PD CEN/TR 13930:2009

Rotodynamic pumps — Design of pump intakes — Recommendations for installation of pumps

ICS 23.080

British Standards

National foreword

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Pompes rotodynamiques - Conception des ouvrages d'aspiration - Recommandations d'installation des pompes

Kreiselpumpen - Gestaltung der Einlaufbauten - Empfehlungen zur Installation der Pumpen

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Foreword

This document (CEN/TR 13930:2009) has been prepared by Technical Committee CEN/TC 197 "Pumps", the secretariat of which is held by AFNOR.

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This document supersedes CR 13930:2000.

Introduction

In addition to the risks of cavitation that may exist at the intake of any pump depending on the NPSH available, pumping from a sump poses specific problems.

In fact, if the water passes from a flow state with an exposed surface to flow under pressure, significant swirling movements may occur and sometimes be amplified, thus creating a sort of funnel or vortex which opens out into the exposed surface of the sump with a risk of air being entrained or creating a swirling chimney, or whirl between the bottom and the intake producing degassing or vaporisation of the liquid in the entrance of the pump (see Figures 1a) and 1b) below).

These phenomena, which are generally unsteady, can have unwanted effects on the plant:

— undesirable vibration of various pump components;

— increased risk of cavitation;

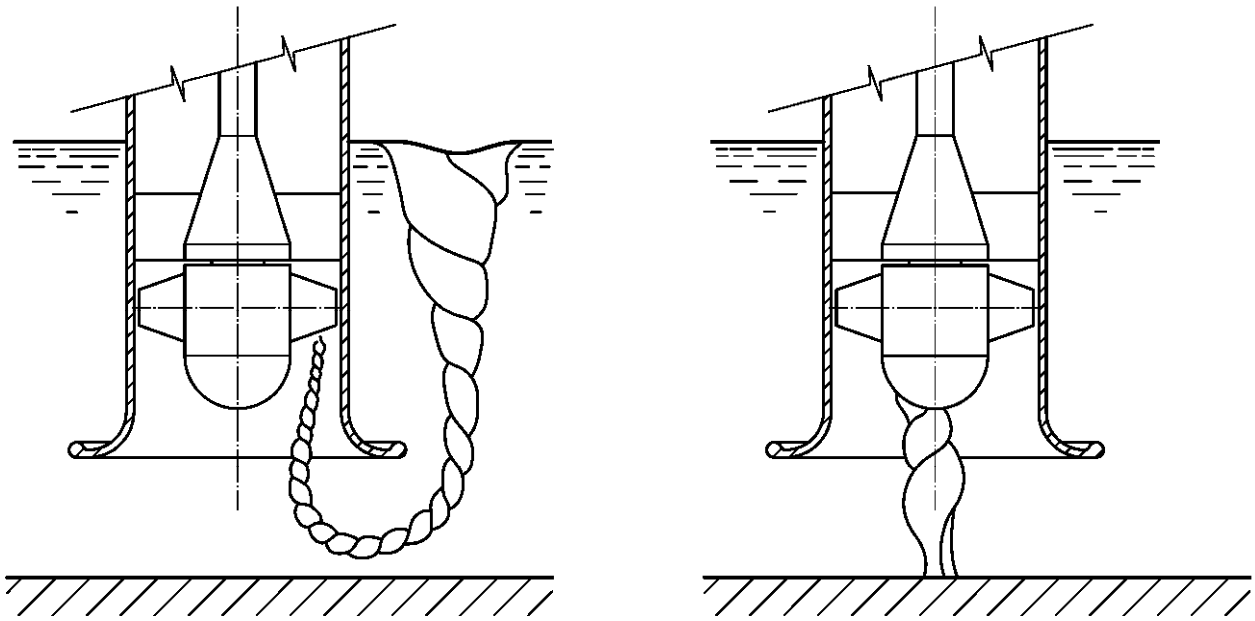
— drop in efficiency;

— reduction in flow rate and/or head;

— risk of floating bodies being sucked in;

— intense and irregular noise.

Compliance with the recommendations in this document makes it possible, in most commonly encountered industrial applications, to avoid or at least limit the phenomena mentioned above.



1a) Vortex causing entrainment of air in suction piping

1b) Chimney or whirl between the floor and the suction inlet

Figure 1 — Types of possible disturbances

1 Scope

1.1 This technical Report contains recommendations for the design of pump intakes and the installation of pumps.

As far as possible, these recommendations should be adhered to in order to obtain correct operation of the plant.

These recommendations are applicable regardless of the flow rate of the plant:

— plant which works with clear water (or relatively unclouded) and relatively non-aerated water or any other liquid having physical and chemical properties which are similar to those of water;

NOTE This document nevertheless contains several general recommendations for operation with cloudy (or very cloudy) water.

— pumping plant which has its own floor.

1.2 This document deals with various intake configurations:

— Clause 3 contains recommendations which apply to intakes with vertical suction inlet;

— Clause 4 contains recommendations applicable to intakes with top suction inlet;

— Clause 5 contains recommendations applicable to intakes with floor suction inlet;

— Clause 6 contains recommendations applicable to intakes with side-wall suction inlet.

2 General

2.1 Factors which influence the operation of the plant

The following factors have an effect on the operation of the plant:

a) Characteristics and position of the suction inlet:

  — arrangements of the suction inlet (vertical with bellmouth or tapered suction, top, floor or side-wall intake);

  — presence or absence of a bellmouth or tapered suction;

  — distance between suction inlet and floor;

  — distance between suction inlet and side-walls;

  — submergence (level of liquid relative to suction inlet);

  — strainer.

b) Inflow of liquid to the intake:

  — inflow velocity of the liquid;

  — shapes and dimensions of inflow;

— position of inflow.

c) Environment of the pump in the plant:

— velocity of liquid close to the pump;

— shapes and dimensions of the plant;

— special devices (gratings), anti-vortex device;

— relative positions of pumps to each other and in the plant.

Clauses 3 to 6 below contain recommendations concerning the determining factors for each arrangement of the suction inlet.

NOTE If the liquid is charged with solid particles in suspension, the following recommendations may be amended. Prevent the velocity of the fluid falling below a value which allows the deposition of solid materials. A minimum value of 0,7 m/s close to the suction inlet is currently admitted.

2.2 General design principles for a pumping plant

In order for the pump to be fed under the best possible conditions, effort should be made to obtain a permanent, uniform and even flow in the suction pipe. To achieve this, it is necessary to:

— supply the suction pipe for each pump with a balanced flow which is free from swirl;

— ensure that the water accelerates gradually along the intake; any deceleration generates flow instabilities;

— avoid any entrainment of air by suction (vortex) or by churning (weir).

Ensure that these conditions are adhered to as closely as possible regardless of the operating conditions of the plant (one or more pump(s) working, one or more intake sluice(s) or filter(s) in service, high water level or low water level, etc.).

The stipulations in the following clauses are aimed at achieving this. In those, inevitably numerous, situations that are not dealt with in this document, the plant designer should adopt the following principles:

a) in water inflows intakes, stay within moderate velocities which allow gradual acceleration: examples of such velocities are those of the order of 0,3 m/s in the approach channel, 0,5 m/s in the strainer, 1,5 m/s in the bellmouth or tapered suction, and 4 m/s in the suction pipe;

b) avoid excessively large chambers and dead zones which generate overall swirl in the flow and vortices as well as the deposition of solids if the water contains substances in suspension;

c) prevent separation by avoiding sudden widening and excessively divergent angles by preferring shaped forms for pillars, low walls, bellmouth or tapered suction, etc;

d) avoid sudden changes in direction caused, for instance, by lateral feed and excessively sloping falls;

e) eliminate any obstacle which might interfere with flow over a sufficient distance (of the order of 10 times the diameter D at the entrance to the bellmouth or tapered suction) before the suction pipe;

f) avoid any asymmetry in the mode of operation as well as in the design of structures;

g) at the entrance to the suction pipe, ensure an adequate submergence for the minimum working level and increase the submergence recommended below in this standard significantly if flow conditions are mediocre;

h) if a chamber is fed with water by an overflow, ensure that the later does not entrain air and provide a baffle device.

It is far preferable to design a plant which is intrinsically problem-free from the outset rather than to rely on baffles or anti-vortex accessories which are often only a palliative offering efficiency which is difficult to predict.

In difficult cases and if the importance of the plant justifies it, it is recommended to use a reduced model to check whether there is any need to improve the arrangements made.

3 Plant with vertical suction inlet

3.1 General arrangements

In these configurations the presence of a bellmouth is necessary but alternatively, the bellmouth may be replaced by a tapered suction.

Installations with a vertical suction are shown diagrammatically in Figures 2 and 3.

a) The pump design may be:

- axial flow without exceeding the outside diameter of the bellmouth or tapered suction greatest diameter;
- centrifugal or mixed flow with bellmouth possibly wider than diameter of the bellmouth or tapered suction greatest diameter.

b) The position of the pump on the piping can be:

- horizontal or vertical;
- immersed or not immersed.

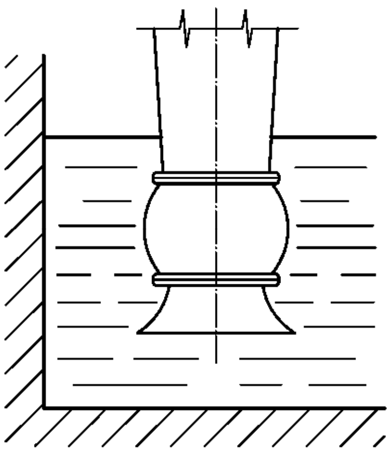
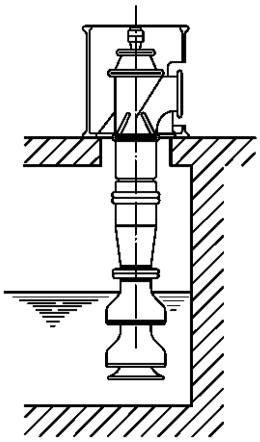
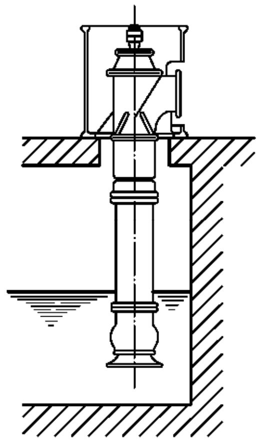


Figure 2 — Vertical suction inlet with bellmouth - Normal configuration



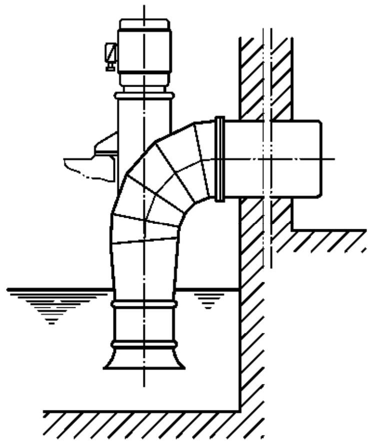
3a) Centrifugal impeller [a)]

a) The number of stages is stated for information only



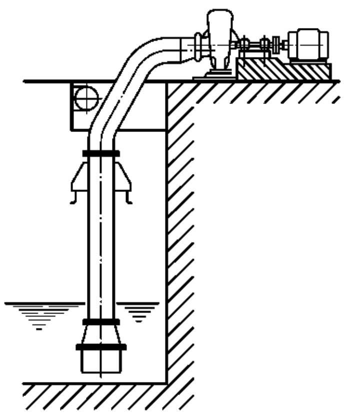
3b) Mixed-flow impeller [a)]

a) The number of stages is stated for information only

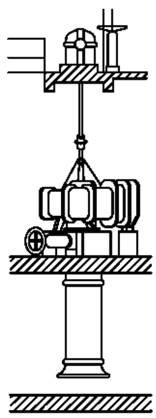


3c) Axial flow impeller [a)]

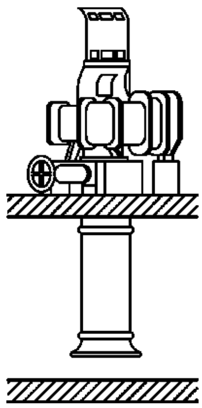
a) The number of stages is stated for information only



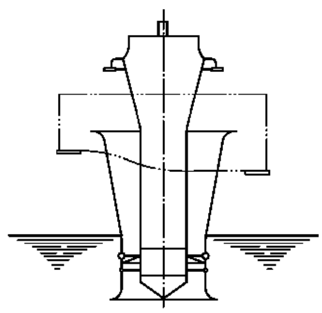
3d) Non-immersed horizontal pump



3e) Non immersed vertical pump



3f) Non immersed vertical pump



3g) Immersed vertical pump

Figure 3 — Vertical suction inlet with bellmouth (or with tapered suction) - Example of possible configurations

3.2 Diameter (*D*) at the entrance of the bellmouth or the tapered suction

Figure 4 shows typical profile of bellmouth.

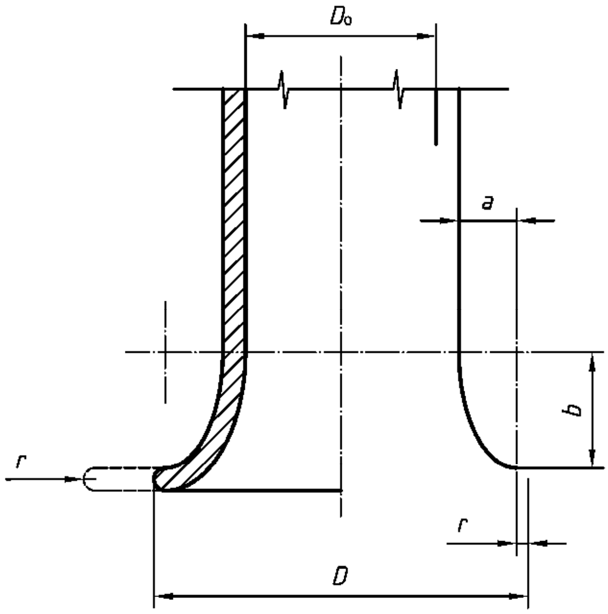


Figure 4 — Bellmouth

The diameter *D* at the entrance to the bellmouth is a result of the bellmouth profile, which is generally a quarter ellipse of which the short and long axes have the values 2a and 2b respectively.

If D_O is the diameter of the piping at the entrance to the impeller of the pump, the value of *D* is generally between 1,4 D_O and 1,8 D_O inclusive, the most common values are between 1,5 D_O and 1,6 D_O inclusive.

It is this value which is used as a reference for the recommendations given in sub-clause 3.3 and so on.

As an alternative of a suction by bellmouth, Figure 5 illustrates typical profile of tapered suction.

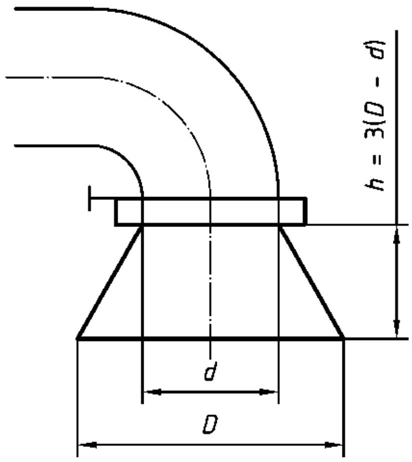


Figure 5 — Alternative with tapered suction

3.3 Distance (*C*) between the bellmouth or the tapered suction inlet and floor

Figure 6 indicates the recommended dimensions between suction inlet and the floor, in the case of a bellmouth.

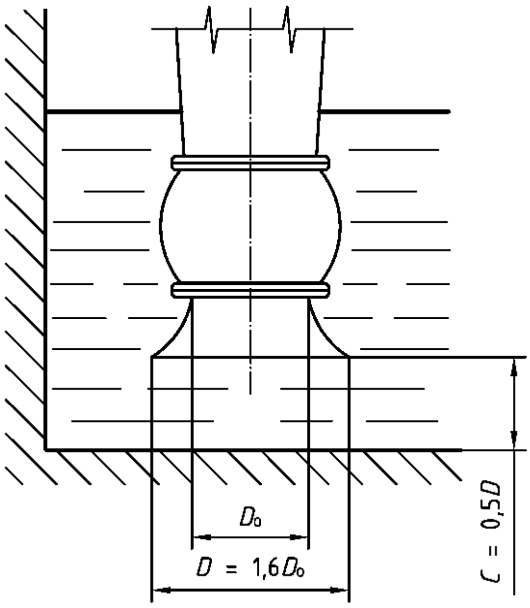


Figure 6 — Distance between the bellmouth and the floor

The distance (C) between the suction inlet and the floor should be between 0,25 and 0,5 times the diameter (*D*) at the entrance to the bellmouth; the most common values are between 0,4 and 0,5 *D* inclusive.

NOTE In the case of an intake on a natural floor (river, pond, sea, etc.) where there is always a risk of filling with sand, silting up or changing water levels, the distance (*C*) should be increased. Its value should be specified jointly with the pump manufacturer.

As an alternative of bellmouth suction, the case of tapered suction inlet is illustrated by Figure 7.

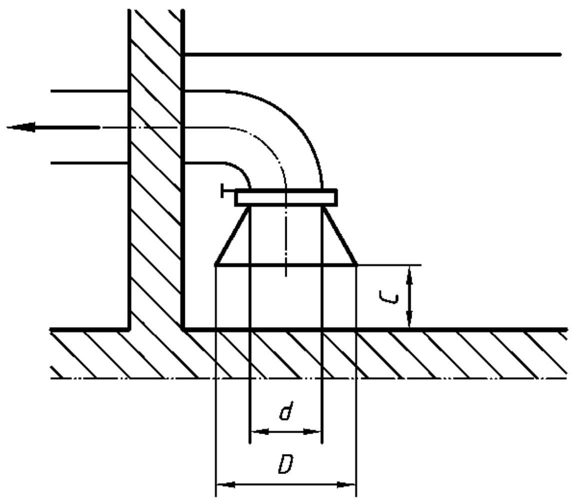
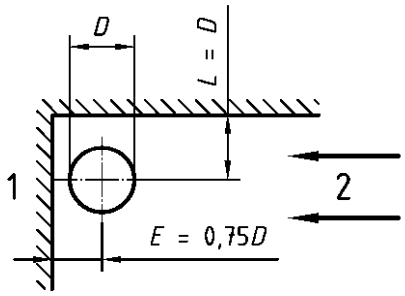


Figure 7 — Distance between the tapered suction inlet and the floor

3.4 Distances between suction inlet axis and walls

Figure 8 indicates the dimensions between suction inlet axis and walls.



Key

1 Rear wall

2 Water inflow

Figure 8 — Distance between suction inlet axis and walls

3.4.1 Distance (*L*) between suction inlet axis and side walls

The recommended dimension (*L*) is 1 *D*.

3.4.2 Distance (*E*) between suction inlet axis and rear wall

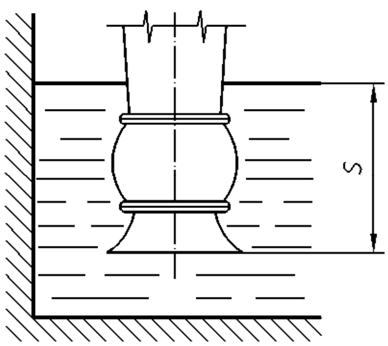
The recommended dimension (*E*) is 0,75 *D*.

NOTE If cloudy or very cloudy water is sucked in, consult the pump manufacturer before specifying dimensions (*L*) and (*E*). In fact, it is necessary to take into account the risks of the pump feed being disturbed if deposits form (see note to sub-clause 2.1).

3.5 Submergence (*S*)

3.5.1 Conditions to be satisfied for the determination of submergence

Figure 9 shows a typical submergence.



Key

S = 1 *D* to 1,5 *D*

Figure 9 — Submergence

The submergence value (*S*) should satisfy two conditions:

a) the NPSH available should exceed the NPSH required at the maximum flow rate during use by a sufficient margin. In particular, this margin should make allowance for the air content of the water;

b) the maximum submergence value selected (*S*) should prevent the formation of a vortex or whirl by taking into account all the layout and installation conditions.

Sub-clause 3.5.2 contains recommendations on the selection of *S*.

3.5.2 Determination of submergence (*S*)

The choice of submergence should result of an exchange of information between the pump manufacturer and the plant designer.

— As a general rule, the submergence should be between 1 *D* and 1,5 *D* inclusive with a minimum of 0,5 m but the parameters stated below influence the required submergence and may result in a different value being adopted.

— For instance, if the values of the following parameters are high, the submergence should be increased:

  — air content of the water;

  — linear velocity of the fluid at the entrance to the bellmouth or tapered suction;

  — pumps with high rate of flow and extremely small head, etc.

In addition, other parameters such as intake environmental conditions, number and spacing of pumps, layout of feed intakes, presence of walls or anti-vortex devices, occurrence of ripples or waves, etc. may influence the submergence value to a greater or lesser extent.

3.6 Strainer

The shape of the strainer depends on the environment of the intake. Its shape should not interfere with the correct flow of the fluid at the entrance to the bellmouth or tapered suction.

Generally speaking, the velocity through the holes of the strainer should not exceed 0,5 m/s taking the real surface over which the fluid passes in the installed position.

The strainer may be fitted with external or internal "anti-rotation ribs" which should be appropriately installed relative to the environment of the intake.

Typical strainer is represented Figure 10.

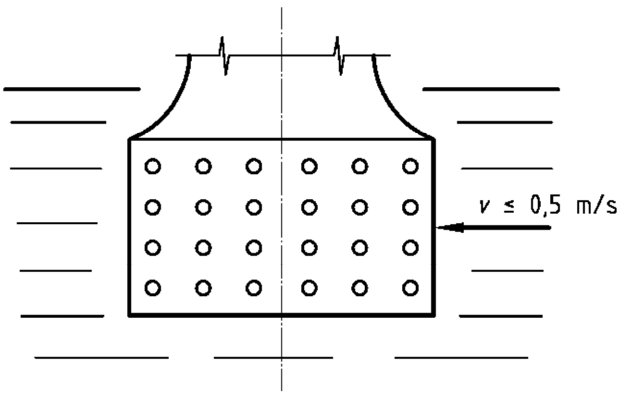


Figure 10 — Strainer

3.7 Feed intake - Pump environment

3.7.1 Feed intake

3.7.1.1 General

The general principles defined in sub-clause 2.2 of this document should be complied with, as far as possible, when designing the feed intake. Sub-clause 3.7.1.2 lists the main configurations which are encountered.

3.7.1.2 Main feed intake configurations

The shapes and dimensions of the feed intake may vary depending on the type of water inflow.

The main configurations dealt with below are as follows:

a) Water inflow facing the pumps:

- centred, wide see sub-clause 3.7.1.3;
- centred, narrow, single: see sub-clause 3.7.1.4;
- centred, narrow, multiple: see sub-clause 3.7.1.5;
- off-centre, narrow, single: see sub-clause 3.7.1.6.

b) Water lateral inflow relative to pumps:

- centred: see sub-clause 3.7.1.7;
- off-centre: see sub-clause 3.7.1.8.

3.7.1.3 Water inflow facing pumps, centred, wide

a) Simultaneous operation of all the pumps (see Figure 11):

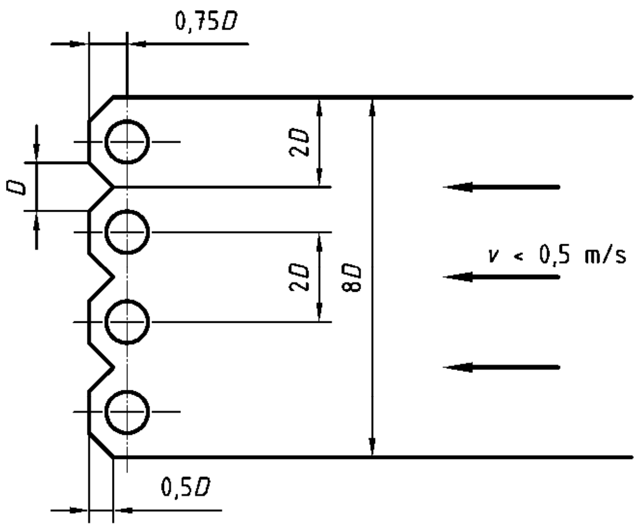
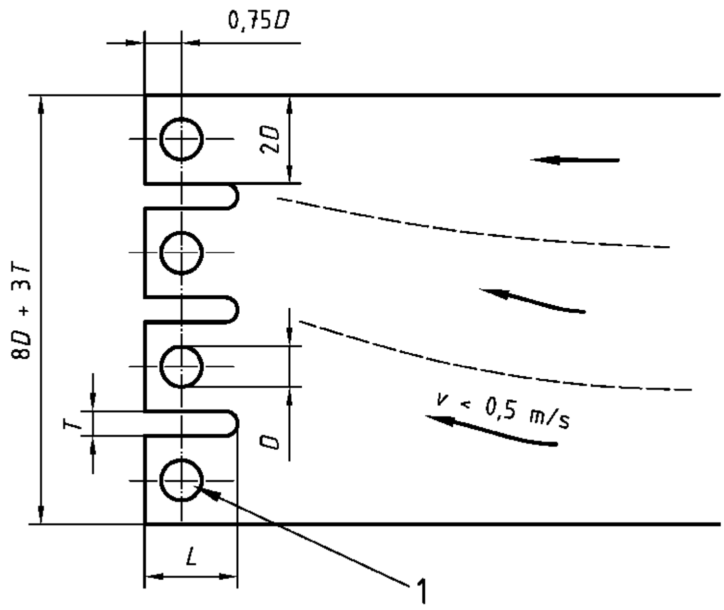


Figure 11 — All pumps in operation

b) Operations with pumps switched off (see Figure 12):



Key

1 Pump switched off

Figure 12 — One or several pumps switched off

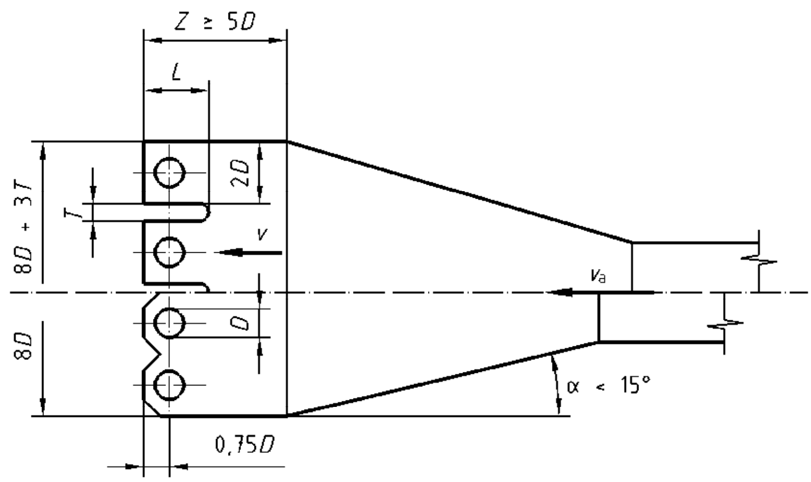
The length *L* of the low walls should be equal to or greater than 2 *D* and depends on the number of pumps that operate simultaneously.

The ends of the separating low walls should be rounded if their thickness permits.

NOTE *L* = 2 *D* may be acceptable when all the pumps operate simultaneously and may be increased up to 4 *D* or more when one or several pumps are switched off.

3.7.1.4 Water inflow facing pumps, centred, narrow, single

Figure 13 shows the recommended shapes and dimensions of the feed intake.



Key

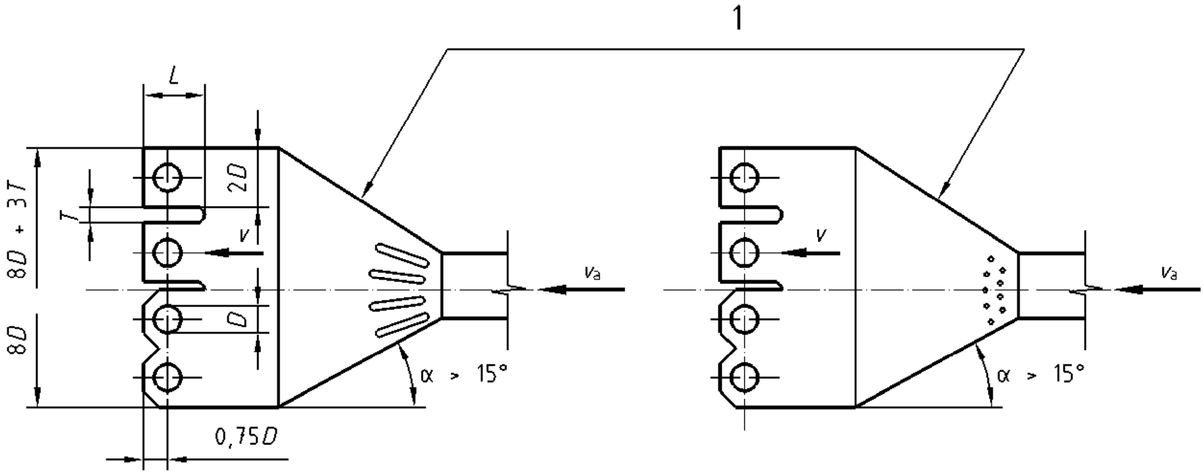
v Velocity close to the pump

v_a Velocity at the water inflow

Figure 13 — Recommended dimensions of the feed intake (α 〈 15°)

Velocities v (close to the pump) and v_a (at the inflow) should comply with the general principles defined in sub-clause 2.2.

If the angle α cannot be specified as a value less than 15°, distribution structures (partitions or posts) may be fitted (see Figure 14).



Key

1 Distribution structures

Figure 14 — Recommended configurations of the distribution structures (α 〉 15°)

NOTE Figures 13 and 14 are divided up into 2 half views:

— the top half views include low walls which correspond to operation with pump switched off;

— the bottom half views do not include low walls and correspond to simultaneous operation of all the pumps.

See sub-clause 3.7.1.3 for details of the length L of the low walls.

In addition, the configurations shown in Figure 15 are highly inadvisable.

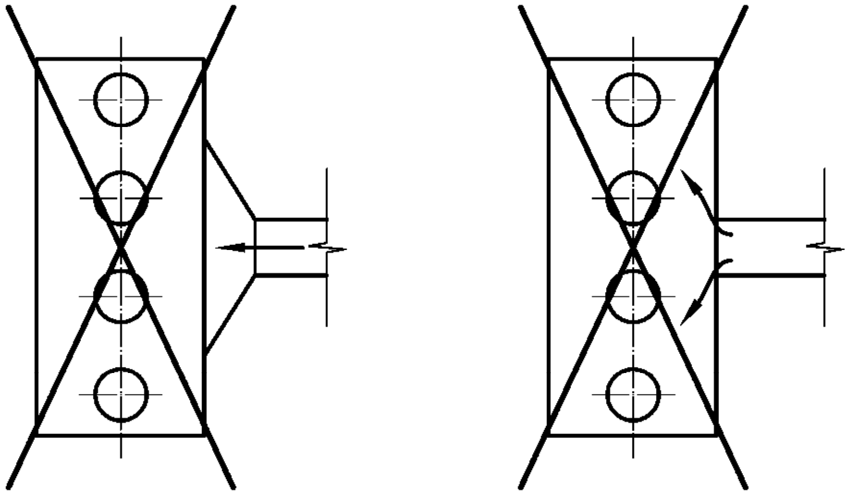
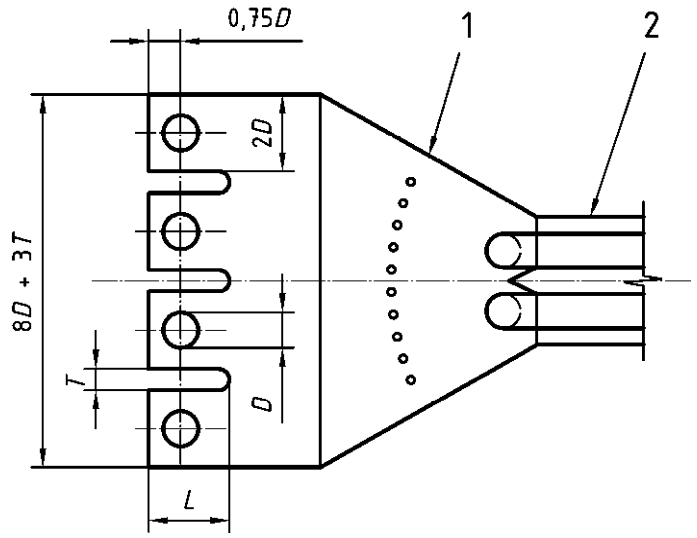


Figure 15 — Highly inadvisable configurations

3.7.1.5 Water inflow facing pumps, centred, narrow, multiple

a) Case in which all inflows operating (see Figure 16):



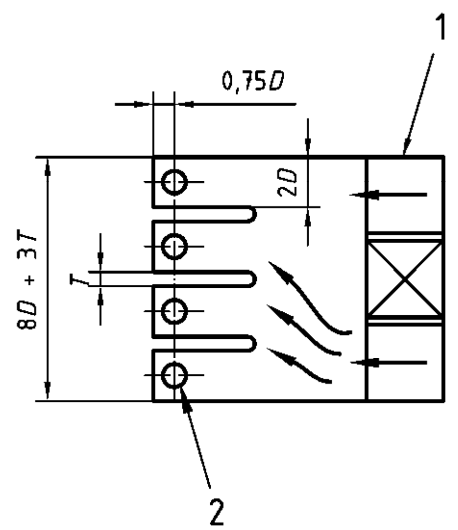
Key

1 Distribution posts

2 Manifolds or siphons

Figure 16 — All water inflows and pumps in operation

b) Case in which some inflows and some pumps are not operating (see Figure 17):



Key

1 Filters mounted in parallel

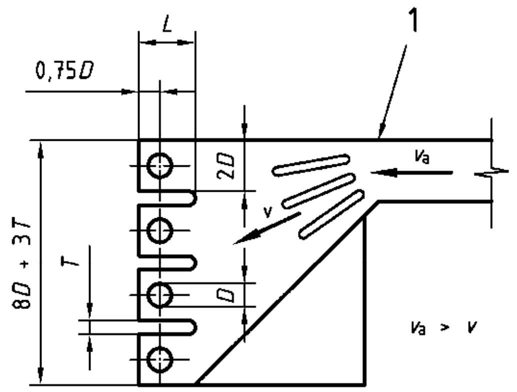
2 Pumps switched off

Figure 17 — Some water inflows and pumps not in operation

NOTE See sub-clause 3.7.1.3 for details of length *L* of the low walls.

3.7.1.6 Water inflow facing pumps, off-centre, narrow and single

Figure 18 shows a recommended configuration.



Key

1 Distribution structure

Figure 18 — Recommended configuration of the feed intake

NOTE 1 In general, it is a typical case, where it is advised to use a reduced model.

NOTE 2 See sub-clause 3.7.1.3 for details of length *L* of the low walls.

Figure 19 shows a highly inadvisable configuration.

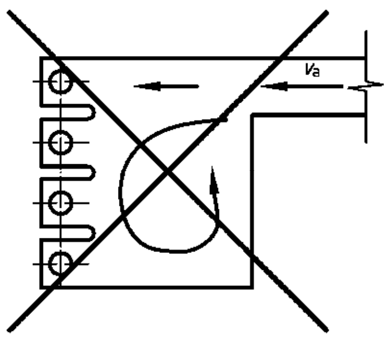


Figure 19 — Highly inadvisable configuration

3.7.1.7 Water lateral inflow, centred

The dimensions recommended for lateral inflow, centred are shown (see Figure 20).

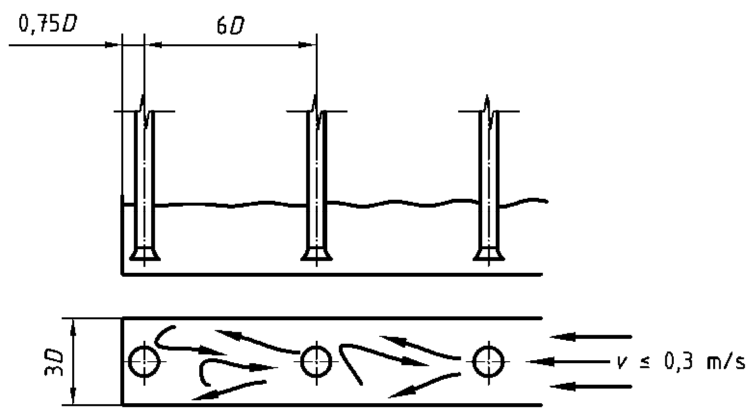


Figure 20 — Recommended dimensions for water lateral inflow, centred

In this configuration, the width of the water inflows should at least equal to 3 *D* (see Figure 21).

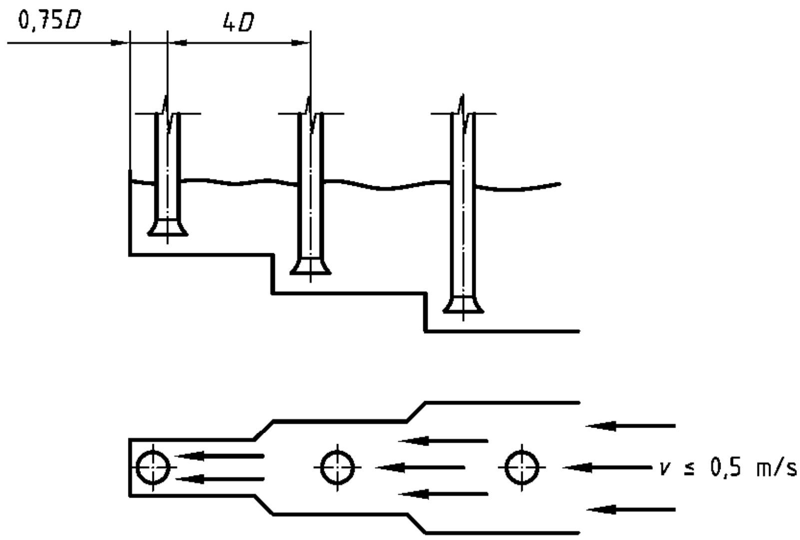


Figure 21 — Alternative configuration

3.7.1.8 Water lateral inflow, off-centre

In every case, this configuration is not recommended unless dimension A is sufficiently large (approximately 8 *D*) to minimise any swirl at the pump suction inlet (see Figure 22).

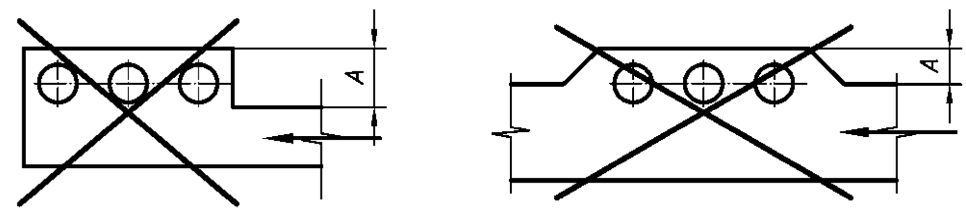
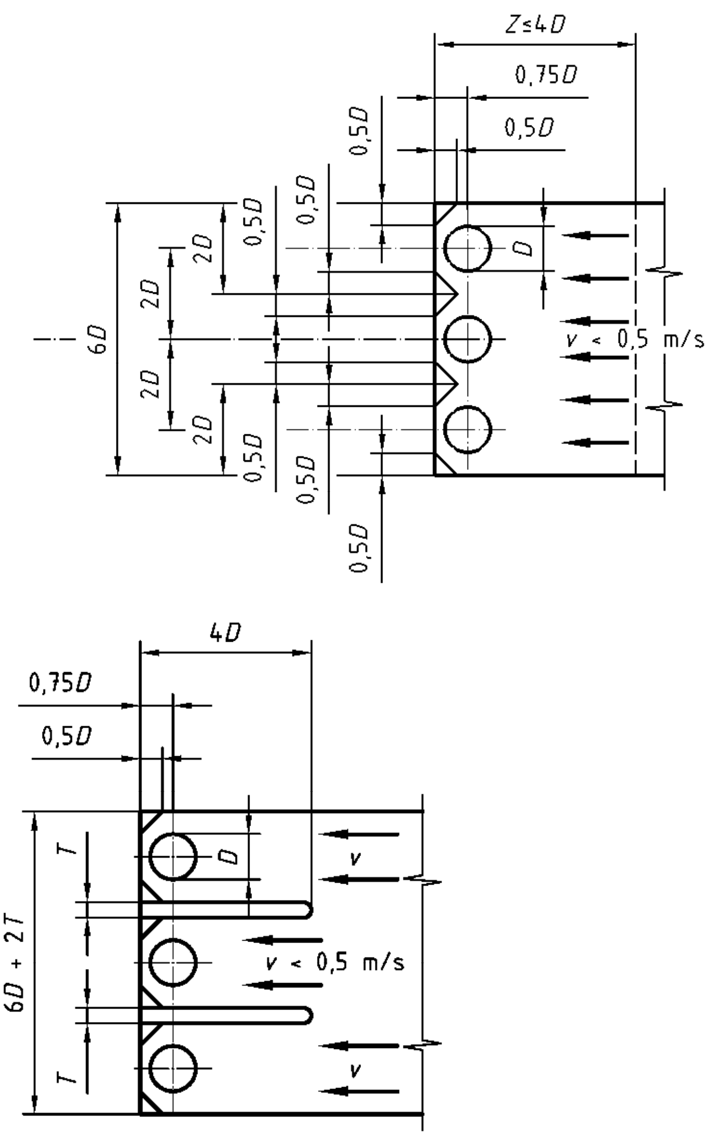


Figure 22 — Not recommended configurations

3.7.2 Immediate environment of the pump

3.7.2.1 Water inflow at suction inlet

The configuration recommended close to the pump is shown in Figure 23.



23a) Uniform current – Common sump **23b) Individually separated sump**

Key

Z Dimension between the grid and the bottom

Figure 23 — Recommended configuration close to the pump

The water inflow at a pump suction inlet should not be disturbed by the wake of another pump.

Under ideal conditions, the water inflow should be such that, under conditions of maximum flow rate, the velocity of the liquid in the approach channel near the intake is less than 0,5 m/s.

NOTE See sub-clause 2.1 for details in case of cloudy waters.

The recommended dimensions of the sump are shown Figure 23.

If several pumps are installed, it is always advantageous to separate the water inflows, e.g. by low walls (see Figure 23). In this case, the minimum height of the walls should be calculated in such a manner that the tops of the walls should be situated at a level corresponding to a submergence (*S*) of 1,5 *D*.

NOTE In the case of pumps having a low flow rate, low walls may be replaced by gratings made of expanded metal.

For the length *L* of the walls, see 3.7.1.3.

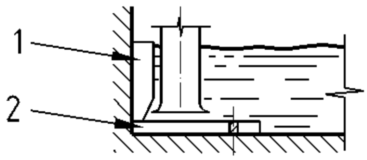
3.7.2.2 Special devices

3.7.2.2.1 Anti-swirl or anti-vortex devices

Anti-swirl or anti-vortex devices may include:

- low walls intended to create individually separated sumps (see Figure 23 and 3.7.1.3);
- gratings (see sub-clause 3.7.2.1);
- walls or ribs (straight or crossed) under the suction inlet and at the rear of the inlet piping.

  Example for anti-vortex wall is shown in Figure 24.



Key

1 Wall splitter plate

3 Floor wall splitter plate under suction inlet

Figure 24 — Example for anti-vortex wall

Ant-swirl or anti-vortex devices may also include:

- Internal or external ribs of the strainer (see sub-clause 3.6);
- Jacket around the bellmouth with internal radial ribs (see Figure 25).

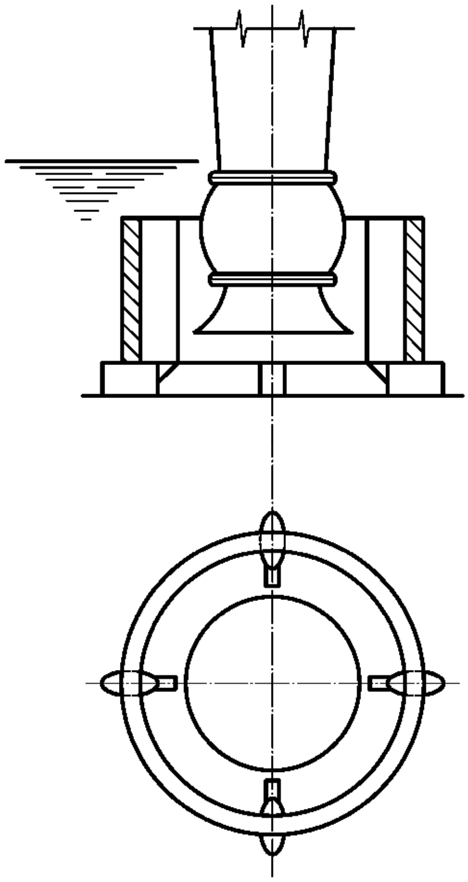


Figure 25 — Jacket around the bellmouth with internal radial ribs

3.7.2.2.2 Other special devices

Other special devices may be used:

— cone: this device prevents the accumulation of particles underneath the suction inlet (see Figure 26).

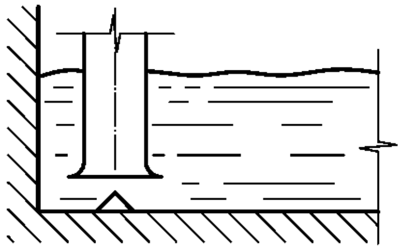


Figure 26 — Cone

— other very special anti-vortex devices may be used (floats, spheres, etc.).

3.8 Case of pumping plant with vertical suction inlet and flow rate less than 50 m³/h

It is always advisable to use a bellmouth, however, in the case of a vertical suction inlet involving a pump having a flow rate less than 50 m^3/h, a suction without bellmouth should be envisaged.

In this configuration, the following conditions are recommended:

— the velocity at maximum rate of flow in the piping immersed in the sump should be less than 1 m/s;

— the submergence value (*S*) should be at least equal to the diameter of the entrance to the piping immersed in the pool and should never be less than 100 mm.

4 Plant with intake with top suction inlet

Installations having a top suction inlet are shown diagrammatically (see Figures 27 and 28).

a) Intake in tank (see Figure 27)

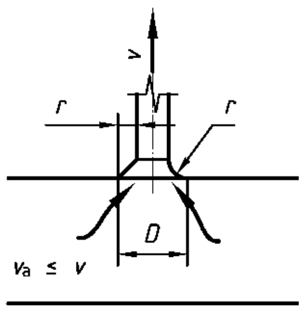


Figure 27 — Intake in tank

b) Multiple intake in manifold or duct (see Figure 28):

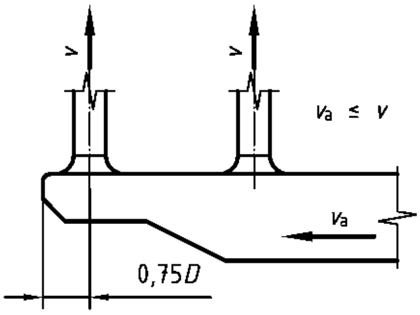


Figure 28 — Multiple intake

The presence of a bellmouth on the intake is recommended in these configurations. The shapes and dimensions of the bellmouth are those defined in sub-clause 3.2 in this document.

Nevertheless, a truncated connection having a height 0,25 *D* or a radius equal to roughly 0,25 *D* is acceptable.

Connecting the intake piping as shown in Figure 29 is not recommended.

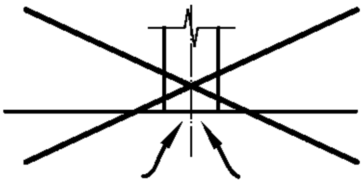
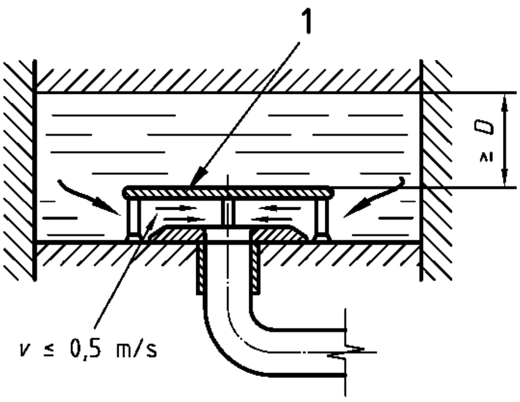


Figure 29 — Not recommended intake

5 Plant with intake with floor suction inlet

Installations with a floor suction inlet are shown diagrammatically (Figure 30).



Key

1 Solid horizontal anti-vortex plate

Figure 30 — Recommended configuration for bottom intake

5.1 Bellmouth

In this configuration, the presence of a bellmouth on the suction is necessary. Its shapes and dimensions are those defined in sub-clause 3.2 in this document.

5.2 Submergence of horizontal plate

This submergence should be at least equal to 1 *D* (*D* within the meaning of sub-clause 3.2 in this document) with a minimum of 0,50 m.

5.3 Special anti-vortex devices

Following special anti-vortex devices may be used:

— horizontal plates above the intake (see Figure 31);

— the water inflow to the suction inlet is made horizontal and this reduces the developments of any vortex;

— ribs.

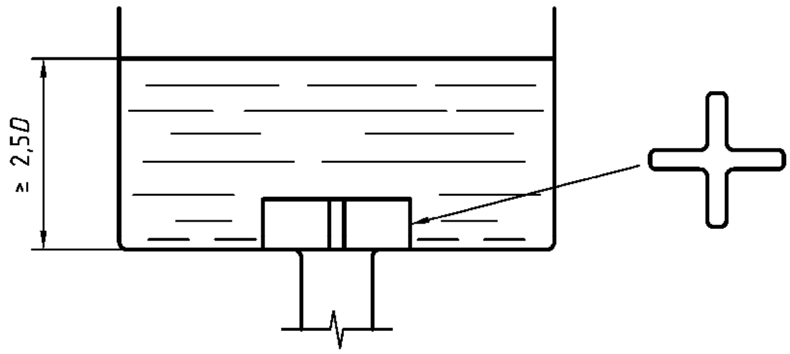


Figure 31 — Anti-vortex-device

In this configuration, the submergence of the suction inlet should be at least equal to 2,5 *D*.

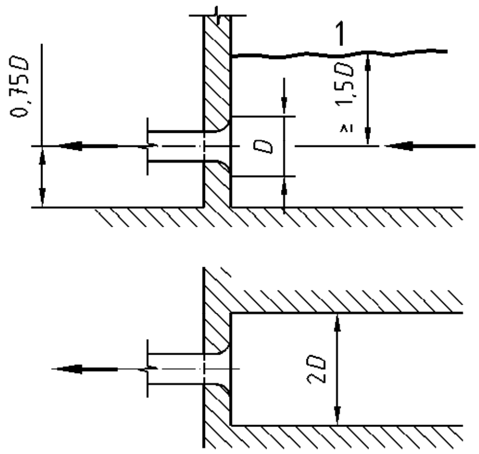
6 Plant with intake with wall suction inlet

Installations with a wall suction inlet are shown diagrammatically (Figures 32, 33, 34, 35 and 36).

6.1 Shape and position of suction inlet

The presence of a bellmouth or tapered suction is not necessary; depending on the situation the intake may be:

a) Included a bellmouth having shapes and dimensions which comply with those indicated in sub-clause 3.2 in this document (see Figure 32).



Key

1 Minimum level

Figure 32 — Intake with bellmouth

b) consisted of a tube which is cut in bevel (Figure 33);

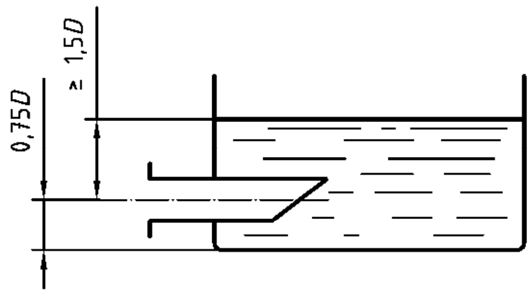


Figure 33 — Intake with tube cuts in bevel

c) connected to the wall by a radius (*r*) at least equal to 0,1 D_o (Figure 34).

NOTE 1 A value equal to 0,25 D_o may be considered as an optimum.

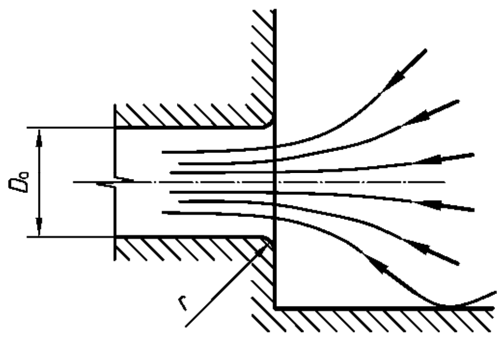


Figure 34 — Intake connected to the wall by a radius

NOTE 2 In this case, the submergence conditions and height between the axis of the inlet and the floor are the same as those in Figure 32.

d) Include an elbow and a downward-facing bellmouth (Figure 35) or a tapered suction (Figure 36).

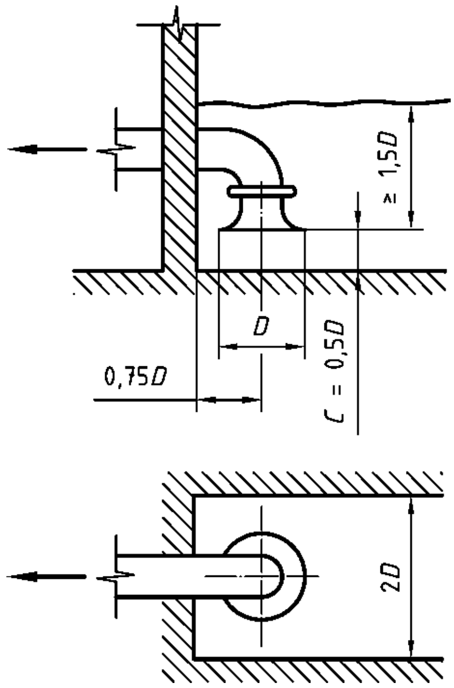


Figure 35 — Intake with elbow and bellmouth

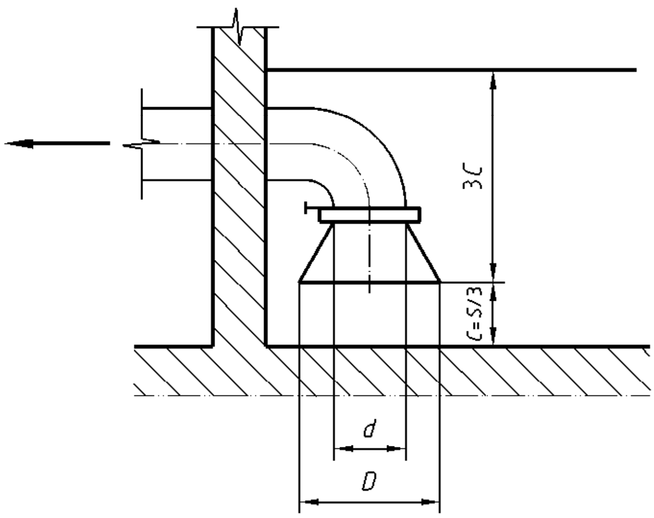


Figure 36 — Intake with elbow and tapered suction

6.2 Submergence

The minimum submergence values as a function of the shape and position of the suction inlet are shown as a function of diameter *D* (within the meaning of sub-clause 3.2 in this document) in Figures 32 to 38. Submergence should not be less than 0,50 m.

6.3 Special anti-vortex devices

Following special anti-vortex devices may be used:

— horizontal plate above intake (see Figure 37);

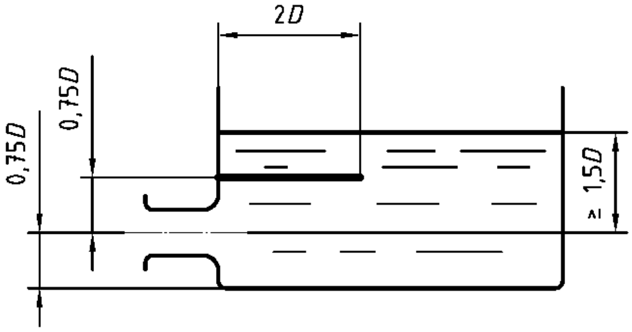


Figure 37 — Horizontal plate above intake

— vertical plate along the axis of the intake (see Figure 38).

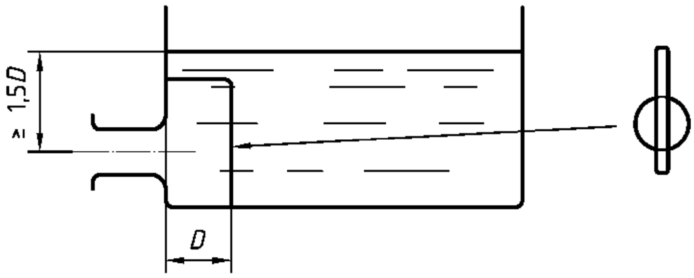


Figure 38 — Vertical plate along the axis of intake

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