Centrifugal Dredgepumps
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By
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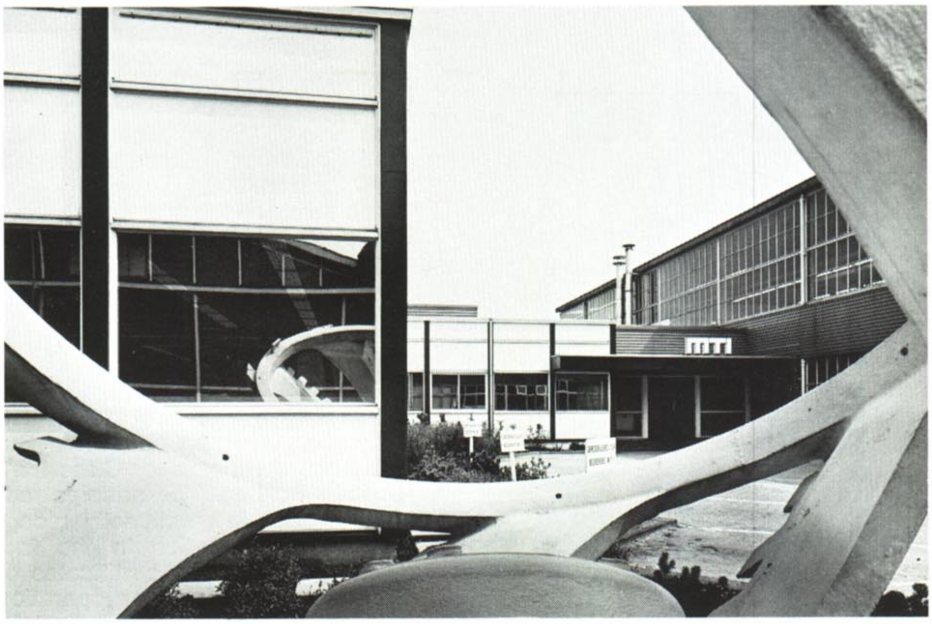

This article is the tenth in a series written by Ir. S. E. M. de Bree, Head of the Mineral Technological Institute, the development laboratory of the Dredger Division of IHC Holland.
The earlier articles appeared in issues 77, 78, 80, 82, 84, 85, 86, 87 and 88 of this publication.

Introduction

Multi-pump installations and the use of a booster unit in the delivery pipeline were discussed in the two preceding articles. Here we shall deal with the location of the booster in the pipeline.

Incorrect positioning of the booster can adversely affect the output of the installation. If it is too far behind the dredger, the pressure at the inlet of the booster pump may be too low – or even negative – producing water hammer and consequent damage to the installation. If the booster is too close to the dredger, the pressure on the delivery side of the booster pump will be so high as to require exceptionally robust components, added to which those subjected to wear will need to be replaced prematurely, i.e. while they still have a relatively high residual wall thickness.

The pressure pattern over the length of the delivery pipeline is a decisive factor in determining the position of the booster. This can easily be shown with the aid of the pipeline layout.

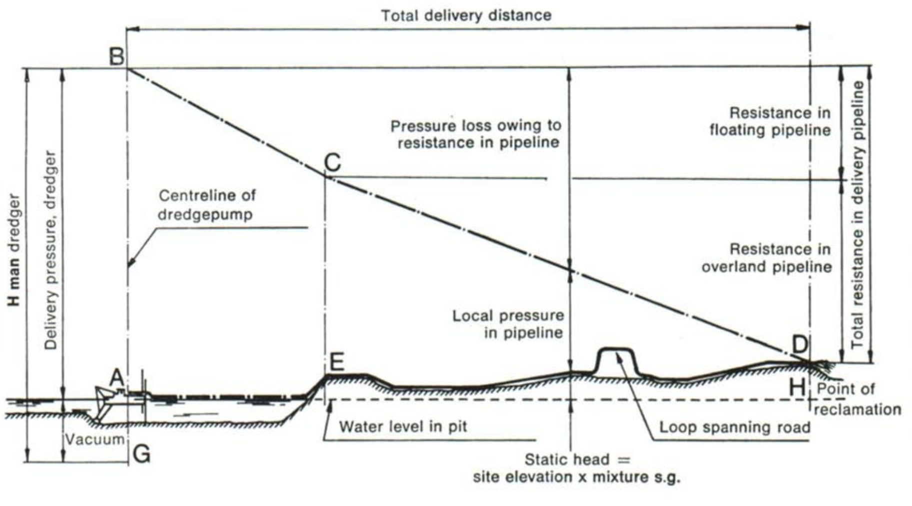

Fig. 1

Pressure pattern over the delivery pipeline

Fig. 1 shows the pressure pattern produced by resistances in, and the geodetic head of, a pipeline used with a suction reclamation or cutter suction dredger without a booster unit and transporting a mixture of the mean attainable specific gravity.

The pipeline is shown schematically by the line AED. Horizontally this represents the delivery distance, vertically the static head at each point along the length of the pipe. At point A (the dredgepump outlet), the delivery pressure of the pump is available to transport the mixture through the pipeline. This pressure, which is equal to the manometric head of the pump (BG) less the existing vacuum (GA), is shown by the vertical line AB. The pattern of the static head is seen by comparing lines AED and AH. The static head is the product of the (geodetic) height of each point along the pipeline above the level of the water in the pit (AH) and the specific gravity of the mixture present in the pipeline at the relevant point.

The point of reclamation is indicated by the letter D. The height DH is the static head at that point, which is equal to the product of the (geodetic) head and the specific gravity of the emerging mixture. The velocity head at which the mixture leaves the pipeline has already been taken into account in the vacuum, i.e. at the entrance to the suction pipe.

The pattern of resistance in the pipeline is represented by the dot-and-dash lines BC (for the floating pipeline) and CD (for the overland section). These are in fact not straight lines, since there are additional local resistances caused by bends, swannecks, hose connexions, swivel joints, bifurcations etc. separating the straight sections of pipe. However, for our purpose they provide a satisfactory approximation of the resistance pattern.

As there are usually more sources of additional resistance in the floating pipeline (bends on board the dredger and the flexible connexions in the pipeline itself) than in the land line (bends and bifurcations), the slope of the line intersecting B and C is in most cases somewhat steeper than that of the line which can be drawn through C and D. The pressure at each point in the delivery pipeline is represented by the vertical distance between lines BCD and AED.

Fig. 2 shows the pressure pattern in the delivery pipeline of a barge-unloading dredger operating without a booster. As in Fig. 1, the pipeline layout is represented by the line AED, and the horizontal delivery distance

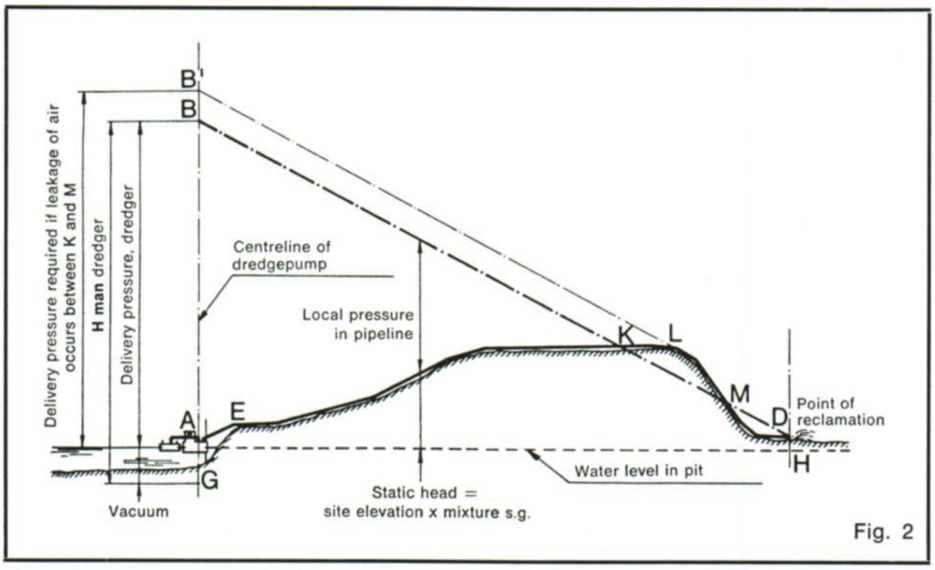

Fig. 2

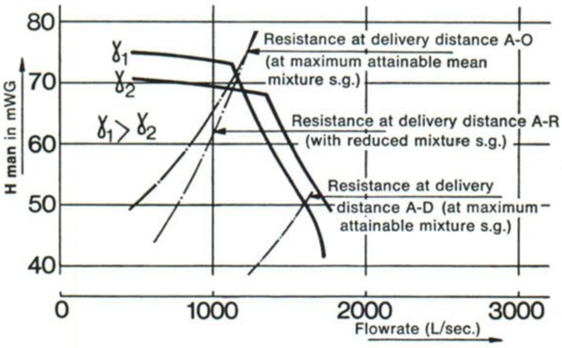

Fig. 3A

and the vertical static head at every point along the pipeline are shown. It will be seen that the line BD, representing the resistance pattern in the pipeline, intersects the static head line at point K. This implies that the pressure at that point is zero, and that if the delivery distance were to be increased a vacuum would exist there. Provided that the pipeline is absolutely airtight, this is feasible because the remainder of the pipeline would then act as a siphon.

With an installation such as is shown in Fig. 2, when the dredging process commences and the mixture reaches point K, the output of the pump, and with it the resistance in the pipeline, will decrease.

As a result, a portion of the delivery pressure of the pump becomes available to build up the pressure required in the section of the line between K and L. Once the mixture passes point L and the siphoning action commences, the mixture flowrate will increase.

Leakage of air between points K and M results in a higher pressure demand on the dredgepump. If the installation is working within the normal operating range and an increase in pressure is feasible, the working point on the pump curve will shift to a lower flowrate. In this situation, the pressure demanded must be high enough to remain positive at the most elevated point along the pipeline.

In Fig. 2, the minimum additional pressure required is represented by the dot-and-dash line B′L, which is parallel to the line BD and intersects the static head line AEKLMD at point L.

If, because the installation is operating in the vicinity of the lower limit (the critical velocity), the increase in pressure is not attainable, the pipeline resistance must be reduced by lowering the specific gravity of the mixture through the admission of water to the suction pipe.

The pressure pattern in the pipeline is governed by, among other factors, the length of delivery pipe behind the dredger. The relationships between the pump and pipeline curves, the output diagram and the pressure pattern in the pipeline are shown in Figs. 3A, 3B and 3C.

Fig. 3A shows the pump curves of a diesel-driven installation in a suction reclamation or cutter suction dredger, together with three curves representing typical delivery distances. Two of these correspond to the highest attainable mean mixture s.g. and the third to a reduced mixture s.g.

The output graph for this installation is reproduced in Fig. 3B. The typical delivery distances referred to correspond to points X, Y and Z (maximum). In Fig. 3C, the resistance encountered over the three delivery distances is shown by broken lines.

Distance A-D

This is the shortest delivery distance over which, at maximum flowrate and attainable mean mixture s.g., the vacuum on the dredgepump remains just below the decisive value. In the output graph (Fig. 3B), this is the distance corresponding to the bend X between line sections I and II. The pattern of resistance in the pipeline is shown in Fig. 3C by the broken line BD.

Distance A-O

This is the greatest distance at which the flowrate corresponding to the critical velocity at the maximum attainable mean mixture s.g. can just be maintained. In the output graph (Fig. 3B), this is the distance corresponding to the bend Y between line sections II and III.

The pattern of resistance in the pipeline is represented by the broken line NO. Point N on this line is higher than point B, because the intersection of the pump and pipeline curves in the Q-H diagram at this delivery distance (AO) corresponds to a lower flowrate and a higher manometric head than at distance AD (see Fig. 3A).

As the resistance per unit of length at distance AD is greater than at distance AO, by reason of the higher mixture flowrate, the pipeline line BD will be steeper than line NO.

Distance A-R

Lowering the specific gravity of the mixture enables the pipeline resistance and also the static head to be reduced. This, in turn, makes it possible to operate at distances greater than AO, albeit at a lower level of output. In the output graph (Fig. 3B), point Z corresponds to the maximum delivery distance AR, at which it is still just possible to achieve a "reasonable" output.

The pipeline resistance pattern at this maximum delivery distance is represented in Fig. 3C by the broken line PR.

Positioning a booster

Figs. 4 and 5 depict a straightforward situation in which mixtures of the same specific gravity are transported and in which either the flowrate remains constant, while the delivery distance increases proportionately, or the reverse occurs.

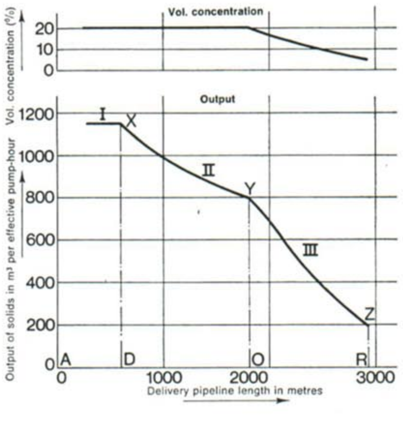

Fig. 3B

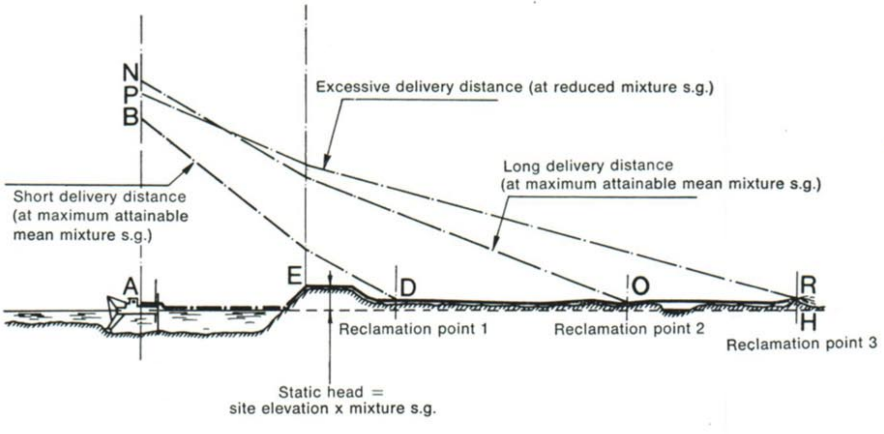

Fig. 3C

In the booster-assisted installation shown in Fig. 4 the delivery distance has been modified so as to arrive at the same flowrate and specific gravity of the mixture as would be the case if no booster were employed. (This is seldom done in practice). The available manometric head of the pump in the dredger is represented by the vertical line BG. The vacuum of the pump is represented by line AG and the available delivery pressure by line AB. With this pressure, and under the given circumstances, the point of reclamation D can be reached. The pattern of resistance in the pipeline when working with the dredger alone is represented by the line BCD.

The most favourable position for the booster coincides with an inlet pressure at the booster pump of 1 kgf/cm² or slightly more. In the diagram this is point F (Fig. 4). If it is thus situated, the pressure in the pipeline at point F will be raised by the value of the manometric head of the booster pump (SJ).

In this situation, the resistance pattern in the stretch of pipeline between the booster and the point of reclamation will be represented by the broken line JR. If the diameter and bore surface of the pipeline sections before and after the booster are identical, the resistances per unit of pipeline length will be identical. Roughly speaking, the resistance pattern according to the line JR will be parallel to resistance line CS.

In Fig. 4, the positioning of the booster is based on an ideal situation in which the pressure at the inlet of the booster pump is approximately 1 kgf/cm². In practice, however, it is frequently impossible to achieve so ideal a position and the booster has to be situated closer to the dredger, say at point F′. In that case, both the inlet and outlet pressures of the booster pump will be greater. The resistance pattern in the pipeline leading from the dredger and booster will be represented by the line BCS′J′JR. The closest the booster can be placed to the dredger is immediately after it. In that position, the resistance pattern will be as shown by the line KJ′JR.

As stated, it is at all events preferable to choose a position in which the pressure on the delivery side of the booster pump is not excessive, in order to avoid the necessity for exceptionally heavy components.

In the installation shown in Fig. 5, the introduction of the booster has produced a change in the flowrate, but the delivery distance and the mixture s.g. have not been affected.

The manometric head of the pump in the dredger is represented by the line section GB′. The pattern of resistance in the pipeline when working with the dredger alone is then represented by the section B′C′D. Because the delivery distance and the mixture s.g. do not change, the indroduction of a booster will result in an increase in the flowrate of the entire installation. This increase, however, is dependent upon the absence of any limitation by the decisive vacuum on the suction side of the dredger-mounted pump or any restriction of output attributable to the pit supply.

The new working points of the dredger and booster pumps, operating together, can be determined from the pump curves obtained by summation and pertaining to these pumps and the pipeline curves. If the booster is positioned in such a manner that the pressure on the inlet side is of the order of 1 kgf/cm², the resistance pattern in the pipeline leading from

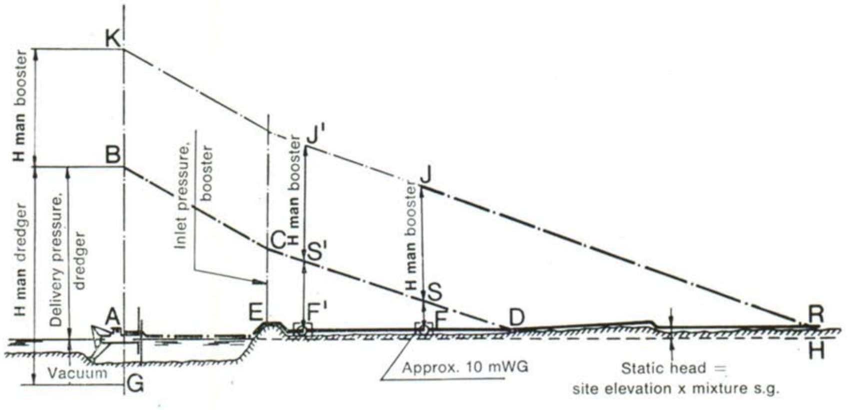

Fig. 4

the dredger and the booster will be as indicated by the line BCSJD in Fig. 5. Here, too, JD is virtually parallel with CS, because, as is usual, the pipeline diameters before and after the booster are identical.

Determining the booster location by means of graphs

In most instances the delivery distance does not remain constant throughout the job, but varies continually to meet the situation at the reclamation point. However, for reasons of supply and accessibility, it is desirable to have a fixed booster position. In most cases the minimum delivery distance is the decisive factor in determining the optimum position.

The location of the booster is determined by means of graphs. The first step is to calculate the curves for the dredgepump with and without a booster in series, and the pipeline curve. The curves pertaining to a given installation are reproduced in Fig. 6A. With the aid of these, the output of the dredger, alone and with a booster, is calculated at the various delivery distances. Fig. 6B shows the output as a function of the delivery distance. Using this graph, the minimum delivery distance at which the use of a booster is justified on cost and other grounds can be calculated. (Naturally, cost is not the only governing factor). The diagram shows the minimum delivery distance at which the booster, if present, would continue to be fully utilized and also the maximum distance over which mixture of the highest attainable mean specific gravity can be transported.

The position of the booster can now be simply determined with the aid of the diagram reproduced in Fig. 6C, in which the resistance and static head patterns are plotted against the delivery distance. The resistance patterns for two delivery distances are given, namely the minimum and maximum distances shown in Fig. 6B with the dredger and booster pumps operating in series.

At the minimum delivery distance, the data for the resistance pattern – which is determined by the soil, the dredging installation and the pipeline layout – are obtained from the curves calculated previously (Fig. 6A).

The manometric head of the dredger-mounted pump (X) in Fig. 6A is equivalent to BG in Fig. 6C. The delivery pressure of this pump – line AB in Fig. 6C – is obtained by subtracting the vacuum occurring (line AG) from the manometric head.

The manometric head of the booster pump (Y) in Fig. 6A is represented by the line BK.

To arrive at the total pressure available to transport the mixture through the pipeline, Y (the manometric head of the booster) is first plotted in the diagram, after which the delivery pressure [(X) – Vacuum] of the dredger is superimposed on Y.

The pipeline resistance pattern is represented by the broken line ACD (Fig. 6C). This can be divided into two sections, AC (the resistance pattern in the pipework on board the dredger and the floating pipeline, complete with bends and flexible connexions) and CD (the resistance pattern in the overland portion of the pipeline). The static head is also plotted vertically for each point along the length of the delivery pipeline. This is represented by the line KED.

The maximum permissible distance between the booster and the dredger is now determined. A minimum of 10 mWG on the vertical axis must be maintained between line ACD, representing the resistance pattern, and line BN, representing the manometric head of the booster. In the example shown in Fig. 6C, the maximum distance between dredger and booster is seen to be KF.

If point F in Fig. 6C were to coincide with the floating section of the pipeline, i.e. between K and E, three possible courses of action would be open:

- To employ a floating booster.
- To shorten the floating pipeline (if possible) so as to enable the booster to be positioned just on the land.
- To employ a different dredger. The delivery pressure of the pump, or pumps, of the substitute vessel must be such that point J shifts upwards, which implies that the booster can be positioned on land. In most cases, however, such a vessel is not immediately available.

If none of these solutions is practicable and the booster has to be positioned on land and at a greater than permissible distance from the dredger, the delivery pressure of the booster when working at the shortest delivery distances must be reduced sufficiently to restore an inlet pressure of approximately 1 kgf/cm². In practice, this usually means throttling back the diesel engine driving the booster pump, added to which it is often necessary to replace the booster pump impeller with one of smaller diameter, or with a smaller number of blades, in order to reduce the effect of the booster. The reduction in booster pressure produced by these measures results in a drop in the output of the installation.

The booster position for the minimum delivery distance having been determined, it is necessary to check the

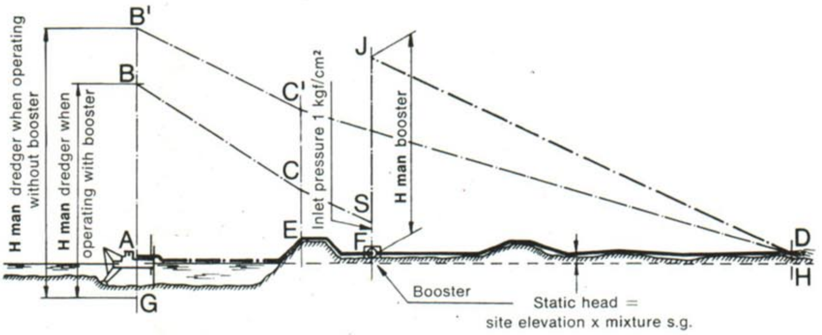

Fig. 5

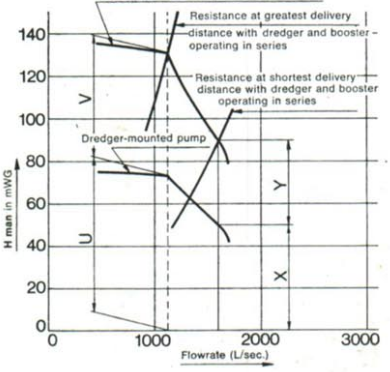

Fig. 6A

inlet pressure and, more important still, the delivery pressure of the booster pump at the maximum delivery distance.

This operation has been incorporated in Fig. 6C. The data are again calculated from the basic factors, such as the soil, the installation and the pipeline layout.

The total available manometric head is again obtained from the intersection of the pipeline curve at maximum delivery distance with the pump curve obtained by summation (Fig. 6A). From this, in turn, are derived the individual working points of the dredger and booster pumps with their respective manometric heads U and V. These manometric heads are again corrected and plotted in Fig. 6C, as was done for the minimum delivery distance.

In Fig. 6C, the pattern of resistance in the pipeline at the maximum delivery distance is represented by line MPR. The inlet pressure of the booster pump is shown by line NJ. The total pressure after the booster pump is represented by the line OJ.

It is necessary to verify that the booster pump and the components situated immediately behind the booster are suitable for this high pressure (OJ) in terms of strength, resistance to wear and sealing arrangements. If not, consideration must be given to:

- choosing an alternative booster pump, or
- positioning the booster in such a manner that the pressure in the pump when operating at the greatest delivery distance is equal to the maximum permissible pressure for the pump.

Exercise of the latter option implies that the pressure at the inlet of the pump when working at shorter delivery distances will be less than the 10 mWG demanded. It will then be necessary to adopt measures such as throttling down the booster engine and reducing the impeller diameter in order to reduce the overall contribution made by the booster and thus avoid falling below the minimum inlet pressure of 1 kgf/cm². If such measures are taken, the output of the installation at shorter delivery distances will be somewhat diminished.

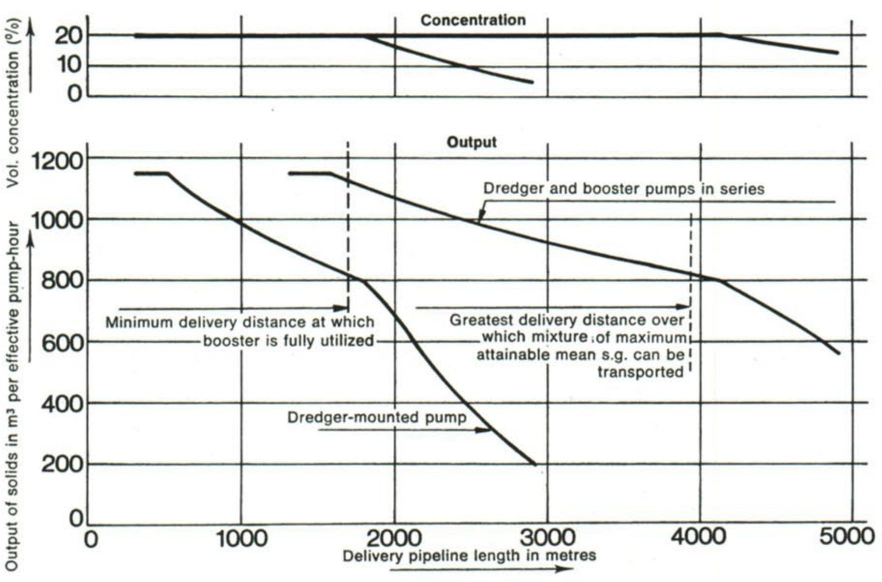

Fig. 6B

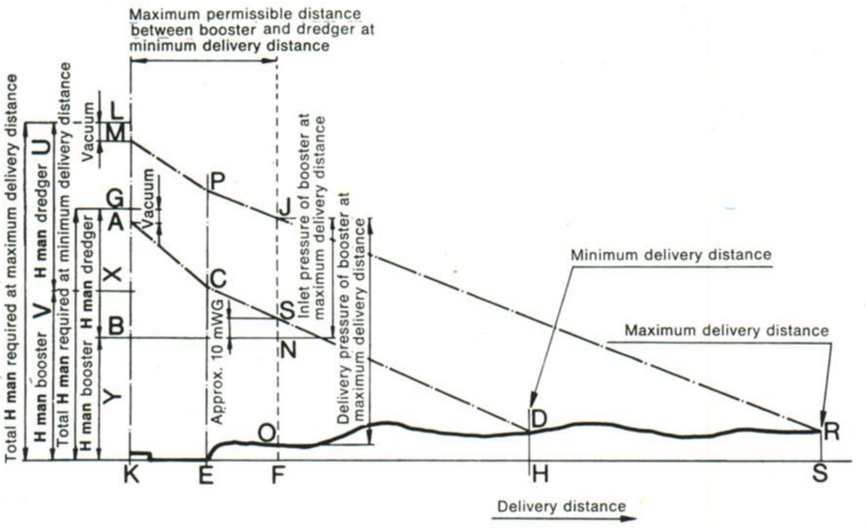

Fig. 6C