.
- the maximum mixture forming that can be reached with the water nozzles and the jets at the suction mouth and the flow rate of the jet pump.
- the height of the suction pipeline. Because the maximum under pressure is created here, it determines for a large part the maximum concentration. As a value a concentration of 1400 kg/m³ is maintained.

This last factor can be checked with the vacuum formula (see also *Figure 5-7*):

$$H\rho_b g + vac = \left\{\left(\mu + \lambda\frac{H+k}{D\cdot\sin\beta}\right)\frac{v^2}{2g} + H + k\right\}\rho_m g$$

$$\rho_m = \frac{H\rho_b g + vac}{\left\{\left(\mu + \lambda\dfrac{H+k}{D\cdot\sin\beta}\right)\dfrac{v^2}{2g} + H + k\right\}g}$$

In which:
H	Depth suction mouth below water level in barge	[m]
k	height discharge piping above the water in the barge	[m]
vac	maximum allowable vacuum in the discharge piping	[kPa]
ρ_w	density water	[k/m³]
ρ_m	density mixture	[k/m³]

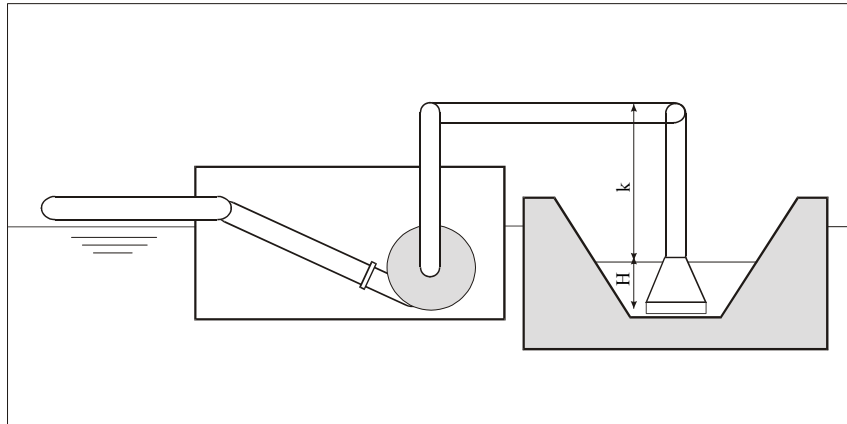| ρ_b	density mixture of the water in the barge	[k/m^3]
β	angle of suction pipe with horizontal.	[°]
μ	loss coefficient	[-]
λ	friction coefficient Darcy Weissbach	[-]
D	diameter suction pipe	[m]
v	suction velocity	[m/s]
g	Gravity	[m/s^2]

Figure 5-7

For H=2.5 m; ρ_b=1050 [k/m^3]; vac = 90 kPa; $\left(\mu + \lambda \dfrac{H+k}{D \cdot \sin \beta} \right) = 1.5 + 0.01 \left(h_z + k \right)$ and v= 4 m/s the below shown graph is obtained.
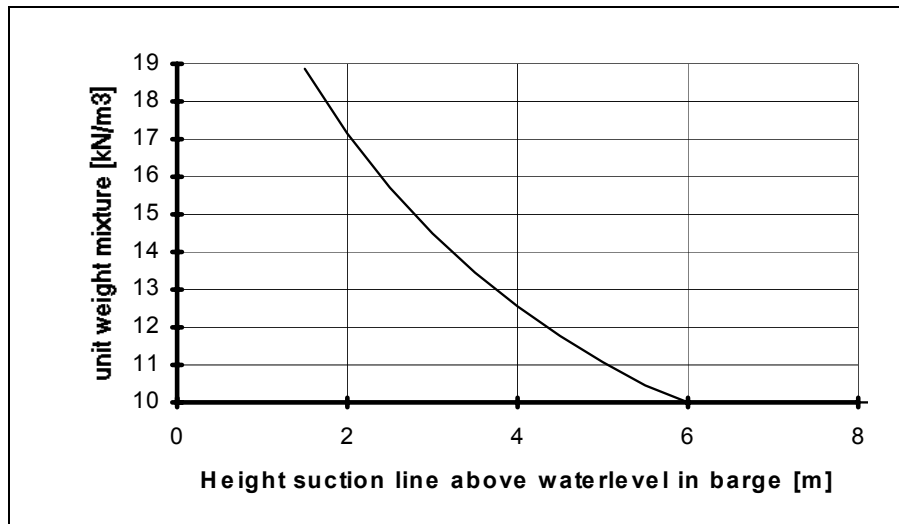

Figure 5-8

This graph shows (*Figure 5-8*) that the upper side of the suction pipe may lay hardly more than 3 m above the water level in the barge to meet the earlier mentioned requirement of γ_m=1400 [kN/m^3]. This height needs than to be sufficient to haul the barge underneath the suction pipe.

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The expected average concentration during the suction of the barge is dependent on:
- the time necessary to start the process, see the chapter the dredging process 5.4.
- the availability of a barge hauling installation. The production is mainly determined by the haul speed of the barge.
- the whether or not present of additional bulkheads in the barge, for which extra breaking in necessary.

When both the critical velocity as the average and maximal concentration are determined, both the pump flow rate and the diameter of the pressure piping are also fixed (see chapter 4.2.1).

5.1.1.2   The suction mouth and pipe

Nowadays the suction mouth of a BUD is provided with jets to improve the mixture forming and to hindered the settling of material behind the suction mouth (***Figure 5-9***)

The width of the suction mouth is based on the smallest hopper width of the barge. Are barges used with different sizes it is advisable to design a flexible suction pipe (***Figure 5-9***).

Sometimes the suction mouth is provided with bars to avoid debris and boulders entering the suction mouth.

Figure 5-9 Suction mouth and pipe

5.1.1.3   The jet pumps

All the water necessary to transport the sand over the required distance must be supplied to the barge by the jet pump.

The flow rate of the jet pumps depends on the functions of these pumps. Usually two functions are considered:
1. The activation of the breach. By way of a water nozzle before the suction mouth the breach is activated. Usually a second water nozzle is present that jets loose the sand behind the suction mouth so that it still is sucked up by the suction mouth.
2. The mixture forming. The flow rate of the jet pump must be related to the average concentration that can be sucked. Here also that the following condition must be met:

$$\frac{Q_j}{Q_m} = 1 - \frac{C_{vd}}{1-n}$$

In this:

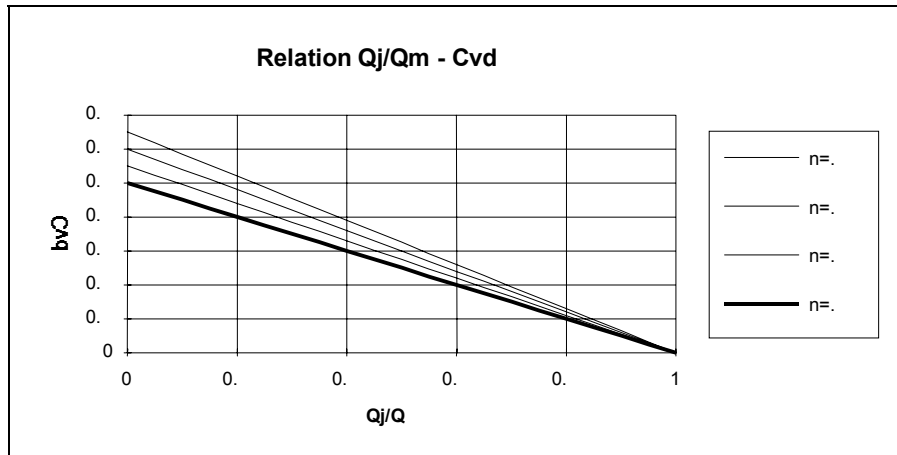|			
Q_j	=	the jet flow rate	[m³/s]
Q_m	=	the sand flow rate	[m³/s]
C_{vd}	=	the transport concentration	[-]
n	=	pore percentage	[-]

Figure 5-10

Looking at the above mentioned boundary conditions (*Figure 5-10*) the flow rate of the jet pump needs to be 0.4 to 0.5 times the flow rate of the sand pump. With a decrease in the concentration, like when the suction mouth reaches the end of the barge, the flow rate of the jet pump will have to increase to maintain the desired velocity in the pressure piping. If this is not possible the water level in the barge will drop. If there is however enough water in the barge to maintain the velocity there is no problem. If this is not the case water have be supplied in another way to maintain the velocity in the discharge line. F.i. an additional water inlet connected to the suction side of the discharge pump
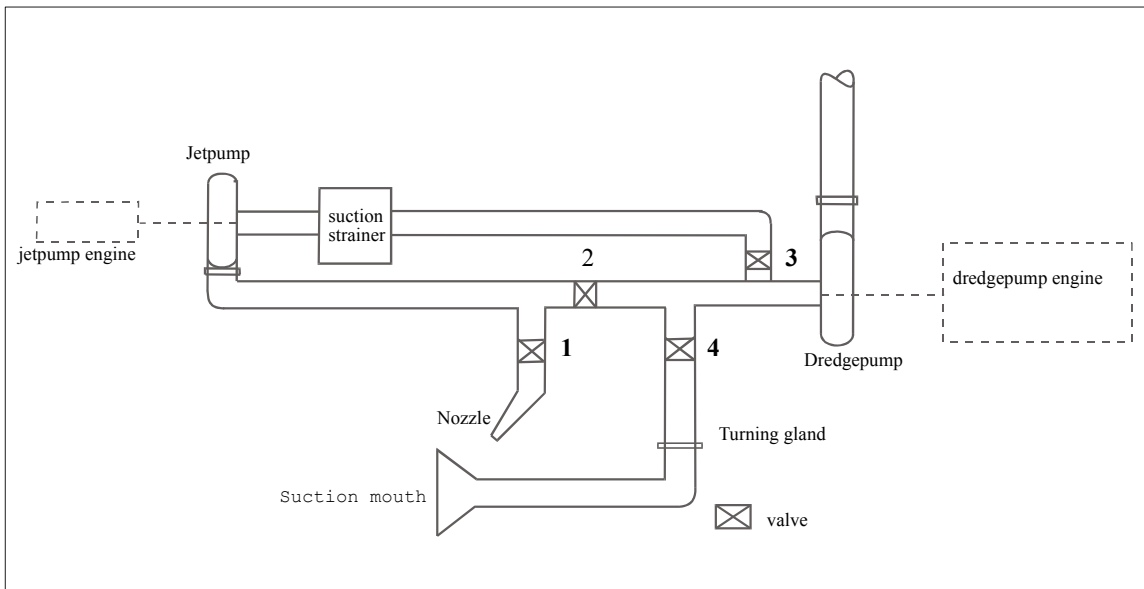

Figure 5-11 Pump-pipeline layout on board of a barge unloading dredger

This is possible by installing a pipe from the suction side of the pump to the bottom of the pontoon or the suction strainer or weed box (***Figure 5-11***). In such a design enough water can be sucked up at all times to maintain the dredge pump process , also when the unloading of the barge is stopped completely.

5.1.1.4   The jet pump drive

The drive of the jet pump may be electrical or diesel driven. The dredge master controls the process visually by keep the water level in the barge at a constant height. Increasing or decreasing of the water level determines that there is no equilibrium between the volumes water pump into the barge and the mixture pump out of the barge. Therefore speed control is necessary to control the unloading process well.

5.1.1.5   The sand pump.

The dredge pump should be chosen on basis of discharge properties and less on suction properties, because the last properties are mainly determined by the highest point of suction pipeline.

The required manometric pressure of the pump is determined by the transport distance. When large pumping distance is large, more than one dredge pump may be necessary.

The use of submerged pumps close to the suction mouth to increase to design density of the mixture is also possible but expensive. For Dutch dredging environment it seems not useful due to the shallow and relatively small barges. However in Japan where large sea-going barges are frequently use, there is a need for a submerged pump as shown in*Figure 5-12*.

Figure 5-12 Japanese BUD

5.1.1.6   The sand pump drive

In the process of barge unloading suction dredging the control of the sand pump(s) plays an important part. After all, when the sand pump is not connected to a suction strainer, the flow rate must drop to the value of the jet pump when exchanging the barges. This is done by decreasing the number of revolutions of the dredge pump drive. By the decrease in flow rate this will usually not cause any trouble for the allowable couple of the drive.

5.1.1.7   The barge hauling installation
Modern BUD"S have an installation to move the barge along the dredger by means of a so-called barge hauling installation.

The installation consist of a steel wire or rail along the full length of the mooring side of the BUD. (*Figure 5-13*)
On a pulley or a movable part on the rail two slings are connected. These sling are on the side connected to the bollards on the barge. (*Figure 5-14*)
This construction has the advantage that the barge is kept along side of the BUD, The pulley or slide is connected via a wire to a winch, which makes it possible for the dredge master to control the haul speed by himself.

Figure 5-13 Sliding part of the Barge Hauling installation

Figure 5-14 Barge hauling installation with pulley and wire

5.3. Main layout

The layout of the barge unloading suction dredgers is quite simple. The hull consists of a simple rectangular pontoon, usually anchored by spuds at the ends (*Figure 5-16Figure 5-16*). Centrally in the pontoon the pumps (dredge and jet pump) and engine room are located. Furthermore fuel and water tanks and storage rooms are situated in the pontoon. The control of the dredger is done from a cabin at the side of the deck from which the suction operator has a good view on the alongside moored barge. Present accommodations are also situated above decks (*Figure 5-15* and Figure 5-16). Instead of spuds the barge unloading dredger might be moored on wires. Suction pipe, discharge pipe are supported by booms or A-frames. The jet pipe or nozzle by hydraulic cylinders to control the direction of the jet water.
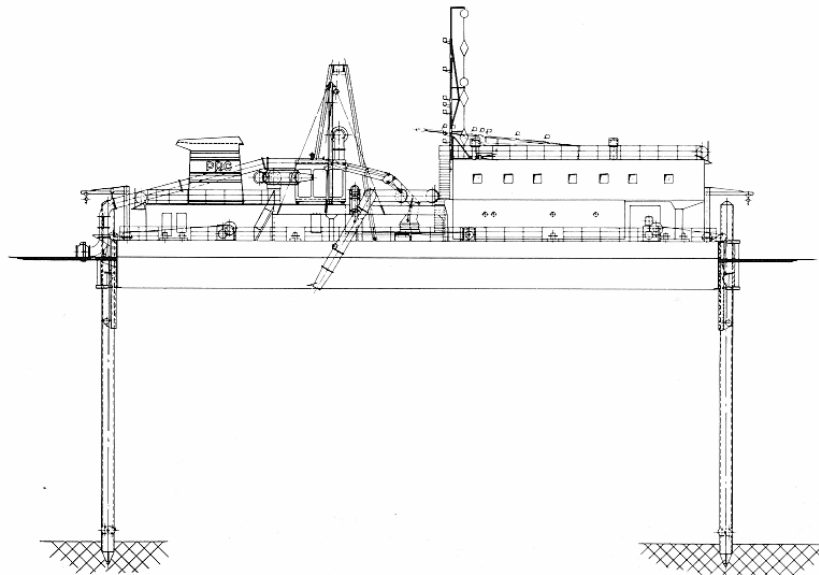

Figure 5-15 BUD Rozkolec

Figure 5-16 View of the BUD Rozkolec

Figure *Figure 5-17* shows the top view of the BUD Sliedrecht 14 and Figure 5-18 the side view of the same dredger.
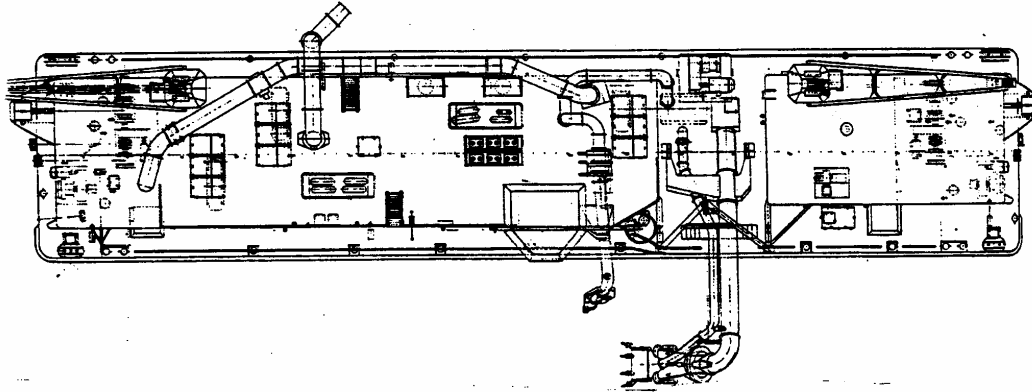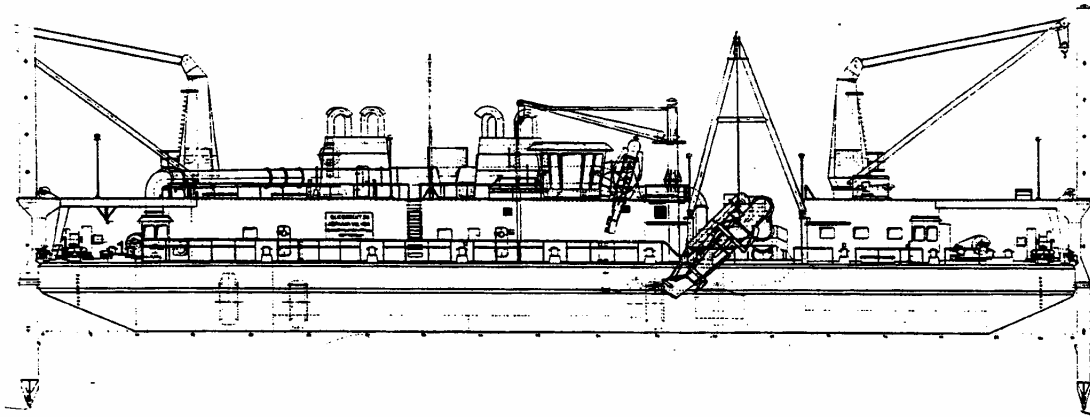

Figure 5-17 Top view of BUD Sliedrecht 14

Figure 5-18 Side view of BUD Sliedrecht 14

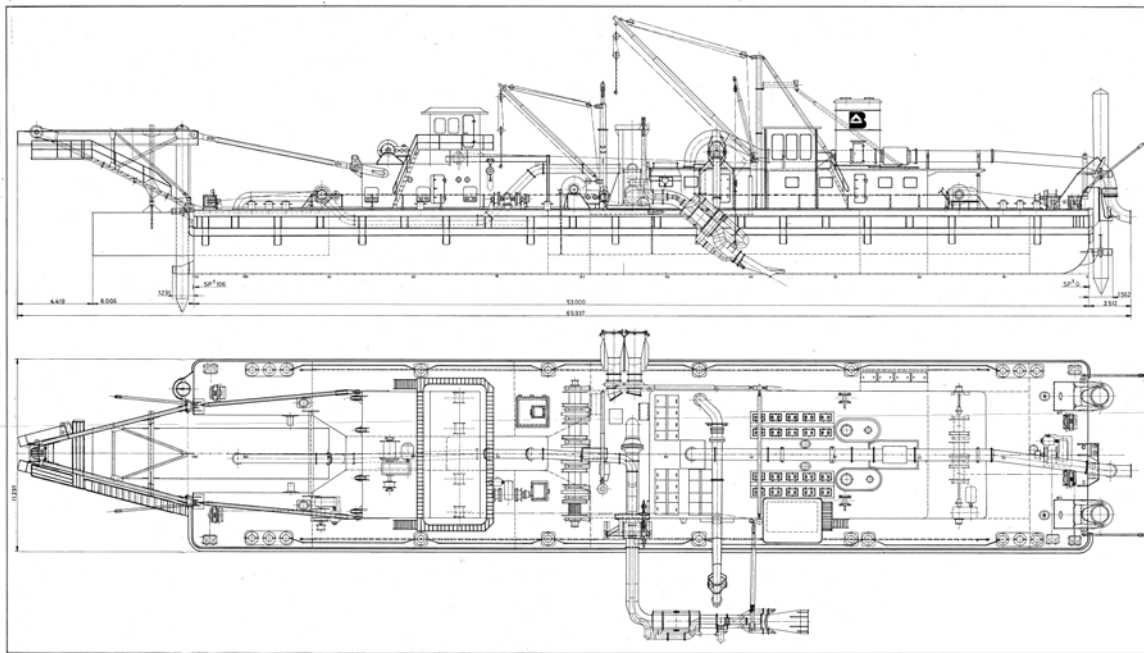Figure Figure 5-19 shows a barge unloading dredger that can be used as a plain suction dredger too.

Figure 5-19 BUD Hercules

5.4. Technical construction

5.4.1.   The hull

The main dimensions length, width and depth of the pontoon depend totally on the requirements for the above mentioned design parameters and the from these following demands for stability and strength.

The light weight of the pontoon in tons is roughly 25 % of the total power installed (Figure 5.12)
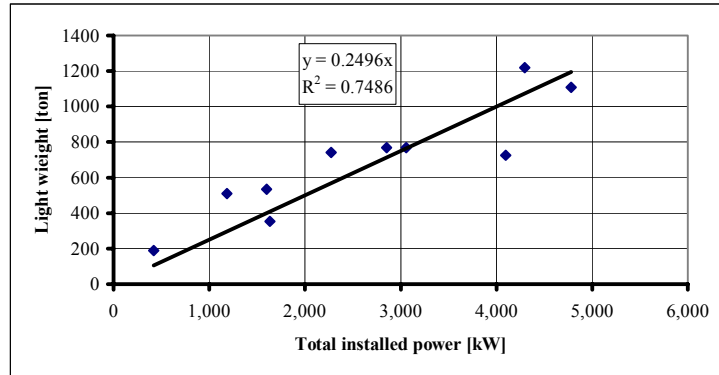

Figure 5-20 Light weight versus installed power.

The pontoon volume in cubic meters is almost 2.5 times the light weight in tons (Figure 5.13).

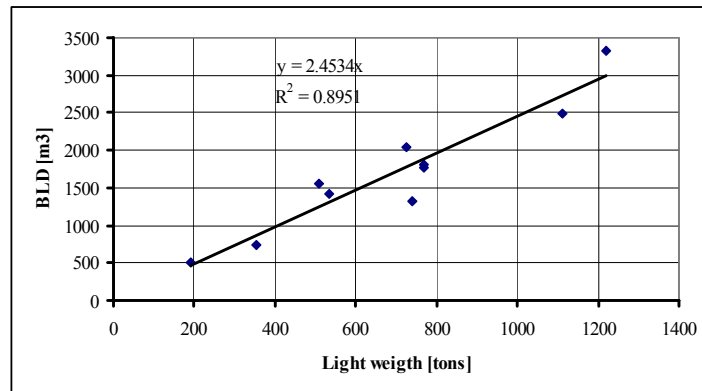Length of width have values between 4 and 4.5 while width over draught have values between 3 and 6.

Figure 5-21 pontoon volume versus light weight

The fuel and water tanks are distributed such over the pontoon that a good trim of the ship is obtained.

The winches for hauling the barges during the suction process are located on the deck.

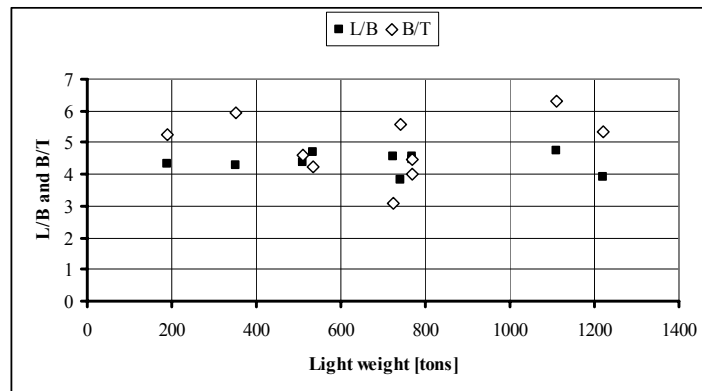The barge unloading suction dredger is in general equipped with spuds for anchorage.
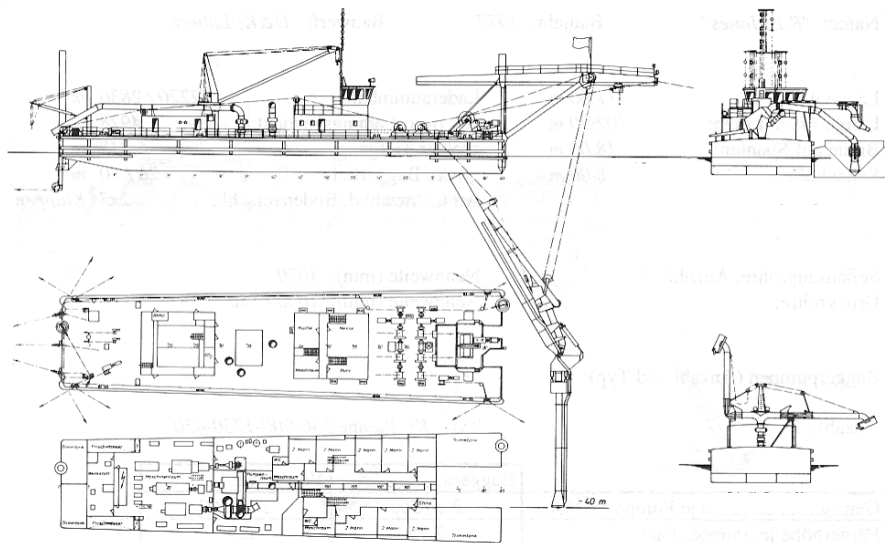

Figure 5-22

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Figure 5-23 Plain Suction and BargeUunloading Dredge Seeland

Besides plain suction dredgers Figure 5-1 and Figure 5-23 also cutter suction dredgers can be converted into a barge unloading dredger. (Figure 5-24), although the last conversion will be more expensive.

Figure 5-24 The CSD "VICKSBURG" converted to a Barge Unloading Dredger

5.4.2. The pipelines

The suction pipe that sticks out of the construction on the side where the barges are moored, must on the one hand be located as low as possible for the pump process and on the other hand be high enough to let the empty barges through underneath. The lower part of the suction pipe, the haul pipe, runs parallel and approximately in the centerline of the barge. This part can rotate around a horizontal axis by way of a rotation gland mounted in the horizontal part of the suction pipe. Since this construction causes a under pressure in the suction pipe during dredging, a lot of attention must be given to the air tightness of the piping. The necessary movability of the suction pipe is obtained by hanging this pipe in a boom with a hoist cable. For good movability the suction pipe can swing in a horizontal plane by a hinge mounted in the suction tube. (Figure 5-25)

The suction mouth is in general widened to obtain a lower height of the suction mouth with a similar opening surface. This reduces the chance of sucking in air. (Figure 5-9)

Figure 5-25 Movable suction tube

The supply of the necessary dilution water to the barge is done with one or two water nozzles. In case of one nozzle the suction mouth is usually equipped with jets, while the movability of the main nozzle is than so large that it can also spray behind the suction mouth. To present sand well to the suction mouth it is necessary to have moveable water nozzles. This is done using hydraulic cylinders.

For the dredging process the pressure side of the jet pump is, except for the water nozzles, also connected with suction side of the dredge pump.

5.4.3. The shore connection

The connection of the dredger to the shore needs to be flexible at all times, due to the movements of the barge unloading suction dredger by:

- trim during dredging
- difference in draught by supplies
- tides or water levels
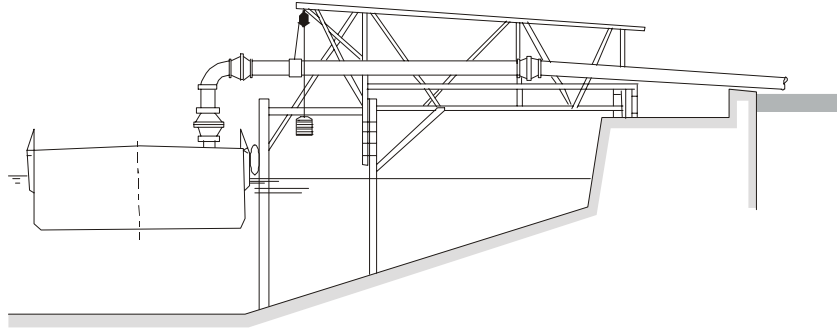- hits of the barges against the dredger

Figure 5-26 Shore connection for a barge unloading suction dredger

The shore connection must therefore consist of enough hinges. A flexible hose can also possibly give enough flexibility, if this doesn't get stuck on the slope of the embankment. For large differences extra attention must be paid to this movement (Figure 5-26).

5.5. The dredging process

The dredge process is a hydraulic transport process with a clear non-stationary character as a result of the exchange of the barges. After all this results that on regular intervals the production reduces to nil.

In Figure 5-27 the concentration and the sand pump speed and jet pump flow rate are shown as function of time.

The first phase is characterized by an increasing concentration during the process to bring the suction mouth to the bottom of the barge. During the second phase the concentration is approximately constant. The barge is hauled under the suction pipe with constant velocity. The last phase consists of a decreasing concentration because the suction mouth reaches the end of the barge, resulting in a decreasing face height
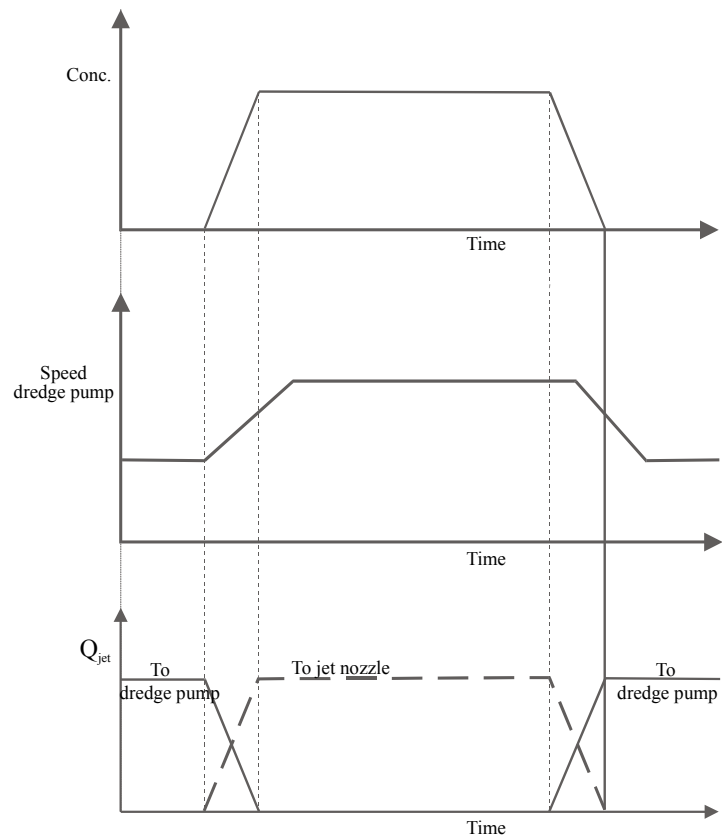

Figure 5-27

This phase is lengthened if the barge have to be cleaned. (The barge is pulled back and the remaining sand is dredged.) Such a process might be necessary when the barge is relative wide compare to the suction mouth and the suction mouth can't swing in the horizontal plane.

The production is determined by the breachebility of the sand in the barge and the erosion by the jet water. This dredging process is mainly determined by the minimum NPSH value on top of the suction pipeline and the time necessary to change the barge and to start the dredging process again, as mentioned above.

A complication however is that during the emptying of the barge the sand pump flow rate corresponds to the jet pump flow rate and the amount of sucked up sand. If this is not the case than the flow rate in the barge will raise or drop. In a good tuned up process the suction operator maintains the water level in the barge by hauling the barge slower or faster underneath the suction mouth. If there is a continuous increase or decrease of the water level in the barge than the number of revolutions of the sand pump must be adjusted. To obtain the highest possible concentration the water level in the barge must be as high as possible. Unfortunately the breaching of the sand behaves different under water than above water. If the water level in the barge is high the dredge master can't see if sand flows behind the suction mouth and prefers a low water level in the barge.

During the exchange of the barges the velocity in the pressure piping needs to be maintained to avoid sanding up. For this the suction side of the sand pump can be connected to the weed box (figure 5.7). This is not directly necessary. Since the pressure side of the jet pump is in connection with the suction side of the dredge pump a situation with two pumps in series is obtained. The required sand pump flow rate can now be reached by the control of the number of revolutions of the sand pump engine.
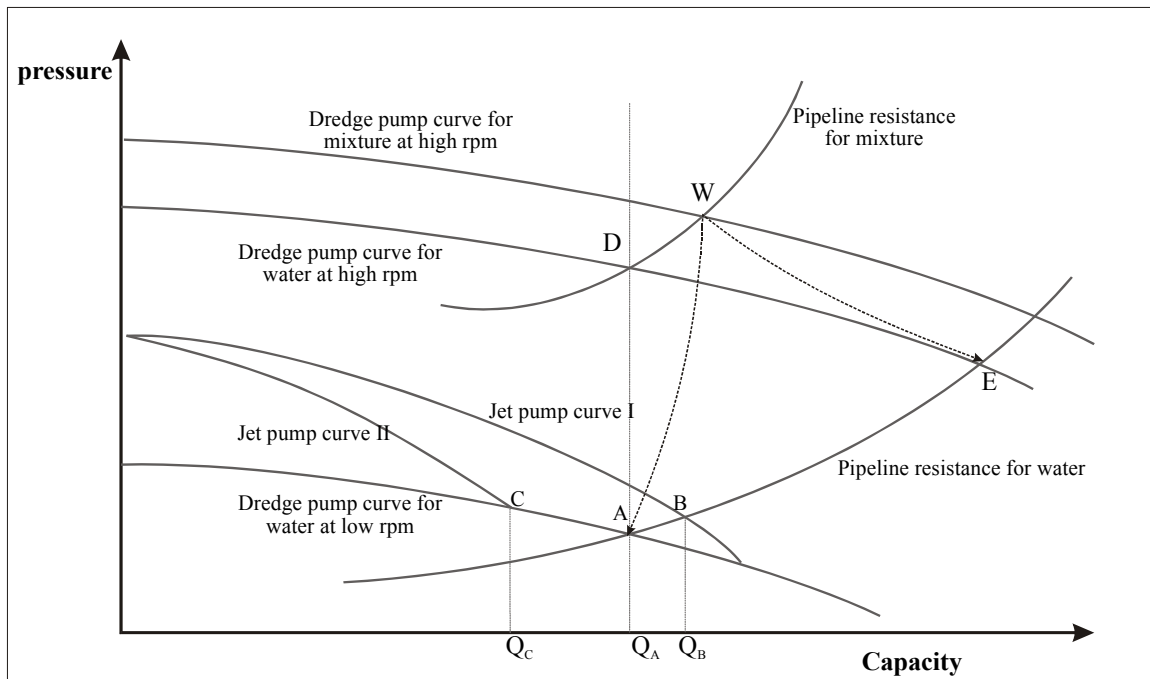

Figure 5-28 Pump –pipeline interaction for a barge unloading system

In Figure 5-28 the pipe and pump characteristics are drawn for the pumping of water and mixture. If it is desired to maintain the minimal flow rate Q_A during the exchange of the barges, than this is possible, when the suction side of the sand pump is connected with the weed box, by reducing the number of revolutions regularly. This makes the operating point W shift to A. Without a reduction of the number of revolutions of the sand pump, in the last phase of the emptying process, the operating point W will shift over the dotted line to point E, so to a reasonable higher flow rate. If the suction side of the sand pump is connected to the pressure side of the jet pump than the operating point will be in A or B for the same low number of revolutions of the sand pump and dependent on the pump characteristics of the jet pump.

For the calculation of the hydraulic process one can refer to the course Wb3414 Dredging Processes 2.