10.
SYSTEMS WITH PUMPS IN SERIES

10.1 CHARACTERISTICS OF A SYSTEM WITH PUMPS IN SERIES

An additional pump (called a booster) is installed to a pump-pipeline transportation system if an original dredge pump is not sufficient to provide a required production. This is the case if the manometric head provided by a pump is not high enough to overcome a pipeline resistance and install an appropriate value of mixture velocity in a pipeline. Typically, a pipeline resistance grows because a pipeline is lengthened (a larger dredging depth or a larger distance from a dredge to a deposit site) or a coarser soil must be transported.

Pumps operating in series should be compatible, i.e.:

- to be designed for the same working range of flow rates
- to have similar shape of the Q-H curve
- to have virtually identical position of the nominal full-torque
- to have passages and connections of similar dimensions (passages of boosters should be at least of the same size as that of a first pump).

The total manometric head provided by a set of pumps in series is equal to the sum of manometric heads of particular pumps for a given flow rate. A new H-Q curve for an installation composed from a set of pumps and a pipeline is a result of this summation (see Fig. 10.1).

For manometric head, H_{man}, and manometric pressure, P_{man}, by a pump at a given mixture flow rate Q_m

$$H_{man,total} = \sum_{i=1}^{n} H_{man,i} \text{, i.e. } P_{man,total} = \sum_{i=1}^{n} P_{man,i} \qquad (10.1).$$

For input power of a pump, W_{in},

$$W_{in,total} = \sum_{i=1}^{n} W_{in,i} \qquad (10.2)$$

and for the pump efficiency, η,

$$\eta_{total} = \frac{Q_m \sum_{i=1}^{n} P_{man,i}}{\sum_{i=1}^{n} W_i} \qquad (10.3).$$

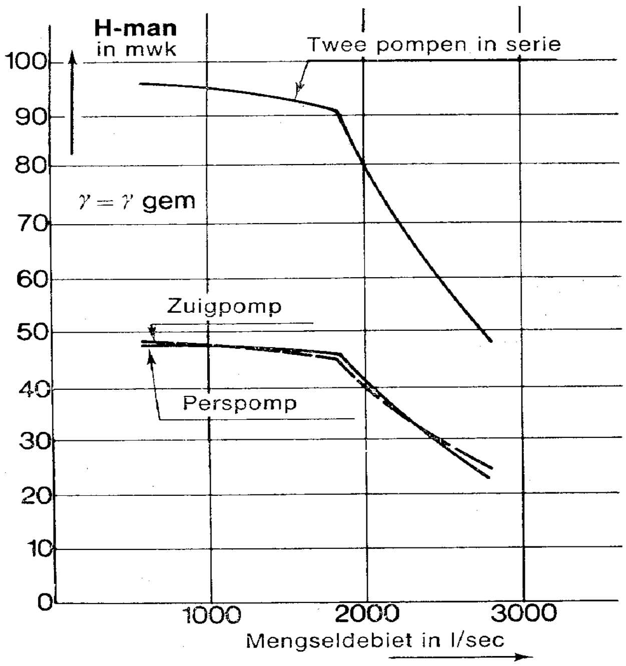

Figure 10.1. H – Q characteristic for two pumps in series.

The working point of a twin-pump - pipeline installation is given by a point of intersection between the twin-pump characteristic and the pipeline characteristic On Fig. 10.2 different working points are found for a set of two pumps and a pipeline at various delivery distances. On the figure the same is plotted also for an installation composed of a single pump and a pipeline at various delivery distances.

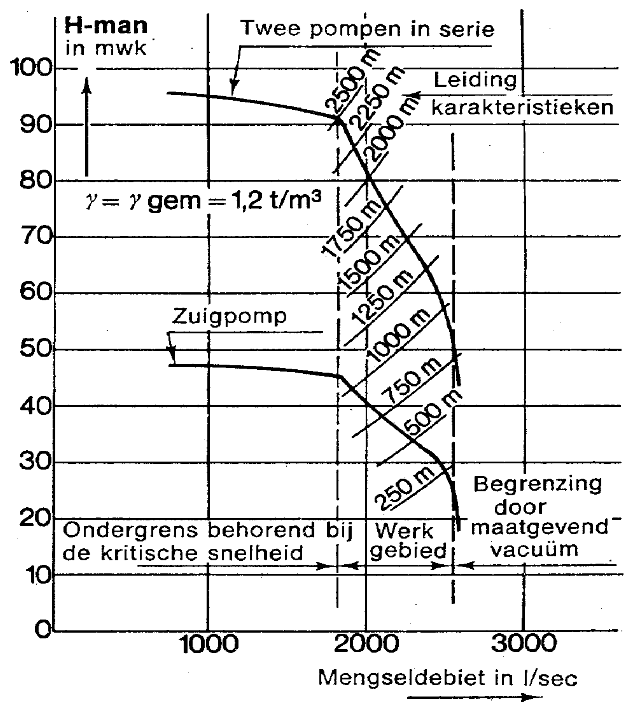

Figure 10.2. Working points for different pump-pipeline installations.

Not only a delivery distance grows if an additional pump is installed, also the production increases significantly as can be seen on Fig. 10.3.

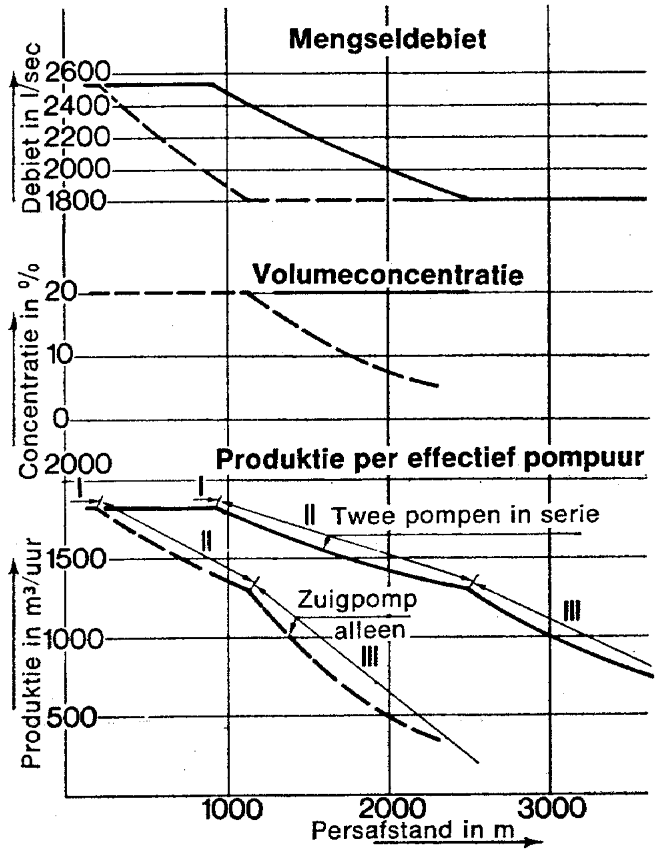

Figure 10.3. Production as a function of a pipeline length for installations with a single pump, a set of two pumps respectively.

10.2 OPERATIONAL RULES FOR PUMPS IN SERIES

If a set of pumps in series is installed to a dredging installation the first pump serves usually as "*the suction pump*" (Dutch: zuigpomp) and the pumps behind the suction pump as "*the delivery pumps*" (Dutch: perspompen). A suction pump is supposed to handle low suction pressure at its inlet (the pump must have a high decisive vacuum) and provides only a low delivery pressure. Delivery pumps operate at higher suction pressure values and provide higher manometric head than a suction pump. Boosters (i.e. delivery pumps) should operate at suction pressure heads not lower than 10 meter water column (mwc), i.e. at suction heads not lower than is the atmospheric pressure head.
A typical example of a set of pumps is an installation with *a submerged pump* on a dredge ladder and one or two *on-board dredge pumps*. The submerged pump acts as a suction pump and the on-board dredge pump(s) as delivery pump(s) for a long delivery pipeline.

10.3 CONTROL OF A SYSTEM WITH PUMPS IN SERIES

An operation of an installation composed of a pipeline and pumps in series should be controlled to maintain a dredging process as steady as possible. The operation control must prevent an on-time magnification of velocity fluctuations in a pipeline that usually develop if mixture is pumped of fluctuating density and solids properties. Large velocity fluctuations might result to water hammer. Water hammer is associated with huge pressure gradients over sections of a transport installation that may cause a total damage of pumps and pipes. To prevent water hammer in uncontrolled installations it is necessary to avoid a situation that a delivery pump performs a suction function (i.e. a suction pressure at the inlet to a delivery pump is lower than the atmospheric pressure). Such a situation may occur, for instance, if a suction pump would collapse. The suction pressure at the delivery pump would drop, possibly even below a non-cavitation limit. A very low pressure in front of a delivery pump increases considerably a risk of water hammer in a system.
Mixture-flow interruptions generated by excavating and suction processes might be a further reason for a development of water hammer in a pipeline with pumps in series. A suddenly low supply of mixture to a pipeline in front of a booster can cause that the booster starts to suck (a result of a low pipeline resistance), i.e. low pressure is generated at the inlet to a booster pump. This causes an acceleration of mixture masses in the pipeline in front of the pump and deceleration of mixture masses in a pipeline behind the pump. If a supply restores again, large masses of mixture are subjected to acceleration with collisions between mass's and pump & pipeline components as results. Further collisions occur between accelerated and decelerated masses in a pipeline. The collisions cause water hammer effects.

If an installation operation is controlled a delivery pump may perform a suction function without disastrous effects. A certain control procedure is required also to start or stop an installation operation. An installation is equipped with various components, instruments and controllers to prevent water hammer effects.

Usually, speed of a pump controls the mixture flow in a pipeline. A delivery pump is regulated to a certain velocity set point in order to maintain stable flow. If the mean velocity in a pipeline grows above a set point value the controller decreases the rpm of the pump. If the velocity drops below the set point value, the controller increases the rpm. The speed of pumps is also regulated to prevent cavitation at the suction side of pimps (the suction pump in particular). If the suction pressure at the inlet of a pump drops below a non-cavitation limit the controller decreases the pump rpm in order to decrease the velocity and so increase pressure in a pipeline in front of a pump.

10.4 LOCATION OF BOOSTERS ALONG A LONG DREDGING PIPELINE

Two most important conditions must be satisfied if a location of a booster is sought:
- a suction pressure at the booster-pump inlet must be sufficiently high (higher than atmospheric pressure, i.e. approximately 1 bar or 10 mwc)
- a discharge pressure at the booster-pump outlet may not be higher than a maximum pressure that the pump components can stand.

Thus a pressure distribution along a long pipeline is of the greatest importance for a determination of a suitable booster location.

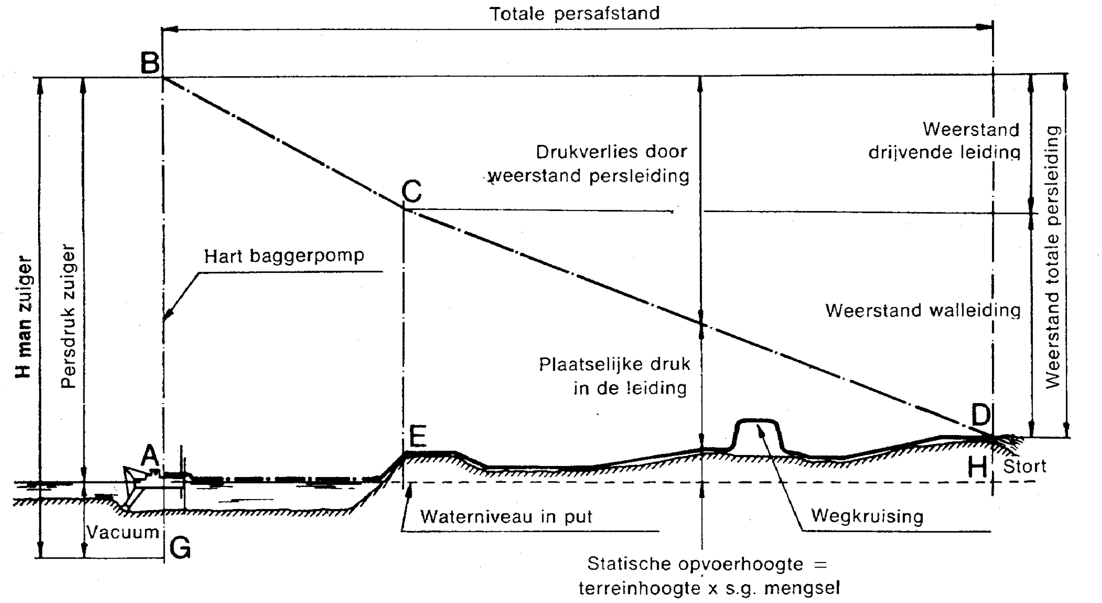

Figure 10.4. Pressure head distribution along a dredging pipeline for an installation without a booster station.

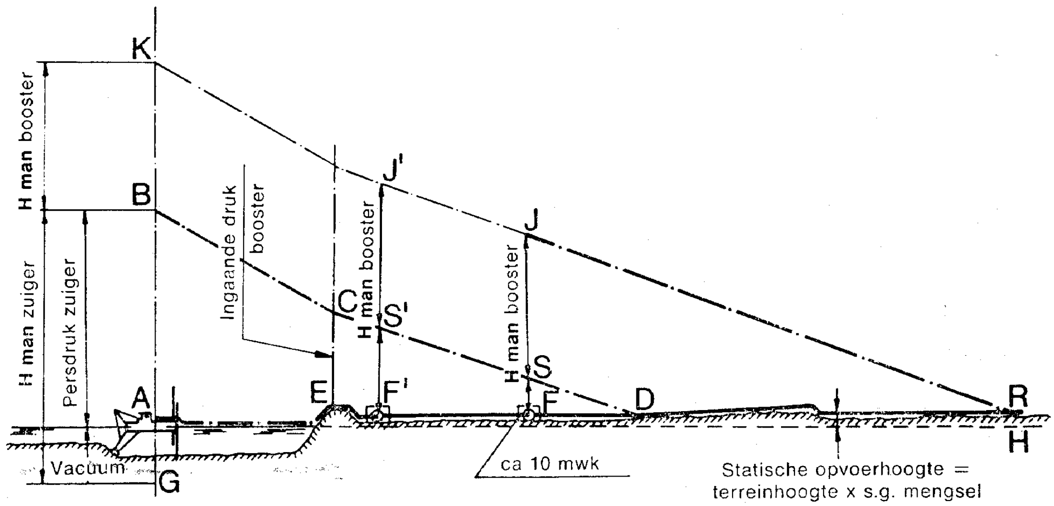

Figure 10.5. Pressure head distribution along a dredging pipeline for an installation with a booster station.

10.5 RECOMMENDED LITERATURE

de Bree, S.E.M. (1977). *Centrifugaal Baggerpompen.* IHC Holland.