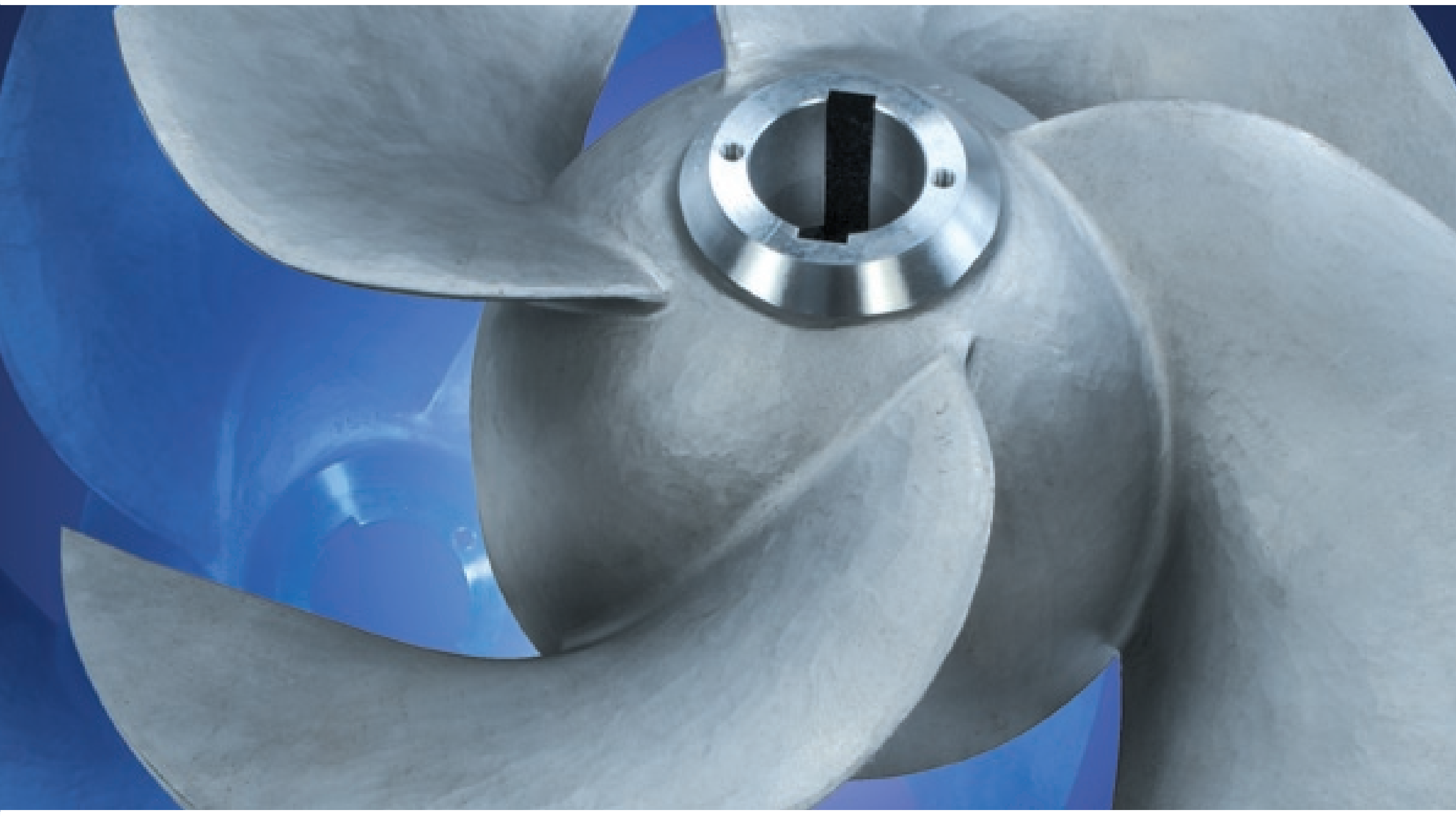
Planning information
Amacan® submersible pumps in discharge tubes



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Introduction

In the fields of water and waste water technology, submersible pumps represent a viable economic and technical alternative to conventional, dry-installed pumps. In particular, they offer a number of handling advantages during maintenance and installation work, a factor of increasing importance in times of general staff cutbacks by operating companies.

In the special case of submersible motor pumps in discharge tubes, there are significant design advantages to be considered. For example, though they have the same hydraulic capacity as tubular casing pumps, submersible motor pumps are a good deal more compact in dimension (no long shaft assemblies, no additional bearing locations in the discharge tube). This means additional buildings to accommodate the electric motor are not required, as the submersible pump and integral motor are installed in the discharge tube.

More and more operators are being won over by these advantages – KSB's Amacan pumps work in irrigation and drainage pumping systems, waterworks, sewage treatment plants, power stations, industrial water supply, water pollution and flood control. They handle raw and clean water (groundwater, storm water, river water) as well as waste water and activated sludge.

With discharge tube pumps the construction and design of the periphery – the pump station as a whole – are crucial in ensuring economical and reliable operation, more so than is the case with other pumps.

In addition to the selection of pump hydraulics, the structural requirements will also be examined in close detail in the following pages, along with the planning of the pump installation and the design of the pump sump. Finally, this brochure will consider relevant aspects of electrical equipment.

The "Amacan® Submersible Pumps in Discharge Tubes" brochure is primarily aimed at pump station designers and operators in the water and waste water engineering sectors.

1.
The Amacan series

1.1
Impeller types and performance ranges

Wherever higher flow rates have to be handled, submersible pumps in discharge tube design have proved their worth in a wide range of applications. These submersible motor pumps can be optionally fitted with three different impeller types enabling them to deal with a wide variety of fluids – from grey water, which is reasonably clean, right up to waste water or activated sludge. Selecting the right impeller type for a particular application will depend upon the nature of the pumped fluid and the pumping task. The following selection charts provide information on the performance of the different impeller types and help designers to choose the right Amacan pump type and size for the pumping task in question. When making a selection, it is not only important to be aware of which impeller type is the right match for the pumped fluid, in some cases additional requirements in the design of the pump station and the choice of the technical equipment must be observed for certain impeller types.

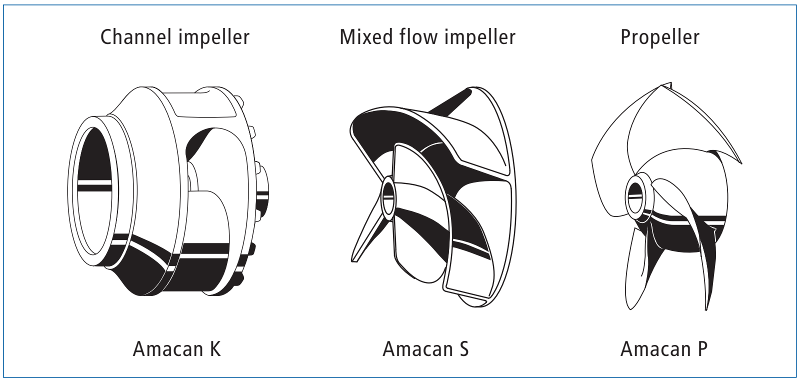


Fig. 1.1-a: Available impeller types for Amacan pumps

Fluids pumped	Notes and Recommendations
Waste water	- Check the free passage through the impeller - Pre-cleaned via a sreen or weir
River water	- Pre-cleaned via sreen or shingle trap
Storm water / waste water	- Check the free passage through the impeller - Pre-cleaned via a sreen or weir - With a propeller a special casing wear ring may be necessary
Activated sludge	- Max. 1% dry solids content
Seawater	- Check possible material combinations or fit anodes with six-monthly check-ups

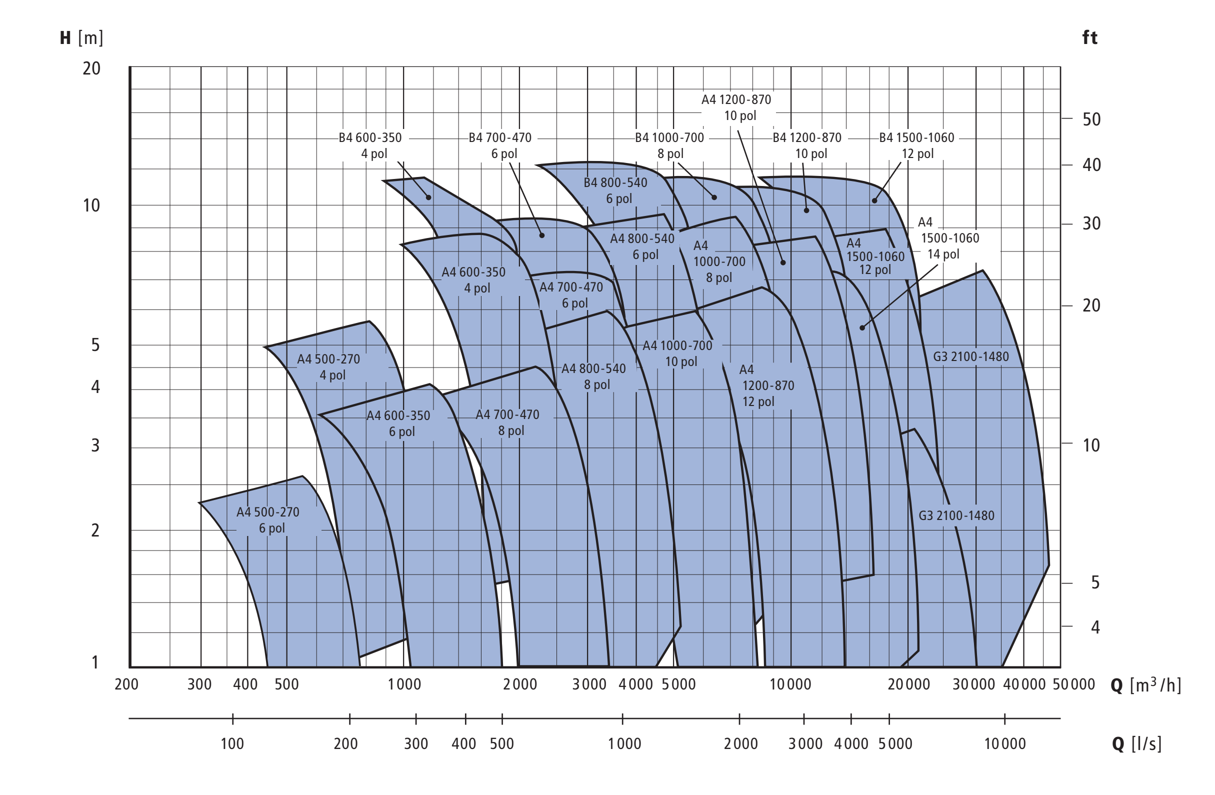


Fig. 1.1-b: Selection chart Amacan P pumps (50 Hz)

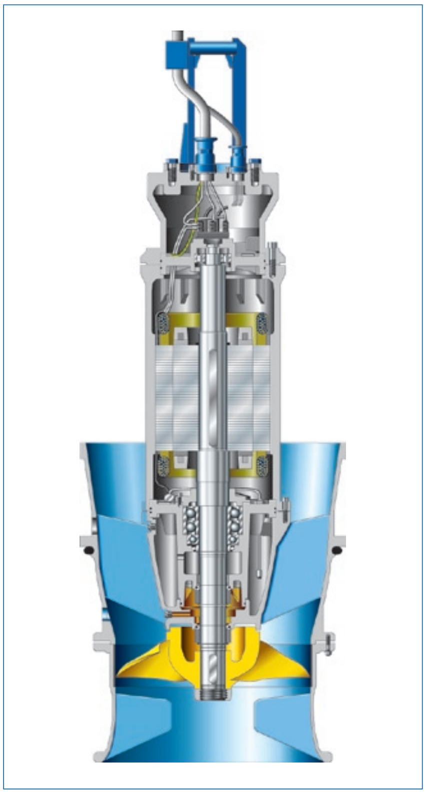


Fig. 1.1-c: Amacan P

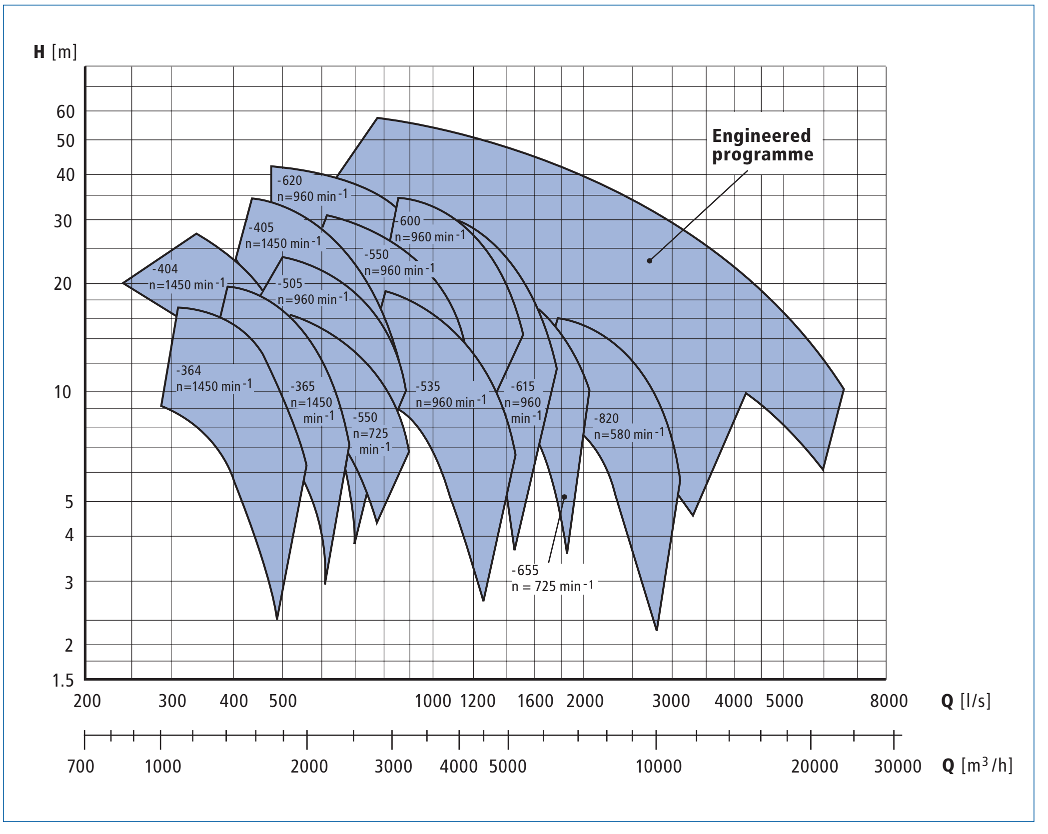


Fig. 1.1-d: Selection chart Amacan S (50 Hz)

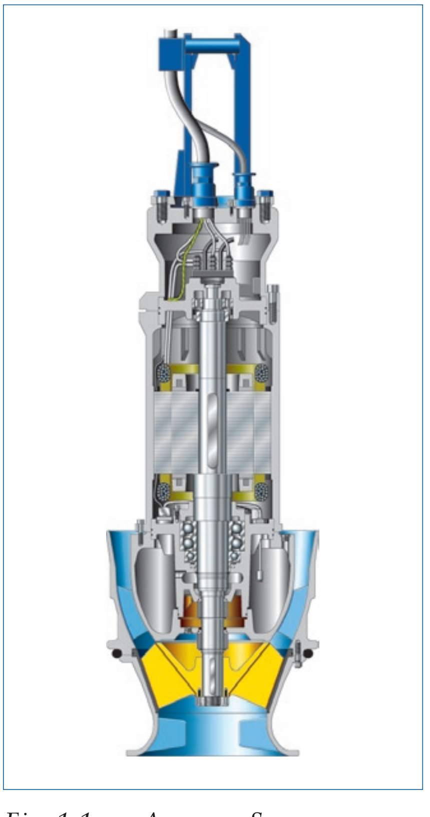


Fig. 1.1-e: Amacan S

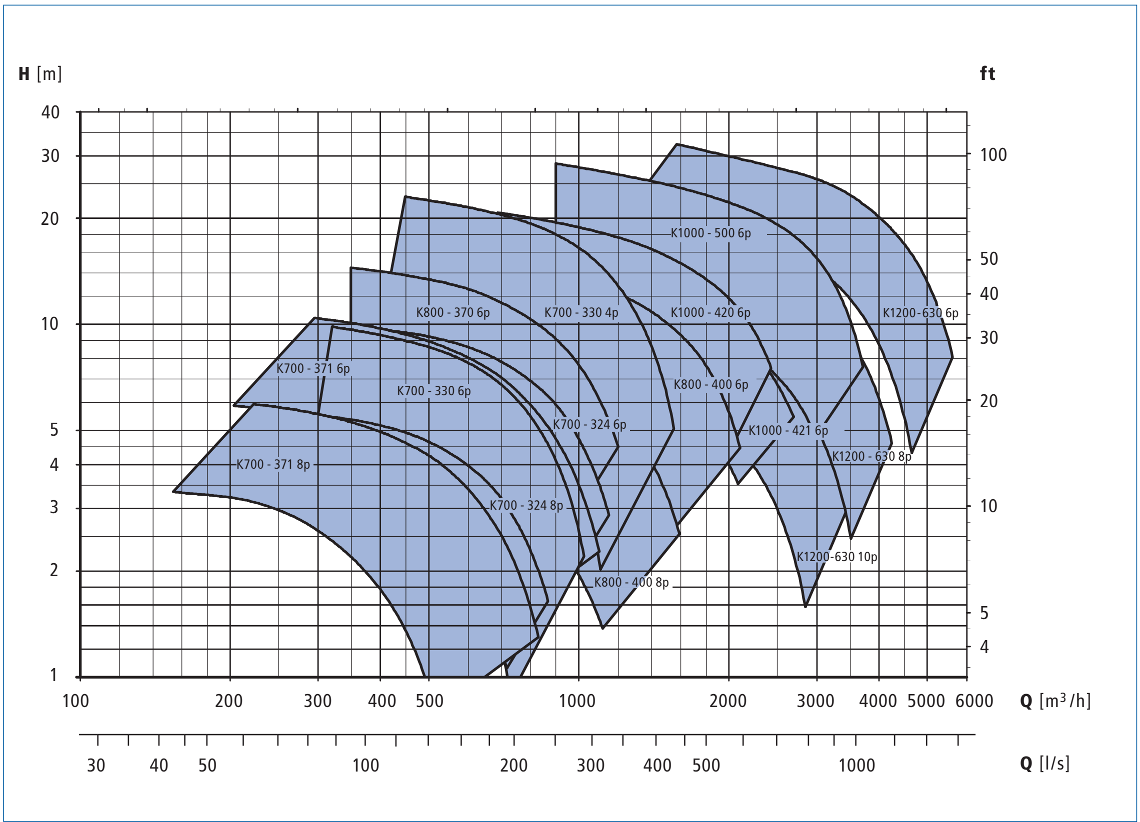


Fig. 1.1-f: Selection chart Amacan K (50 Hz)

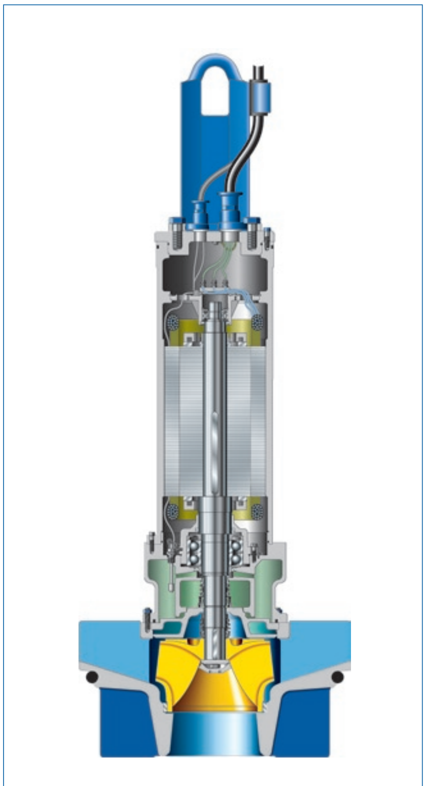


Fig. 1.1-g: Amacan K

The design configuration of modern submersible motor pumps installed in discharge tubes has a number of advantages over that of conventional tubular casing pumps. For example, although these pumps have the same hydraulic capacity (impeller) they are considerably more compactly dimensioned (no long shaft assemblies, no additional bearing locations in the discharge tube). The handling of a submersible pump is significantly more straightforward, simplifying in particular maintenance and installation. In addition, buildings to accommodate electric motors or ventilation equipment are not required. The drive is an integral part of the submersible pump and hence is contained in the discharge tube.

For assembly and maintenance work on conventional pumps it is generally common practice to install large lifting equipment, the size of which will depend on the on-site installation depth. This lifting equipment represents a major investment even though it is only periodically used for repair work or pump installation / removal. In contrast, to carry out the same tasks the Amacan submersible motor pumps only require mobile cranes, which are far more cost effective. In order to fully exploit this advantage, appropriate access must be factored in at the planning stage.

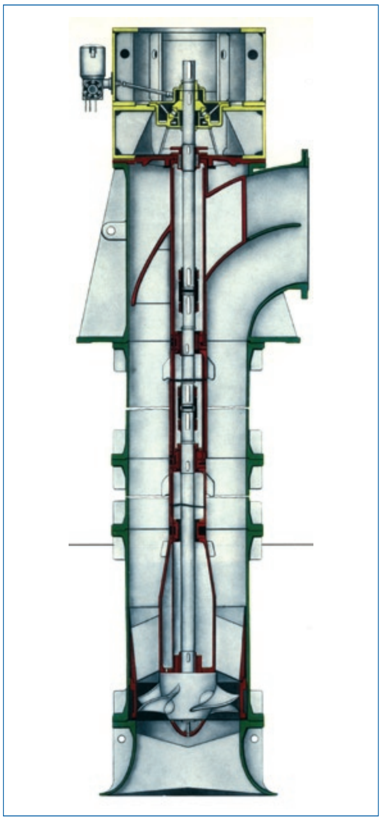


Fig. 1.1-h: Conventional tubular casing pump

Fig. 1.1-i: Installation of submersible motor pump with a mobile crane

Fig. 1.1-j: Pump station with building

1.2 Calculation of operating points

With Amacan pumps, the manometric head required for a certain flow rate will be calculated using the same approach as with any centrifugal pump.

The documented pump characteristic curves already include the internal losses between the impeller inlet and 0.5 m behind the motor. Inlet and discharge tube losses before and after these points and head losses through flow deflection, fittings (valves etc.) and the outlet are to be taken into account as the dynamic head component.

The system curve is composed of the static head component (difference in water levels) and the dynamic head component (friction loss in the pipes and fittings):

$$H_{tot} = H_{stat} + H_{dyn}$$

$$H_{dyn} = \sum_{i=1}^{i=n} \lambda_i \times \frac{L_i}{d_i} \times \frac{v_i^2}{2g} + \sum_{i=1}^{i=n} \xi_i \times \frac{v_i^2}{2g}$$

As propeller pumps in particular often generate only a low head, the loss of head at the pipe outlet (a check valve is often installed!) must be considered in the calculation. When establishing the static head component, the maximum differences between the suction and discharge side liquid levels of the pump station are of interest, especially in low-lift pump stations. During pump selection, these maximum water levels should not lead to unacceptably low or high discharge heads, as this would mean the pump is operating to the left of Q_{min} or to the right of Q_{max}.

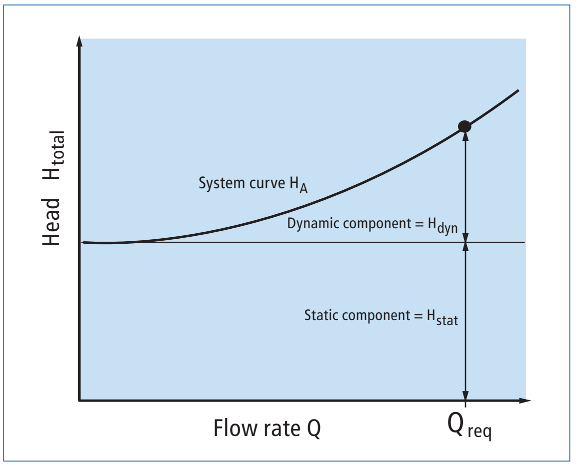


Fig. 1.2-a: Example of a system curve [H = f(Q)]

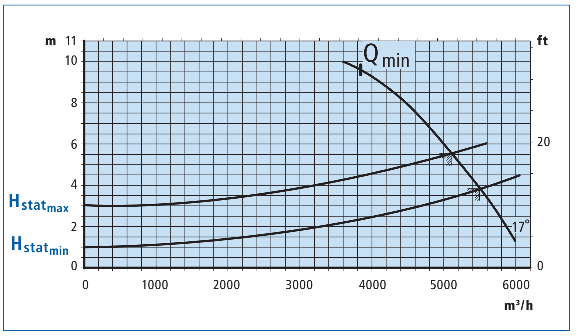


Fig. 1.2-b: Ilustration of possible water levels

i indicates the considered section of the pipe with the pipe length L_i, the pipe diameter d_i and the friction loss coefficient ξ_i as well as the flow velocity v_i in the pipe section.

If some loss coefficients ξ_i are unknown when calculating the dynamic head component, then the literature given at the end of the brochure may be of assistance (e. g. Selecting Centrifugal Pumps [1]).

When selecting pumps installed in discharge tubes particular attention must be paid to the difference in water levels, as the minimum water level Wlmin in the structure must not be lowered below the water level t_1 required for the volume flow rate of the pump; this is the only way to avoid surface vortices. The necessary depth t_{ps} of the pump station building can also be calculated using this water level.

The minimum water level is a function of the volume flow rate required of the pump [$t_1 = f(Q)$] and also of the intake chamber design (see sections 2.2.1 to 2.2.3).

In addition to the fluid level above the impeller (dependent on size) and the water level limit to prevent air-entraining vortices (dependent on flow rate) – both are illustrated in Fig. 1.2-c – the NSPH value of the pump at the operating point is of importance for the required water level t_1. The condition to be fulfilled is as follows:

$$NPSH_{available} > NPSH_{required} + 1.0\,m \text{ safety allowance}$$

If this condition is not fulfilled, the value for t_1 must be increased by the value of the difference

$$t_{ps} = wl_{min} - t_1$$

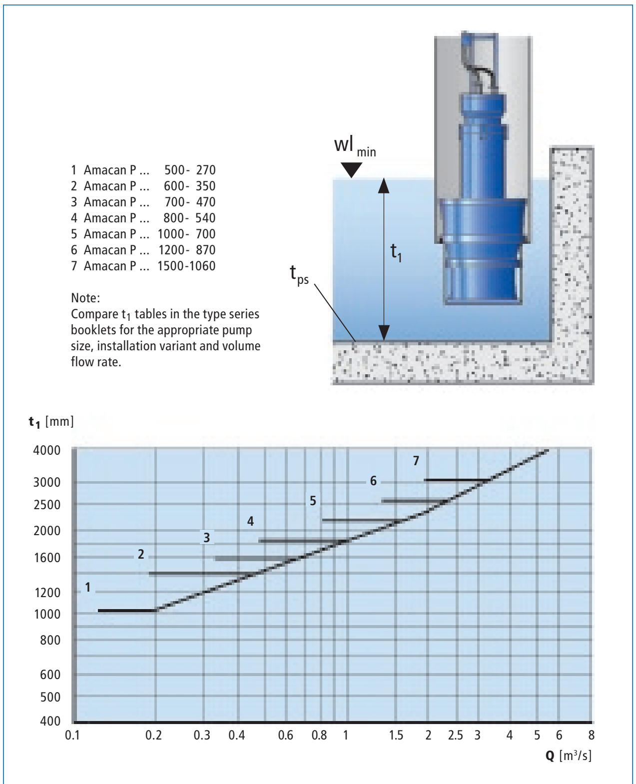


Fig. 1.2-c: Calculation of the minimum water level t_1 for Amacan P (for Amacan K and Amacan S refer to the appropriate type series booklet)

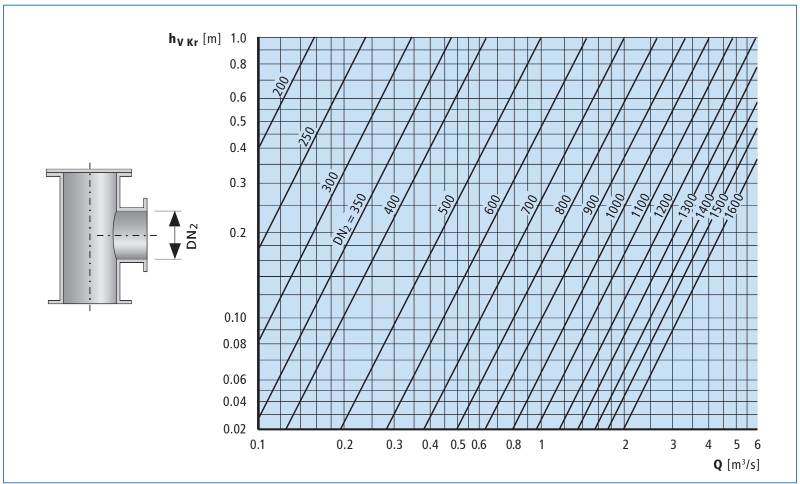


Fig. 1.2-d: Determining the pressure loss in a discharge elbow outlet

Should the discharge tube be open at the top (free overflow from the tube, for instance) then the overflow head h_{overfl} must be taken into account when calculating the total pump head H_{tot}.

If there is no other data available, then the overflow head h_{overfl} can be taken from the following diagram.

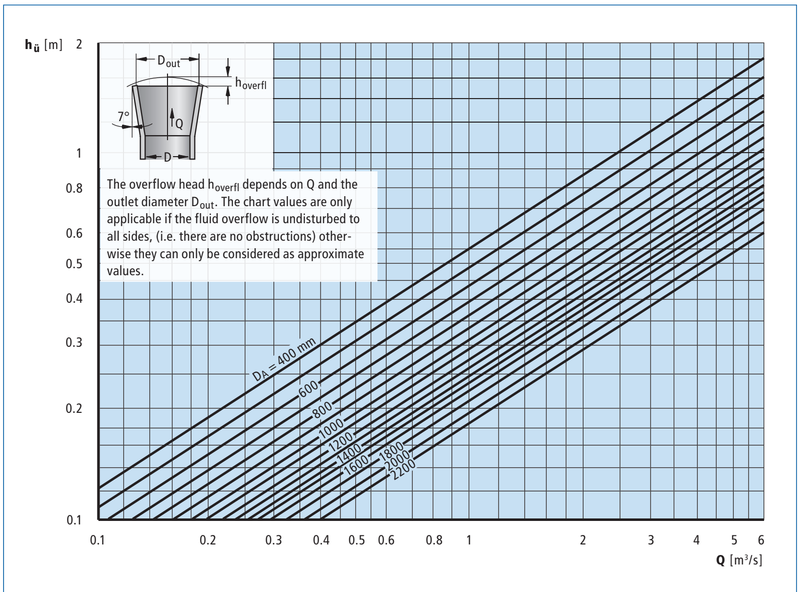
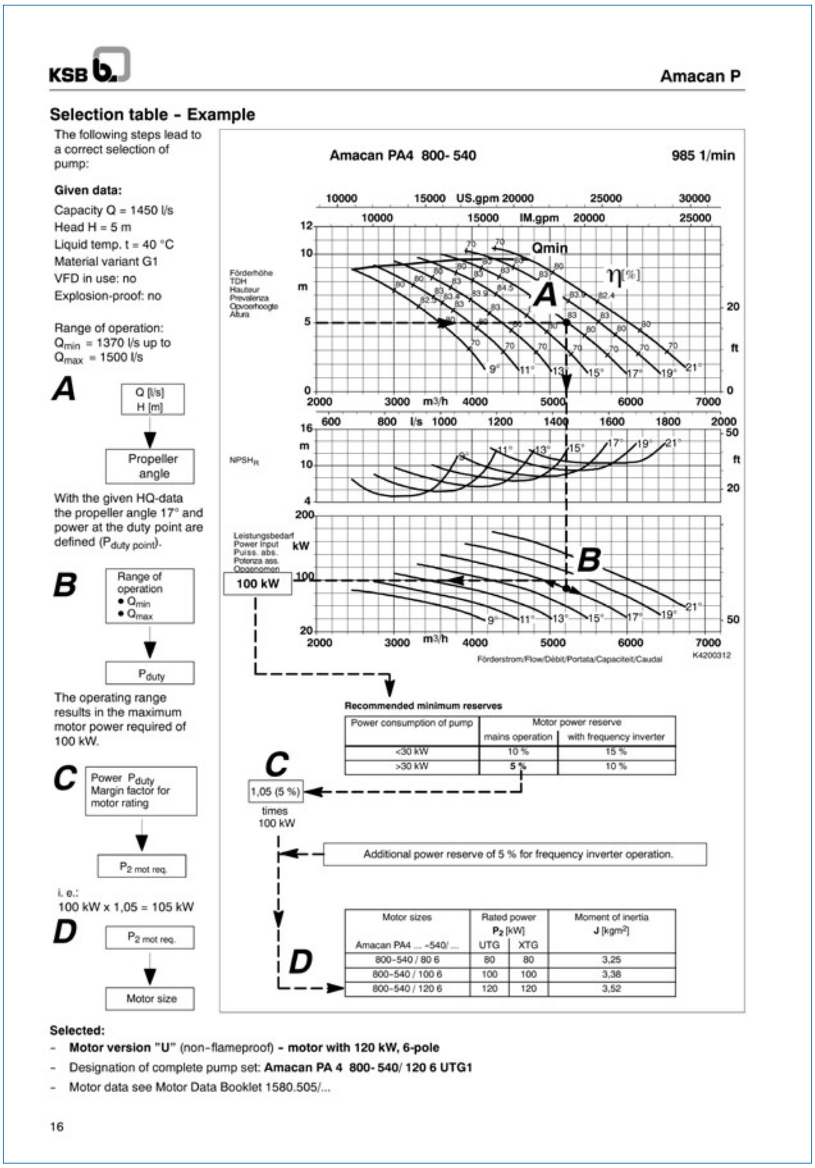


Fig. 1.2-e: Establishing the overflow head h_{overfl}


KSB

Amacan P

Selection table - Example

The following steps lead to a correct selection of pump:

Given data:

Capacity Q = 1450 l/s
Head H = 5 m
Liquid temp. t = 40 °C
Material variant G1
VFD in use: no
Explosion-proof: no

Range of operation:
Q_{min} = 1370 l/s up to
Q_{max} = 1500 l/s

A

Q [l/s]
H [m]

Propeller angle

With the given HQ-data the propeller angle 17° and power at the duty point are defined ($P_{duty\ point}$).

B

Range of operation
• Q_{min}
• Q_{max}

P_{duty}

The operating range results in the maximum motor power required of 100 kW.

C

Power P_{duty}
Margin factor for motor rating

$P_{2\ mot\ req.}$

i. e.:
100 kW x 1,05 = 105 kW

D

$P_{2\ mot\ req.}$

Motor size

Recommended minimum reserves

Power consumption of pump	Motor power reserve	
	mains operation	with frequency inverter
<30 kW	10 %	15 %
>30 kW	5 %	10 %

C

1,05 (5 %) times 100 kW

Additional power reserve of 5 % for frequency inverter operation.

D

Motor sizes	Rated power P_2 [kW]		Moment of inertia J [kgm²]
Amacan PA4 ... -540/ ...	UTG	XTG	
800-540 / 80 6	80	80	3,25
800-540 / 100 6	100	100	3,38
800-540 / 120 6	120	120	3,52

Selected:

- **Motor version "U"** (non-flameproof) **- motor with 120 kW, 6-pole**
- Designation of complete pump set: **Amacan PA 4 800- 540/ 120 6 UTG1**
- Motor data see Motor Data Booklet 1580.505/...

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Fig. 1.2-f: Selection principle for Amacan pumps according to the type series booklet

After the system curve has been determined, this should always be plotted together with the pump characteristic curve in order to check the operating points (curve intersections). In this way, the designer can ensure that no operating conditions outside the permissible section of the characteristic curve arise.

1.3 Pump drive with frequency inverter

Basically all pump motors can be used with frequency inverters. The characteristic curves of Amacan pumps installed in discharge tubes can be calculated using the affinity laws, as is also the case with centrifugal pumps.

$$\frac{Q_2}{Q_1} = \frac{n_2}{n_1} \qquad \frac{H_2}{H_1} = \left(\frac{n_2}{n_1}\right)^2 \qquad \frac{P_2}{P_1} = \left(\frac{n_2}{n_1}\right)^3$$

n_1 Original speed
n_2 New or proposed speed

In principle, the aim of speed control is to optimally match the pump's operating point to the actual system requirements. As mentioned above, three impeller types with different characteristics are available for this submersible motor pump type in discharge tube design.

For each of these impeller types it is always important to check the control range. This includes establishing the system curve(s) with $H_{stat,min}$ and $H_{stat,max}$. The following must also be checked:

(a) the flow velocity in the discharge tube must be adequate to assure the pumping of fibres and solids that might have to be handled (v_{mean} > 2 m/s), and
(b) the circumferential speed on the impeller's outside diameter (not less than 15 m/s). When speed is changed, and taking into account variable water levels, it is vital that no operating point lies to the left of the permissible operating limit. This means: The limit speeds must be matched to comply with the actual water levels.

If two or more pumps with a common discharge pipe are run via frequency inverters, it is recommended that all pumps operate at the same speed. This is to avoid the pumps blocking each other in the low-flow operating range (with the negative effects on impeller, shaft seal and bearings this can have).

If checking the minimum flow velocity poses problems, under some circumstances (depending on the fluid pumped) it is possible to work with slightly reduced values. To ensure the pumps are not clogged, an automatic control can increase the speed for a short period and at set time intervals to activate flushing. After this procedure the pumps' speed can be lowered, automatically again, to the original level.

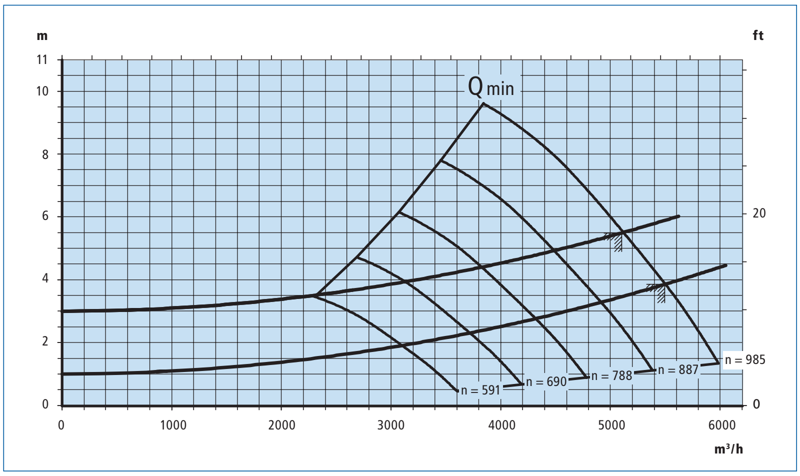


Fig 1.3-a: Amacan P 800 - 540 A 4 with speed curves

2. Pump station design

2.1 General

The structural requirements of a pump station are largely determined by how it is to be used. Alongside purely structural and mechanical requirements, consideration must also be given to hydraulic (fluid dynamics) aspects in the planning and execution of the construction work. The first part of the hydraulic areas to be designed is the inlet upstream of the pump station, followed by the intake chamber upstream of the pump(s), parts of which may require a special shape, and finally the discharge pipe or discharge system.

The pump manufacturer's aim is to specify in the product's technical documentation the dimensions (e.g. geometry of the building) required for the installation of the centrifugal pumps. The reference values provided here are essential for the planning process, in particular for establishing the main dimensions of the pump station. The successful planning of a pump station is a complex task which encompasses questions on how to design the area between the intake and the pump(s) as well as the specification for the minimum spacing between the pumps or, in some cases, the dimensions to be observed for any necessary intake chambers.

If the requirements regarding intake chamber dimensions, minimum water levels or the geometry of hydraulic areas within the pump station are not met, i. e. deviations occur during the planning or construction phase, proper functioning of the entire station can no longer be guaranteed. In such a case, it is irrelevant whether these problems are caused by single or multiple deviations.
The conditions for pump operation are not met due to these modifications or deviations and the problems arising as a result are reflected in either the centrifugal pump's operating behaviour or its performance. If the pump manufacturer's specifications on the hydraulic and mechanical design aspects of the pump station are taken into account in the overall layout early enough, malfunctions such as not achieving the required performance data and operating troubles can be eliminated.

According to Prosser [6], the criteria for unsatisfactory pump station design can be clearly defined and assessed. Poorly performing pump sumps can arise from the following:

1. Undersized control gates and valves
2. Abrupt changes in flow direction (e.g. sharp corners)
3. Submerged high velocity flow areas (e.g. diffusers with too large an angle of divergence)
4. Steep slope
5. Weirs with no provision for dissipating the energy of the falling fluid
6. Blunt pillars, piers and guide vanes
7. Any design, or mode of operation, which leads to asymmetric distribution of the flow into the sump
8. Inlet to the sump above the water level.

Items 1, 2, 3, 6 and 7 may cause swirls at the pump's inlet. Air-entraining surface and submerged vortices may form in extreme cases.
Items 4, 5 and 8 can produce aeration while items 3, 4 and 5 may cause unsteady flow conditions within the sump.

The purpose of a pump sump is to provide liquid storage and good flow conditions to the pump; therefore, it is important to avoid the following undesirable hydraulic conditions:

1. Jets, or high-velocity flows, discharging into stagnant or slowly moving fluids (as these form large, unsteady eddies as downstream wakes)
2. Areas of separated flow
3. High-velocity flows (v > 2 m/s)
4. Unsteady flow
5. Large surface waves
6. Free-falling fluids.

Observing the above criteria at the planning and construction phase is an important step towards creating a smoothly functioning pump station.

KSB's intake chamber geometries compare favourably with those specified by other pump manufacturers and internationally recognised research institutions in their literature. The intake chamber geometries suggested by KSB in their type series booklets and software tools allow smaller pump stations to be built and therefore lower building costs.

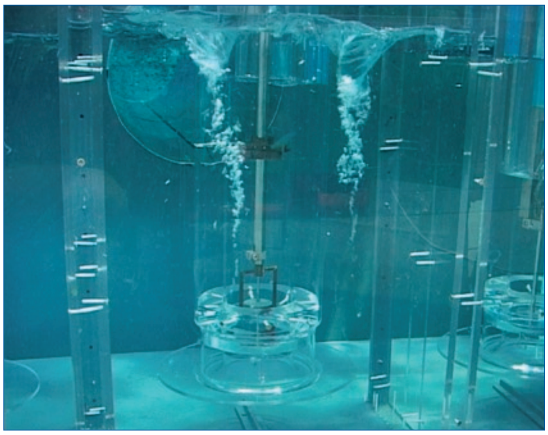


Fig. 2.1-a: Vortices developing as a result of unacceptable approach flows into the chamber – jet directly impinging on discharge tube

2.2
Pump installation planning

After all hydraulic aspects regarding the distribution of the volume flow have been considered and the appropriate pump size chosen, the geometry of the intake chamber must be determined.

Thanks to a flexible discharge tube design, Amacan pumps offer a vast range of installation options, making optimum pump station design possible. This gives system designers the flexibility to adapt the installation to any station design and system condition. Some installation options are briefly presented here.

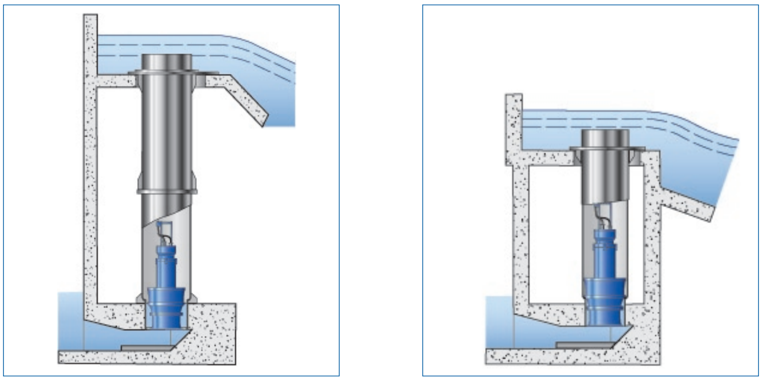


Fig. 2.2-a: Variants of discharge tube design with free discharge

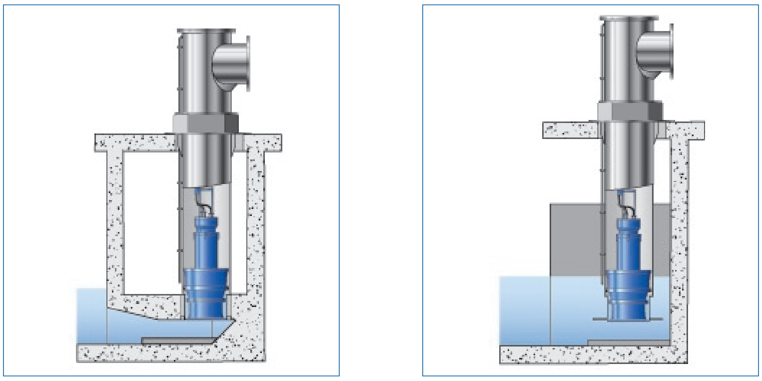


Fig. 2.2-b: Variants of discharge tube design with above-floor discharge nozzle

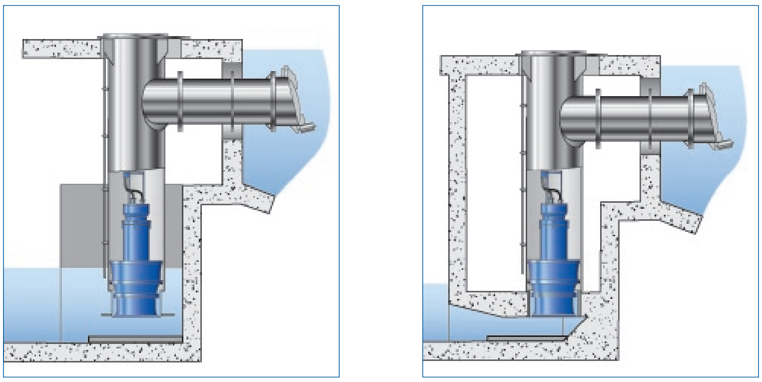


Fig. 2.2-c: Variants of discharge tube design with underfloor discharge nozzle

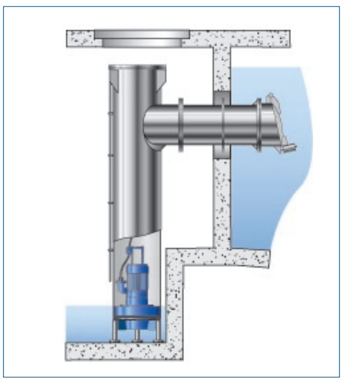


Fig. 2.2-d: Discharge tube design variant with underfloor discharge nozzle, top floor suitable for vehicles

The primary source of advice on planning should be the pump manfacturers' documentation and internationally recognised standards (cf. References).

Once the pump station's dimensions have been roughly defined, detailed planning of the installation of the pump should be carried out in close consultation with the manufacturers' technical literature (e.g. type series booklet or selection software), where detailed information on the exact dimensions required for each particular pump size can be found. It is vital that these dimensions be observed to ensure problem-free pump operation.

Information on permissible maximum inflow velocities and the direction of inflow for the specific intake chamber geometries is also provided (see section 2.3).

The dimensions essential for the intake chamber are its width and length as well as the distances between rear wall / floor and pump. The minimum water level has to be established on the basis of the pump's volume flow in order to ensure smooth pump operation without air-entraining surface vortices.

When determining the appropriate intake chamber geometry, the pump station designer must also consider any operating conditions which will occur when the pump station is being operated with a reduced number of pumps. This may result in substantially different intake chamber flow conditions in terms of inflow velocity and inflow direction (see section 2.3).

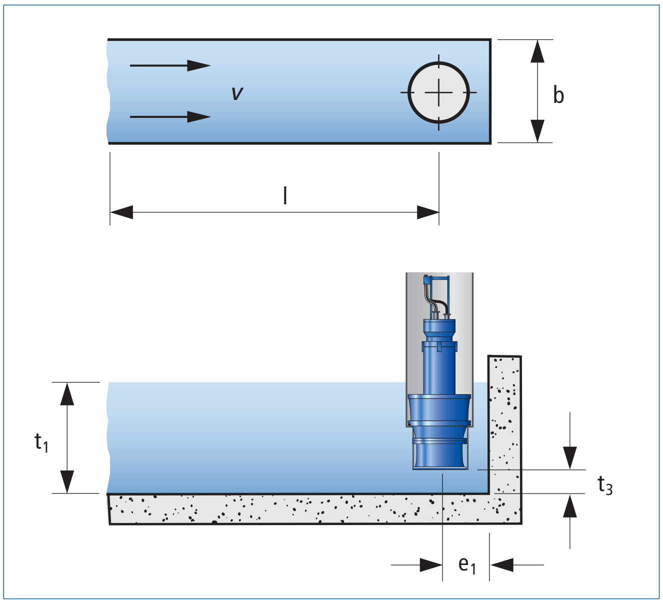


Fig. 2.2-e: Important intake chamber data (for actual dimensions refer to the type series booklet or selection software)

Whether the pump station is equipped with one or several pumps has no influence on the intake chamber dimensions or the discharge tube.

- e_1 *Distance between pump and rear wall*
- b *Approach channel width*
- l *Length of approach channel with uniform, straightened flow, where changes in flow direction do not occur*
- v *Mean flow velocity in approach channel*
- Q *Volume flow rate*
- t_1 *Minimum submergence*
- t_3 *Distance between floor and pump*

2.2.1
Open intake chambers

If the water level in the pump sump is sufficiently high and the flow approaches the chamber directly from the front, with a tolerance of 10 degrees maximum, then this form of intake chamber design is the most cost-efficient variant.

The flow velocity must not exceed 1 m/s within the intake chamber. Flow approaching the pump at an angle of more than 10 degrees must be ruled out to avoid flow separation and vortex formation. This also applies in the event of altered operating conditions.

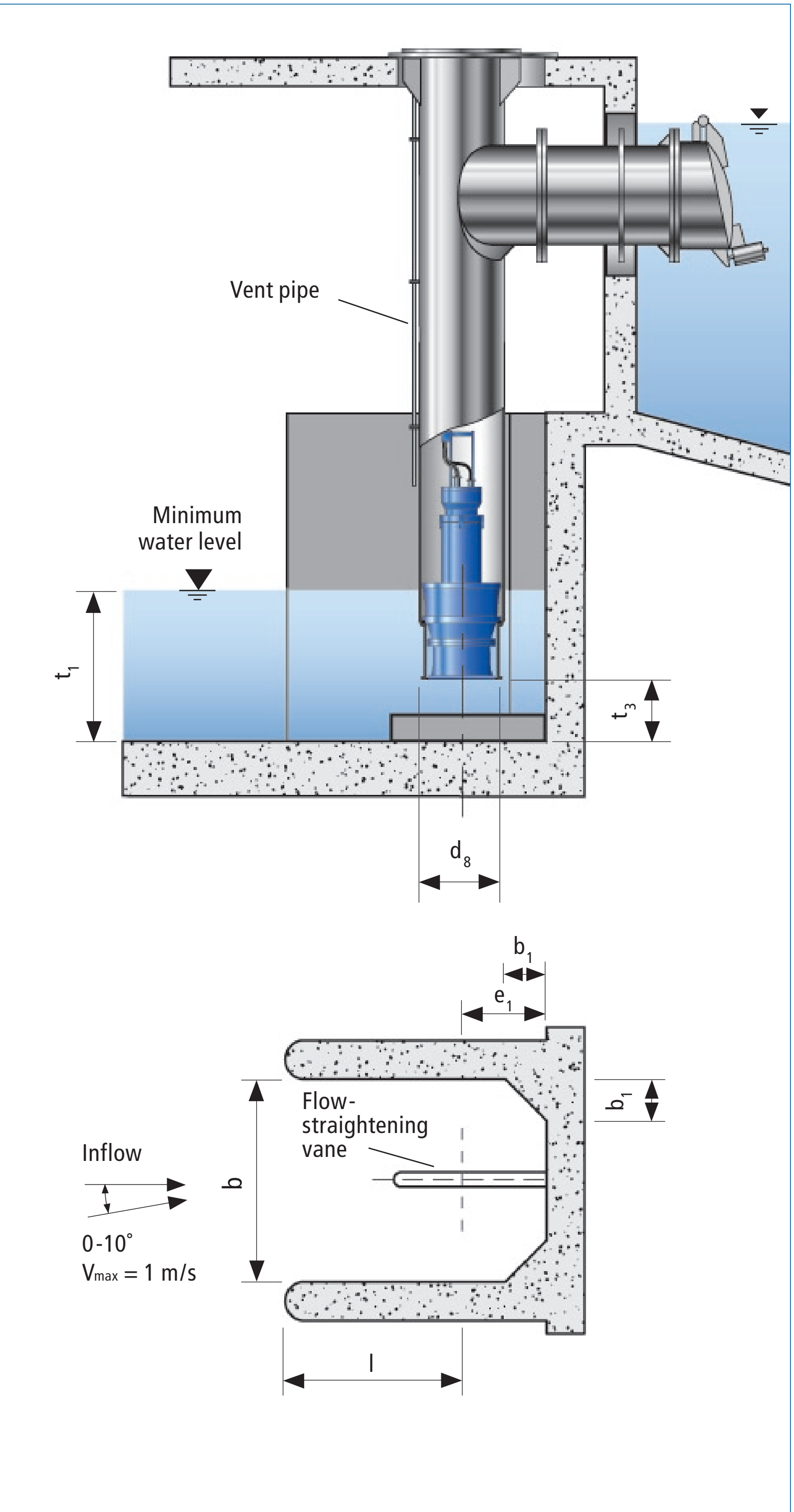


Fig. 2.2.1-a: Open intake chamber without suction umbrella (see the type series booklet for the actual dimensions)

2.2.2 Open intake chambers with suction umbrella

If a check of the minimum water level in the pump sump establishes that this is insufficient, another chamber variant that provides sufficient submergence to prevent air-entraining vortice should be chosen. One such option, involving a few changes, is the open intake chamber with a suction umbrella. This allows the pump to operate at a lower suction side minimum water level t_1 with the same pump size and the same operating point.

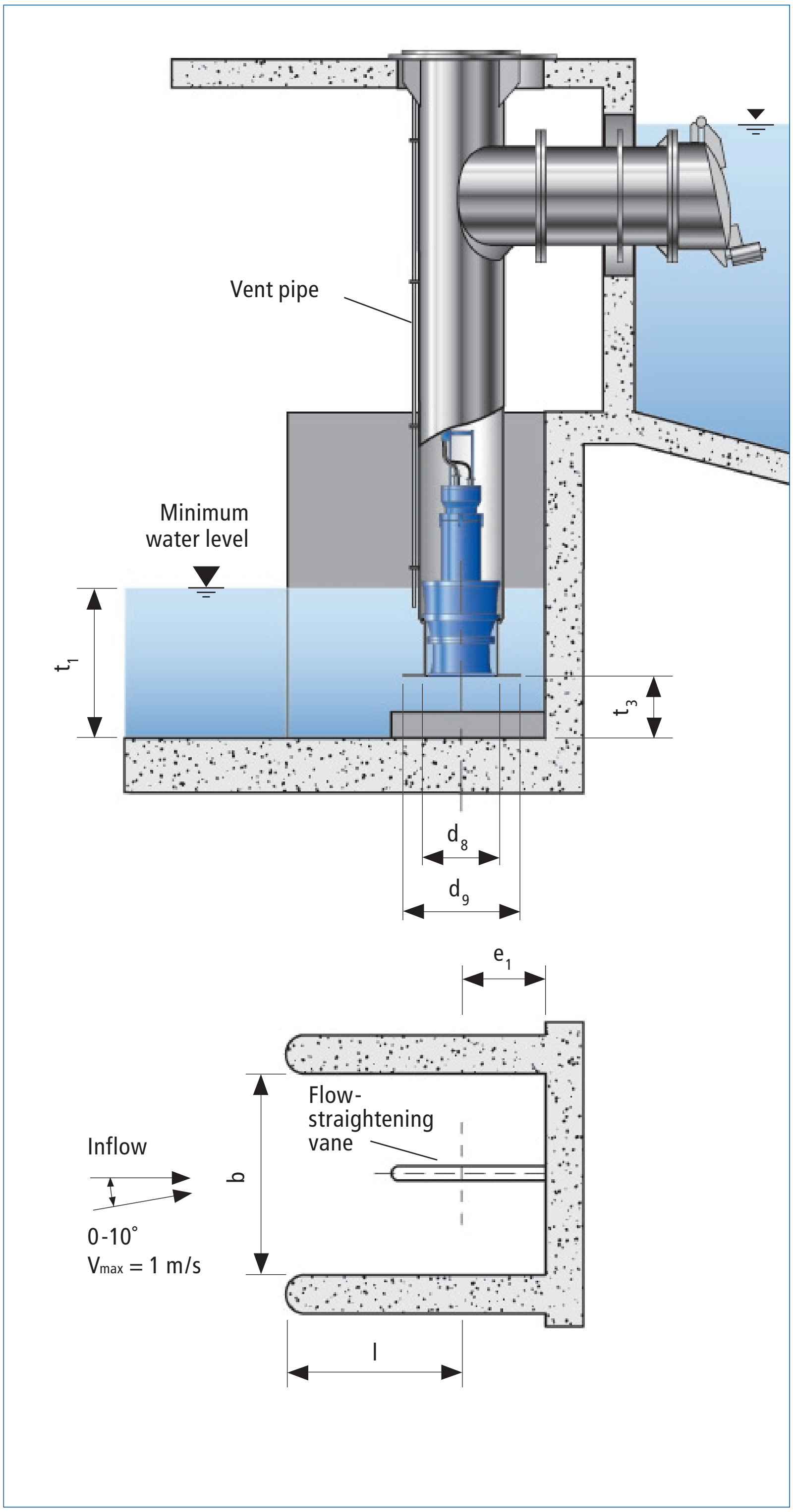


Bild 2.2.2-a: Open intake chamber with suction umbrella (see the type series booklet for the actual dimensions)

2.2.3 Covered intake chamber

A special type of chamber is the covered intake chamber. It allows the lowest minimum water levels without the occurrence of air-entraining surface vortices and can accommodate flows approaching at an angle of 0 to 90 degrees at 1 m/s max. However, this variant involves higher construction costs than the chamber types previously described. This type of chamber has more than proved its worth under unfavourable approach flow conditions and low water levels.

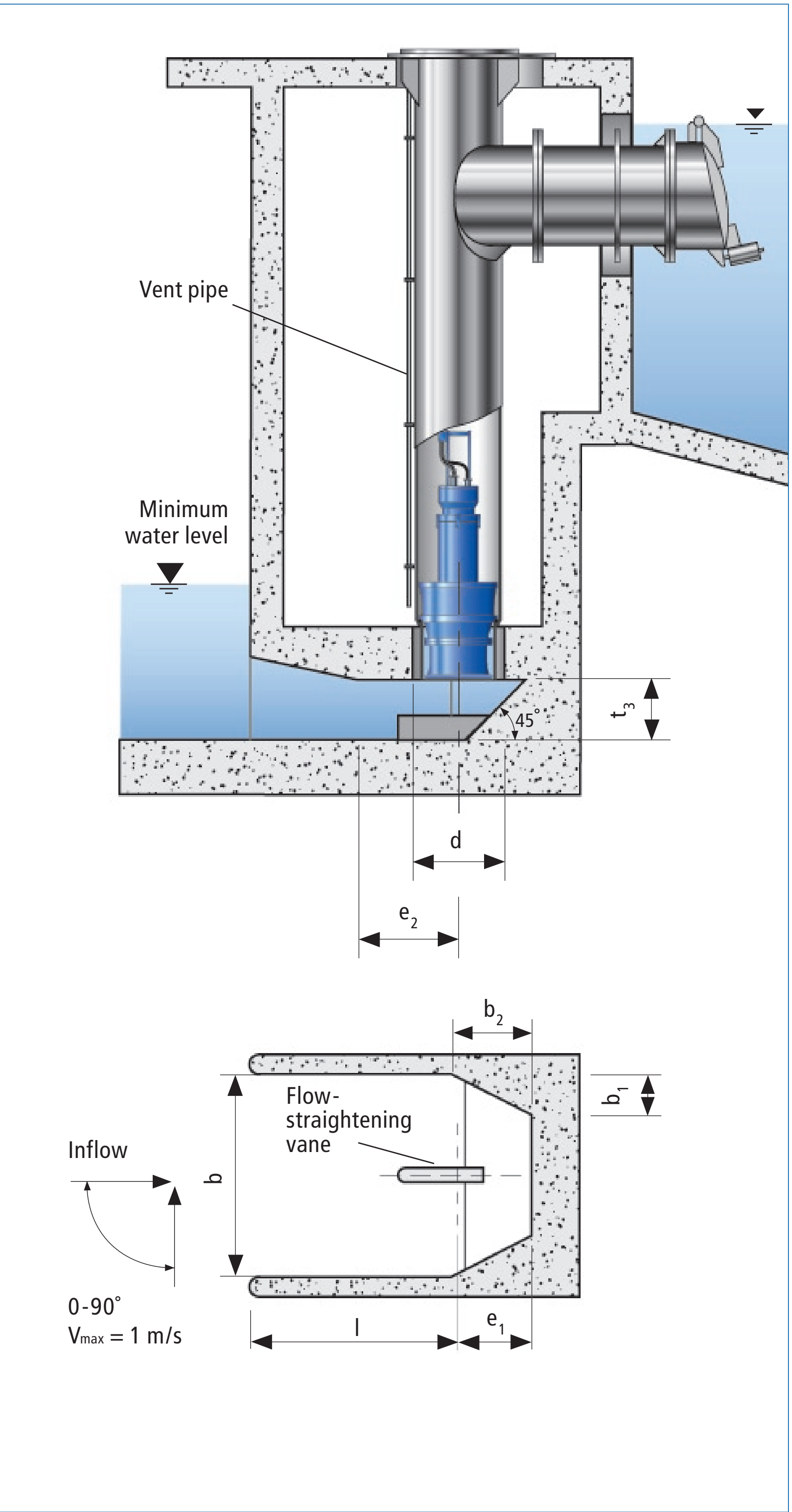


Fig. 2.2.3-a: Covered intake chamber
(see type series booklet or selection software for the actual dimensions)

2.2.4 Details of intake chamber design

Unlike pumps from the Amacan K series, Amacan P and Amacan S pumps have to be installed in dedicated compartments in the intake chamber. An important criterion for the chamber walls is a minimum height of 150 mm above the maximum water level in the pump sump. This is to ensure that the shape of the chamber does not favour vortex formation even under maximum water level conditions.

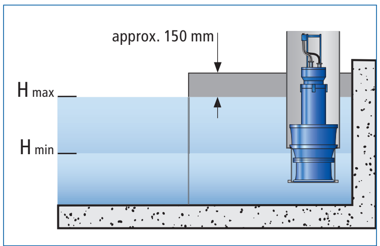


Fig. 2.2.4-a: Chamber wall height

The walls in the intake section of the chamber should always be rounded to rule out the possibility of additional vortices forming if the flow to the chamber is skewed. This requirement is vital for both single-pump intake chambers with approach flows from the side and multiple-pump chambers with central inlet flows.

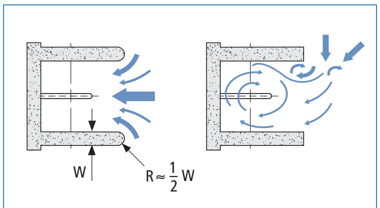


Fig. 2.2.4-b: Chamber intake design

Mounting a flow-straightening vane under the pump inlet is important in all intake chamber designs for Amacan P and Amacan S pumps as this device prevents the occurrence of a submerged vortex which may cause a drop in performance, among other things. This vane can either be a concrete or steel construction.

The precise vane dimensions are stipulated in the type series booklet or selection software.

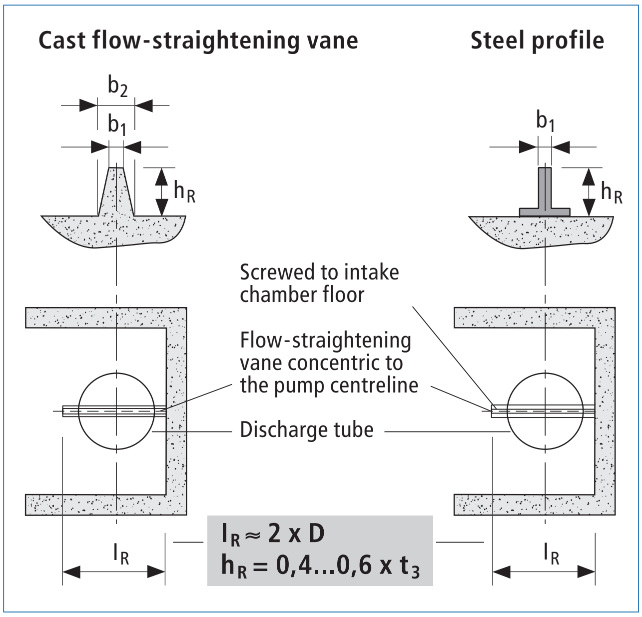


Fig. 2.2.4-c: Sizing the flow-straightening vane

Experience gained over the past few years has shown that the costs for concrete formwork in the chambers can be reduced by using straight contours. Concrete fillings are, however, needed in areas where dead water zones could occur. The intake chamber corners must then be filled with concrete up to a minimum height of 150 mm above the maximum water level.
Depending on the pump station concept, the designers may allow for the possibility of shutting off and draining individual intake chambers, if required.

For this purpose, mounting devices for stop logs can be integrated into the chamber wall or the chamber can be shut off by appropriate flood gates. If these mounting devices constrict the free flow cross section, the distance be-tween the pump and this point of flow disturbance must be checked and increased where necessary.

The intake chamber surfaces as well as the wall around the pump sump should have rough concrete surfaces. If the areas in contact with the pumped fluid are too smooth or even provided with a paint coat, this may lead to the reduction of the wall shearing stress – and thus in-crease the risk of vortex formation (submerged vortices, and possibly surface vortices). The roughness of surfaces in contact with the fluid should range from 1 to 3 mm.

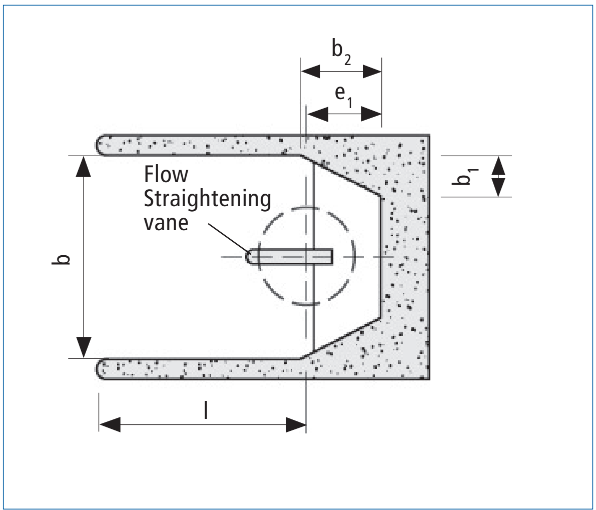


Fig. 2.2.4-e: Corner fillets

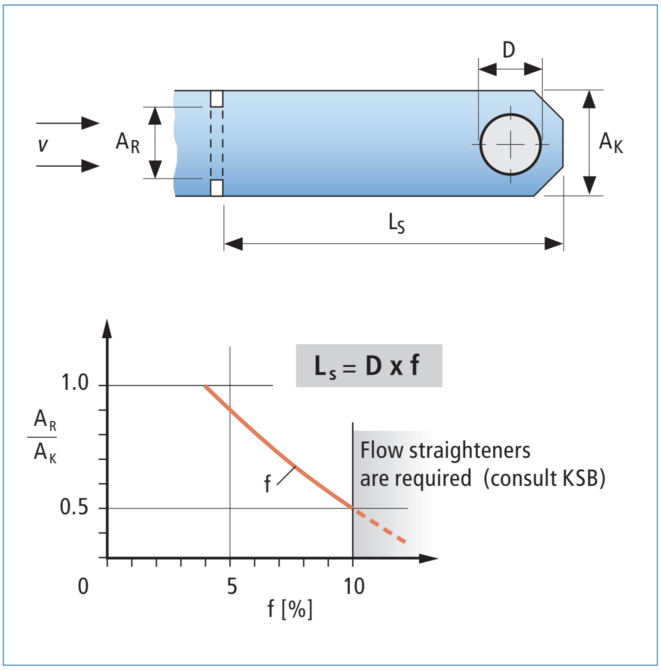


Fig. 2.2.4-f: Influence of cross-sectional constriction

In some circumstances, it might be necessary to adapt the intake structure to the specific requirements of a project. It is conceivable, for instance, that an intake elbow might be employed in place of a chamber. These elbows have properties comparable with those of covered intake chambers, i.e. they straighten the flow and ensure an even distribution of flow velocity across the inlet cross section of the pump.

These special options must be sized to precisely match the project data, which should, therefore, only be done after consultation with the responsible KSB Competence Center.

If special solutions are unavoidable for certain projects, these should be examined with appropriate model tests and/or CFD (Computational Fluid Dynamics) simulations. As this means they are not standard solutions (see sections 2.5 and 2.6) it is important to obtain prior assurance of the trouble-free functioning of the system under these specific project conditions.

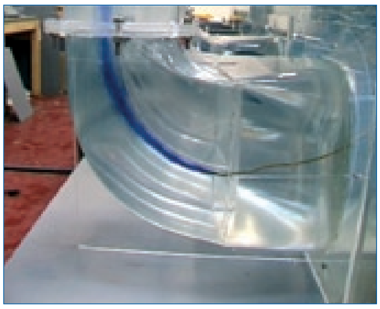


Fig. 2.2.4-i: Variant of a double elbow in a model test

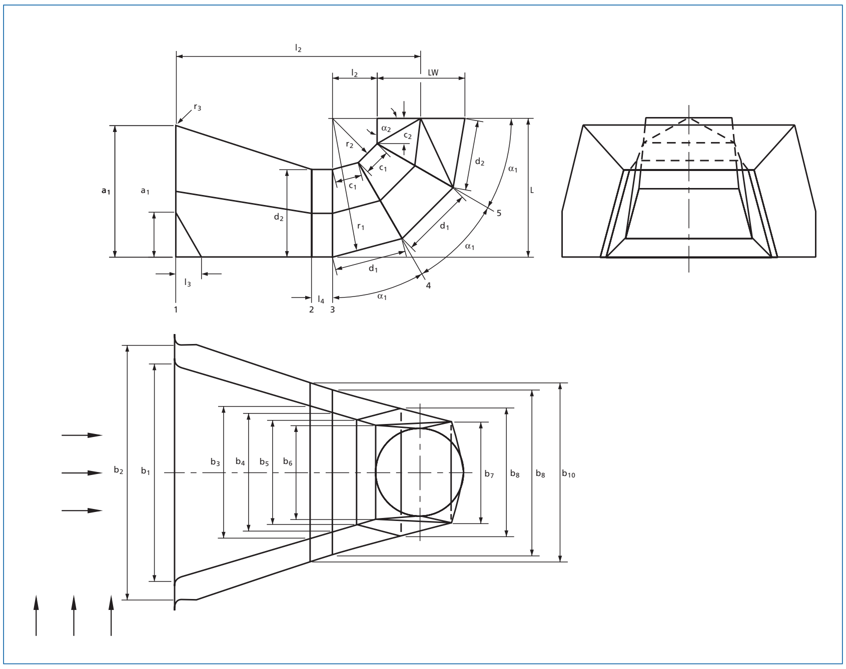
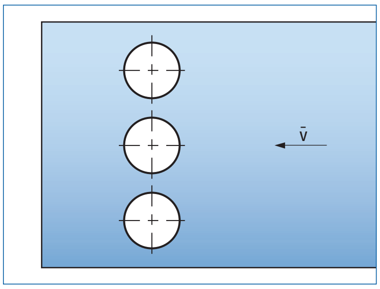


Fig. 2.2.4-h: Variant of a segmental bend

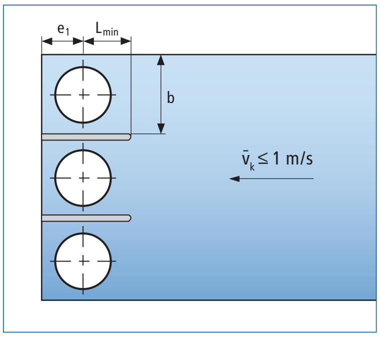
2.2.5 Examples of pump station planning

Variant 1

Given:
Using three pumps, the pump station is to pump fluid from a channel. The inflow to the pumps is described as being even across the channel width.



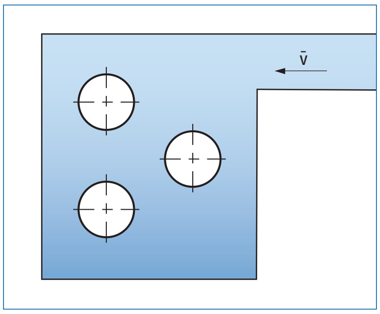
Problem:
As the distance between the discharge tubes and the rear wall is too big, vortices may develop behind the discharge tubes as a result of separated flow. The absence of intake chambers creates the risk of the pumps influencing each other and of undefined approach flow conditions in the case of single pump operation.



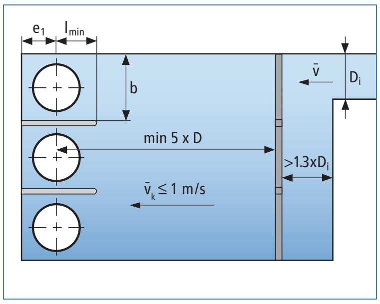
Solution:
Each pump is to be provided with an intake chamber sized to match the respective pump (see the type series booklet or selection software). This ensures defined approach flow conditions and rules out any possibility of the pumps influencing each other during pumping.

Variant 2

Given:
The pump station consisting of three pumps is to convey fluid from a pump sump which is fed with fluid from an off-centre, front pipe / channel. In addition, the pumps are installed asymmetrically with regard to the inflow; intake chambers have not been provided.



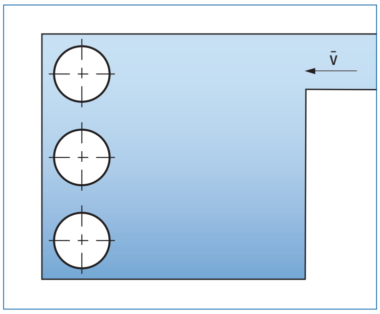
Problem:
The off-centre inflow into the pump sump causes an anti-clockwise rotation of the fluid in the pump sump. The velocity in the inflow channel / pipe determines the intensity of this rotation and, as a consequence, that of the uneven approach flow.



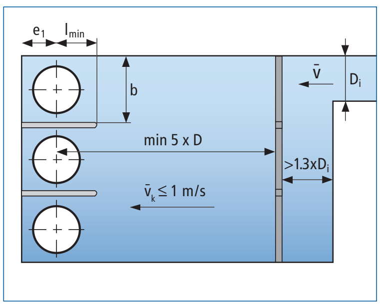
Solution:
Each pump is to be provided with a complete intake chamber sized to match the respective pump (see the type series booklet or selection software). This will rule out any possibility of the pumps influencing each other during pumping. A curtain wall with an opening towards the floor is to be installed to ensure a uniform approach flow. This will help prevent the fluid from rotating.

Variant 3

Given:
The pump station consisting of three pumps is to operate from a pump sump which is fed with water from an off-centre, front pipe/channel. In addition, the pumps are installed asymmetrically with regard to the inflow; intake chambers have not been provided.



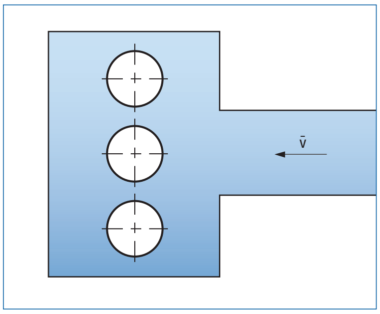
Problem:
The off-centre inflow into the pump sump causes an anticlockwise rotation of the fluid in the pump sump. The velocity in the inflow channel / pipe determines the intensity of this rotation and, as a consequence, that of the uneven approach flow.



Solution:
A curtain wall with an opening towards the floor is installed upstream of the intake chambers. This prevents rotation and ensures the intake chambers are approached from the front without pre-swirl occurring.

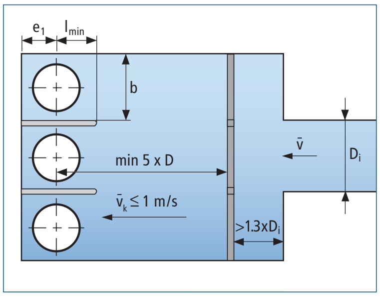
Variant 4.1

Given:
Using three pumps, the pump station is to pump fluid from a channel. The flow from the channel approaches the pumps laterally. The pumps are separated from each other through free standing baffles.



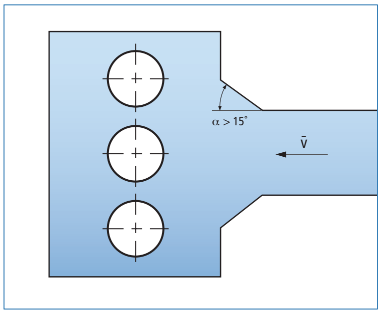
Problem:
The flow moving from the channel into the sump is symmetrical with respect to the installation set-up of the pumps. Vortices may, however, form as a result of flow separation; this leads to the risk of uneven velocity distribution among the pumps. The absence of any intake chambers means an undefined approach flow, with the accompanying risk of the pumps influencing each other.

Solution:
Each pump is provided with a complete intake chamber sized to match the respective pump (see type series booklet or selection software). The intake chambers should be installed on the sump wall opposite the inflow. A curtain wall should be installed across the entire width of the pump sump upstream of the intake chambers. This prevents the pumps from influencing each other during the pumping process; the approach flow is even.



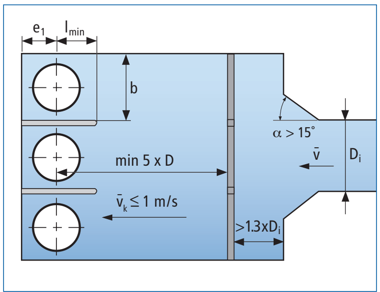
Variant 4.2

Given:
Three pumps are installed to pump fluid from one pump sump. The flow approaches the sump in the centre. The pumps are installed perpendicular to the flow direction and do not have intake chambers.
To reduce the velocity in the sump the inlet channel has been widened. Relative to the inflow, the distance between the pumps and the rear wall is extremely large.



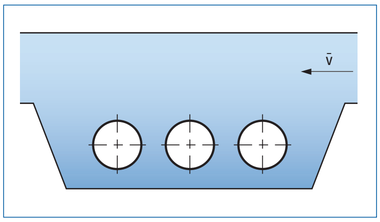
Problem:
Due to the fluid approach from the channel to the sump, vortices caused by flow separation are likely, leading ultimately to the risk of uneven velocity distribution upstream of the pumps. The angle of divergence is too wide and causes problems with vortices and velocity distribution as mentioned above. As intake chambers are not available, there is the risk of the pumps influencing each other and of undefined flow.

Solution:
Each pump is provided with a complete intake chamber sized to match the respective pump (see type series booklet or selection software). The intake chambers are installed on the sump wall opposite the inflow. A curtain wall should be installed across the entire width of the pump sump upstream of the intake chambers. This prevents the pumps from influencing each other during pumping; the flow is even.

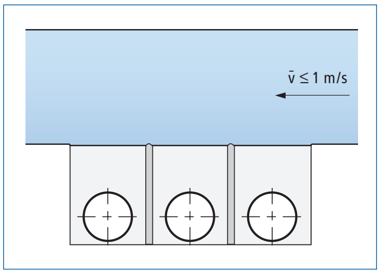


Variant 5

Given:
The pump station consisting of three pumps is to pump fluid from a channel. The pumps do not have intake chambers and the fluid flow approaches the line of pumps perpendicularly.



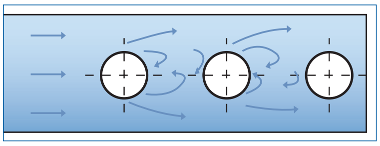
Problem:
The pump station consisting of three pumps is to pump fluid from a channel. The pumps do not have intake chambers and the fluid flow approaches the line of pumps perpendicularly.



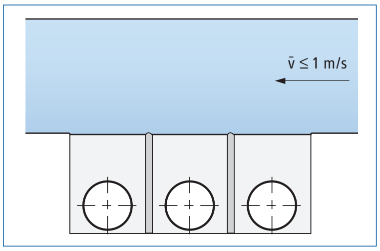
Solution:
Each pump is provided with a covered intake chamber. As a result, perpendicular flows of up to a maximum of 1 m/s can be handled without any problems. The intake chambers are sized to match the actual pump size (see type series booklet or selection software). The front edges of the intake chambers should be in line with the channel wall to avoid additional flow constrictions and marked differences in flow velocities in the channel.

Variant 6

Given:
The pump station consisting of three pumps is to pump fluid from a channel. The pumps are installed in a series. The pumps are not separated from each other through chambers or baffles.



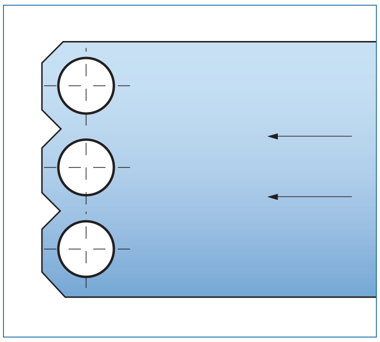
Problem:
The approach flow from the channel creates the risk of vortices caused by flow separation and uneven velocity distribution up- and downstream of the pumps. The absence of any intake chambers means an undefined approach flow, with the accompanying risk of the pumps influencing each other.



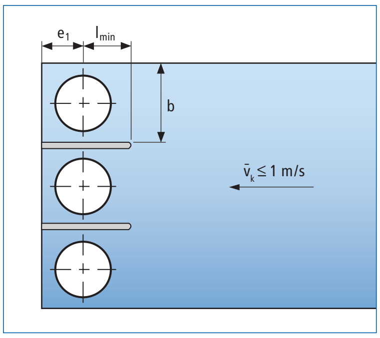
Solution:
Each pump is to be provided with a covered intake chamber sized to match the respective pump (see type series booklet or selection software). This will rule out any possibility of the pumps influencing each other, while the flow conditions are exactly defined.

Variant 7

Given:
The pump station consisting of three pumps is to pump fluid from a channel. The flow is described as being even across the entire channel width. The pumps are separated from each other through profiled rear walls of the sump.



Problem:
The absence of any intake chambers means an undefined approach flow, with the accompanying risk of the pumps influencing each other. This results in unpredictable flow conditions particularly during operation with a reduced number of pumps.



Solution:
Each pump is provided with a complete intake chamber sized to match the respective pump (see type series booklet / selection software). This will rule out any possibility of the pumps influencing each other.

2.2.6
Amacan K: A special case

Thanks to its channel impeller this pump type is relatively straightforward with regard to the pump station design. Amacan K pumps can be installed into the discharge tubes with no need for any special intake chambers or separating walls between the pumps. To rule out any possibility of the pumps influencing each other, it is, however, important to observe the required installation distances: the lateral distance between the pump and the building structure as well as inter-pump spacing, and the distance e_1 between the rear wall and the pumps' centreline. Fig. 2.2.6-a offers basic guidance for a pump installation concept.

The following conditions should be assumed as reference values for a preliminary concept:

Observing the rear wall distance $e_1 \approx 0.6 \times D$ is crucial.

The required minimum water level t_1 – as is also the case with the other submersible pumps installed in discharge tubes – is a function of the volume flow rate Q and documented in the type series booklet.

The lateral distance $s_{min} \approx 1.6$ to $1.8 \times D$ should be also observed.

For discharge tubes with a diameter of D = 700 a factor of 1.6 and with D = 1400 a factor of 1.8 must be applied. Other intermediate values must be established through interpolation. Flow straighteners as used for Amacan P or Amacan S are not required.

Where inflow angles differ and flow velocities are higher than 1 m/s, it is necessary to take measures suited to deal with that specific intake situation (see section 2.3 "Pump sump design").

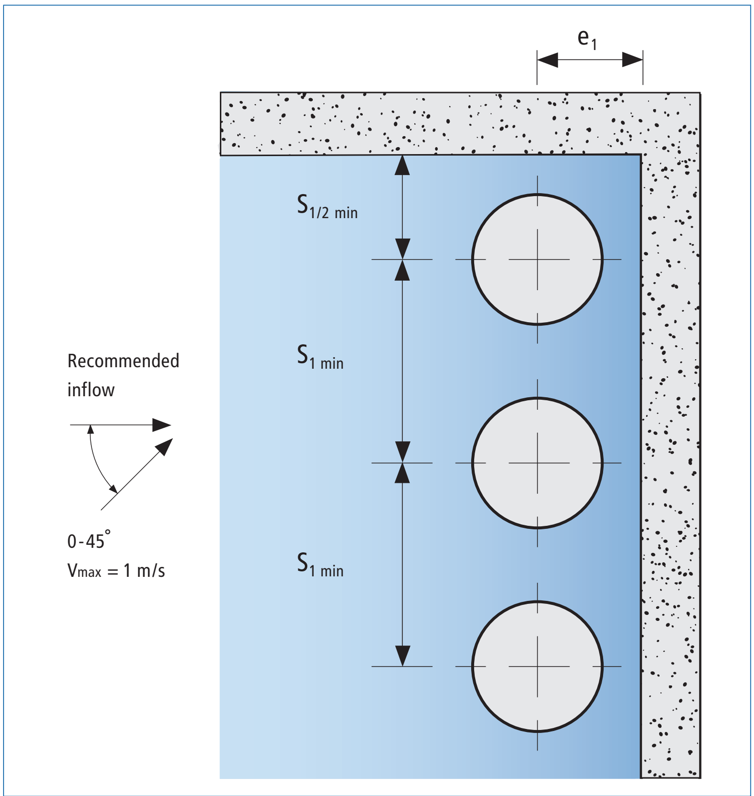


Fig. 2.2.6-a: Minimum dimensions

2.3 Pump sump design

The fluid storage space or the pump sump connects the pump station intake with the submersible pump in the discharge tube. There are as many variations in the design of this part of the intake structure as there are pump installation options. Only a few examples can be looked at in the following chapter; the dimensions in the drawings refer to these cases only. If project or modification conditions deviate from the examples described here, we recommend consulting KSB.

One feature of an optimum pump sump design is that there are no major steps or slopes with an inclination of more than 8 degrees on the sump floor. A distance of at least 4 to 5 D (D = discharge tube diameter) should be maintained from the last point of disturbance or floor alteration to the pump centreline. Higher steps or slopes (> 100 mm) should be avoided at all costs in order to prevent submerged areas of flow separation and floor vortices.

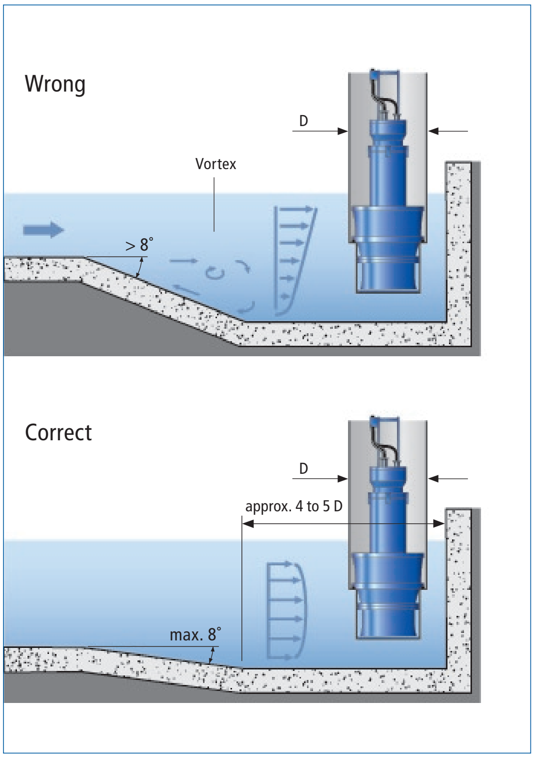


Fig. 2.3-a: Shape of sump floor

When the flow enters the pump station structure from a channel, either a diffuser-type enlargement (number of pumps n + chamber width x n+ (n –1) x wall thickness) or a so-called curtain wall is required. Which of these measures is appropriate for the project in hand, must be individually decided upon.

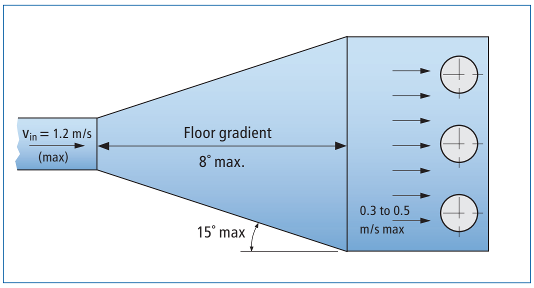


Fig. 2.3-b: Maximum permissible divergence angle for flow cross section and permissible velocities according to HI [5] and SN [12]

While some sources give details of installations where submersible pumps in discharge tube design do not have their own intake chambers, KSB, in contrast, believes that each pump should be provided with its own, fully shaped intake chamber (see sections "Open intake chamber" to "Covered intake chamber") in order to rule out any possibility of the pumps influencing each other. Actual inflow conditions are difficult to predict, as vortices may form even in the case of low pump flow rates as a result of various influences in the intake structure or the pump stations's mode of operation, with the accompanying negative effects on the pumps.

According to KSB, flow velocities of no higher than 1 m/s are permitted for the intake chamber geometries specified in the type series booklets. Therefore, with a view to reducing the intake building structure, it is necessary that the conditions around the pump are optimally designed to avoid problems.

If the direction of the flow (relative to the orientation of the pump intake chamber) discharged from the inlet channel changes, this must be corrected by appropriate devices, so-called "flow straighteners". While one function of flow straighteners is to dissipate the kinetic energy of the fluid entering the pump station, their opening towards the floor ensures the flow moves in the direction specifically required. The result is a symmetrical approach flow into the pump chambers. If such a wall is not installed, the energy contained in the flow may cause vortices; in addition, as shown in Fig. 2.3-c, the flow to the chambers is asymmetrical and therefore detrimental to trouble-free pump operation.

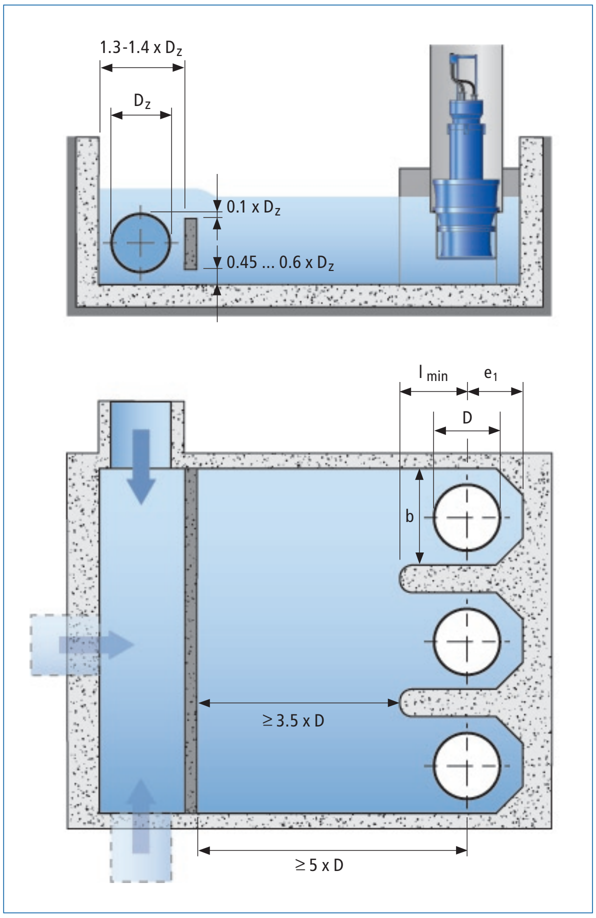


Fig. 2.3-c: Example of a pump station with cross flow and curtain wall

If the difference in height between the inlet structure and the pump sump is large it may be necessary to eliminate the risk of aeration by incorporating a weir-type structure. A difference in height of more than 0.3 m [7] already provides sufficient reason to take appropriate measures. The adjacent illustration shows a pump station with a considerable difference in height between the inlet channel and the pump sump and how this problem has been solved by fitting appropriate structures in the sump. Changes in flow direction can also be expected if only a few pumps are operating in a multiple-pump system. Here preliminary assessment of the situation could help to decide whether a covered intake chamber should be preferred to an open one.

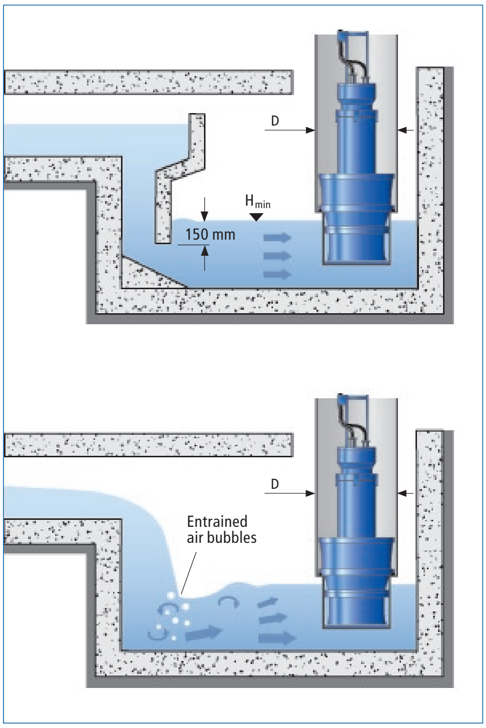


Fig. 2.3-e: Pump station with weir-type structure

If a divergence angle of more than 15 degrees is planned in the building to reduce inflow velocity v_i, additional steps such as the installation of flow distributors and/or baffles are necessary to prevent vortices caused by flow separation. The feasibility of these measures depends on the nature of the fluid pumped.

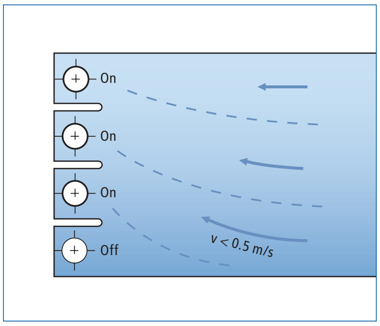


Fig. 2.3-d: Flow pattern developing with variable pump operation

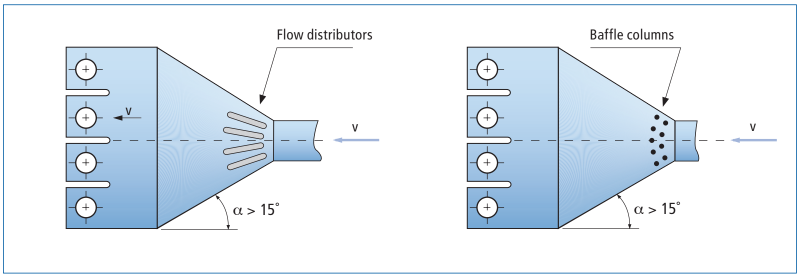


Fig. 2.3-f: Flow optimisation

The intake situation from a channel is comparable with the abstraction of water from a river. Depending on the flow velocity, areas of flow separation can be expected where the water flows into the intake chamber area. If it is not possible to provide a covered intake chamber, then it is important to markedly extend the chamber walls. As a reference value the pump station designer can assume a factor 3 relative to the dimension L_{min} given in the technical literature.

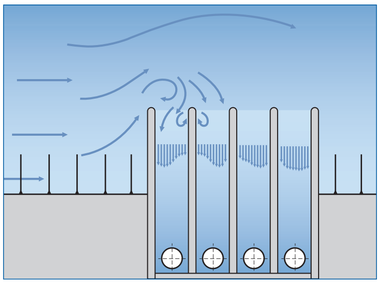


Fig. 2.3-g: Pump station with open chamber for water abstraction from a river

If the fluid is taken from stagnant waters, then cross flow is irrelevant. If the fluid level above the pumps is sufficient for the respective volume flow, i. e. a minimum water level t_1 between the lowest water level in the water body and the intake chamber floor can be assured (see type series booklets), it is no problem to use open intake chambers.
Depending on the design of the pump station's lateral walls, it may be possible to make them slightly longer than the intake chamber wall in order to reduce the influence of flow deflection on the outside intake chambers.

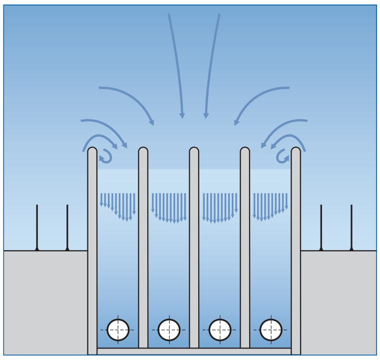


Fig. 2.3-h: Pump station with open chamber for water abstraction from stagnant waters

2.4 Solutions for special cases

If standard intake structures cannot be realised or the conditions in the pump station do not correspond with the above mentioned layouts, KSB's expertise should be utilised to find specific design solutions. The sooner advice is sought in such special cases, the better – and the higher the chance of identifying potential problems and of taking appropriate measures to find a practical solution.

To define these special cases more clearly, a few criteria, like for instance the maximum velocity in the approach zone of v > 1m/s and the large cross flows potentially associated with them must be mentioned. In such cases precisely dimensioned baffling and specially dimensioned intake chambers could possibly help to optimise the approach flow to the pump. The nature of the fluid pumped is here again crucial, thus underscoring the need for an individually engineered solution. KSB has numerous successful designs in this field to its credit.

The extent to which such measures are to be verified by model tests or CFD (Computational Fluid Dynamics) simulations should be individually determined.

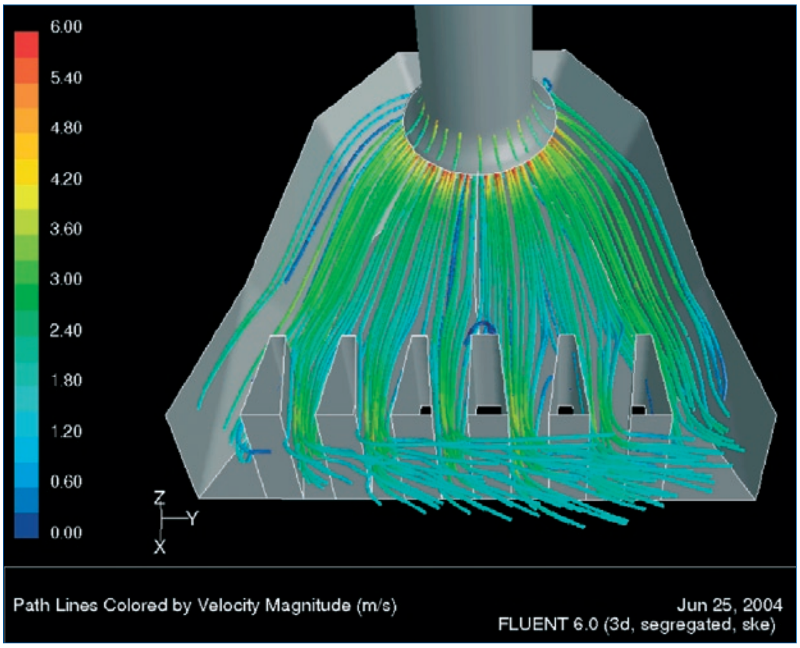


Fig. 2.4-a: Specially dimensioned intake chamber for cross flows of v = 1,8 m/s

2.5 The necessity of model testing

The object of these tests is to simulate the flow of a planned pump station in a scale model. It helps identify precisely where problematic conditions (vortex action, uneven velocity distribution, etc.) might arise and how to then influence these positively, where necessary. The high transparency of acrylic glass makes this material an excellent choice for the construction of suitable models.

In order to be able to tranfer the flow conditions to the full-size structure, dimensionless numbers are applied in the design of the model. These characteristic coefficients describe the forces acting in the flow; they should be as identical as possible for both the model and the full-size structure. The most relevant forces are gravity, as well as those resulting from dynamic viscosity, surface tension and the inertia of the fluid in motion.

The dimensionless numbers applied here are as follows:

REYNOLDS number	$Re = \frac{vd}{\nu}$
FROUDE number	$Fr = \frac{v}{\sqrt{g \cdot d}}$
WEBER number	$We = \frac{\rho \cdot v^2 \cdot d}{\sigma}$

where:

v = flow velocity in m/s
d = hydraulc diameter in m
ν = kinematc viscosity in m^2/s
g = gravitational constant in m/s^2
σ = surface tension in N/mm^2

As these characteristics are to a degree interdependent, it is impossible to apply them at the same time in a scaled model. It is therefore important to find a compromise which helps achieve the optimum for a given application.

Model testing is absolutely necessary when one or more of the criteria listed below apply to the intake structure or pump sump:

- The concept of the pump station building deviates from proven layouts as regards chamber dimensions, piping layout, wall spacing, considerable changes in flow direction between inflow into the building and the approach flow to the pump, etc.

- The volume flow rate per pump is higher than 2.5 m^3/s or 6.3 m^3/s for the entire pump station

- The inflow is asymmetrical and/or not uniform

- Alternating pump operation in multiple-pump stations involves significant changes in flow direction

- An existing pump station has already created problems.

Test set-up
The geometry of the model must correspond with the original structure, taking into account the selected scale and the characteristic coefficients mentioned previously. This applies to the hydraulic part of the building structure and the pumps. Both the structure of the building and the pumps are constructed from transparent material. A model of the impeller is not required as the test aims to simulate only the flow approaching the impeller.

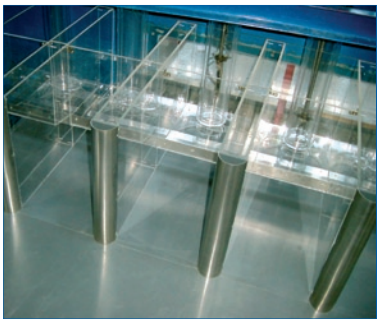


Fig. 2.5-a: Acrylic model of an Amacan P pump station

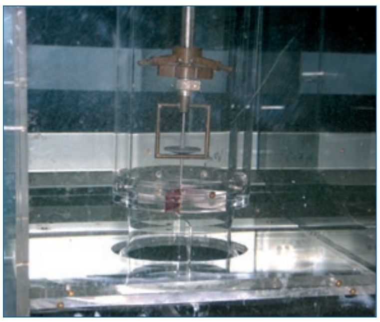


Fig. 2.5-b: Vortometer

Instead of an impeller a vortometer is employed whose rotational speed provides information on the development of vortices in the intake.

The flow velocities are measured at reference points across the model pump's entire suction cross section via Pitot tube or laser. To judge vortex development the fluid surface as well as the wall and floor areas are observed. Vortex intensity in a given flow cross section is visualised by means of dyes while their size is measured by the swirl angle of the vortometer. The following equation is applicable:

$$\Theta = \tan^{-1}\left(\frac{\pi° d_m n}{u}\right)$$

where:

d_m = pipe diameter
(here the pump´s suction pipe)
n = rotations of vortometer
u = axial flow velocity

The surface vortices are classified according to Hecker in six categories (1 = low, 6 = very high) and the submerged vortices in three or four categories according to Tillack [16].

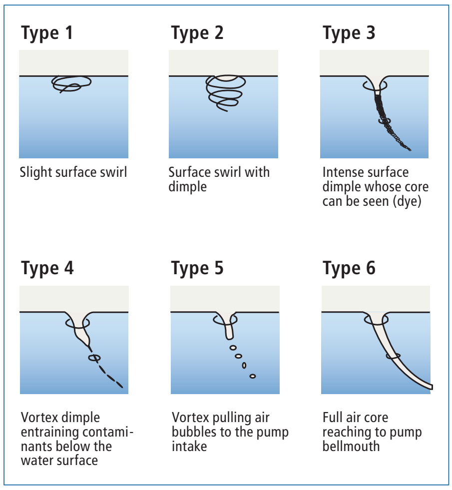


Fig. 2.5-c: Classification of surface vortices according to Hecker (Types 1 to 6)

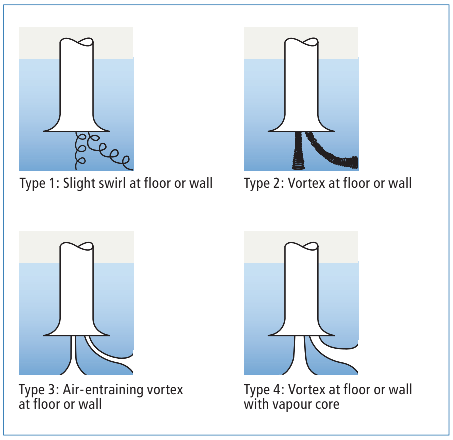


Fig. 2.5-d: Classification of submerged vortices according to Tillack (Types 1 to 4)

If one were only to look at the diagrams, these vortex formations appear relatively harmless. Vortex formation observed in model tests give an idea of what could happen in a real structure. Unlike laboratory situations a real pump station rarely deals with clear water and it is difficult to identify vortex action as the source of problem, especially when submerged vortices are involved.

Fig. 2.5-e: Laboratory photo of a surface vortex type 6

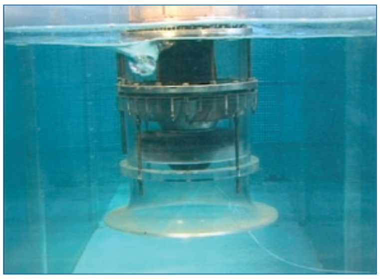


Fig. 2.5-f: Laboratory photo of a surface vortex type 3

The criteria which apply to this method of investigation may vary slightly depending on the type of pump or size of station.

Evaluation of results
Before the design is finalised the measurement results should be confirmed by all parties involved: pump station designer, end user, pump manufacturer and the institution which conducted the tests.

Main criteria:

1. The mean flow velocity at the defined measurement points of the suction cross section should not deviate from the mean value by more than 10 %.

2. The swirl angle should not be higher than 5 degrees. A swirl angle of 7 degrees can be tolerated if it has occurred during less than 10 % of the period of observation or if the pump manufacturer has defined other limits.

3. Surface vortices may only be accepted up to type 2 and submerged vortices up to type 1 if they do not have an unacceptable influence on the measured velocity profile.

In general the following applies: Occurrences that have a minor effect in the model may be considerably more significant in the full-scale structure!

The tests must be concluded with a detailed report on the operating conditions investigated. The vortex formations and operating conditions observed (for the tested water levels in the building structure) have to be documented on video tape and made available to the party commissioning the tests.

KSB will support and co-ordinate project related model tests upon request.

2.6 The significance of CFD simulation

Numerical flow simulation (Computational Fluid Dynamics = CFD) is becoming increasingly important. The software specially developed for this purpose is an effective instrument allowing relatively precise predictions of the flow conditions. The time and cost of flow modelling depends on the

- size of the flow area to be modelled
- desired geometric resolution
- computer performance
- form of presentation of results (report) and scope of results.

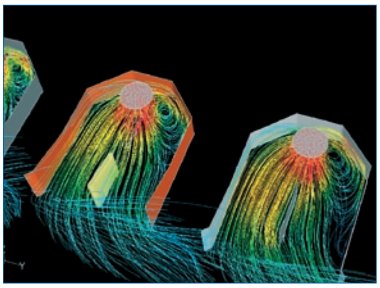


Fig. 2.6-a: Flow patterns in Amacan intake chambers

Methodology

The mathematical description of fluid flows is based on the NAVIER-STOKES equations. They describe the processes at each point of a flow by means of partial differential equations for the mass, energy and momentum.

$$\frac{\partial u}{\partial t} + u\frac{\partial u}{\partial x} + v\frac{\partial u}{\partial y} + w\frac{\partial u}{\partial z} = f_x - \frac{1}{\rho}\frac{\partial p}{\partial x} + v\left[\frac{\partial^2 u}{\partial x^2} + \frac{\partial^2 u}{\partial y^2} + \frac{\partial^2 u}{\partial z^2}\right]$$

$$\frac{\partial v}{\partial t} + u\frac{\partial v}{\partial x} + v\frac{\partial v}{\partial y} + w\frac{\partial v}{\partial z} = f_y - \frac{1}{\rho}\frac{\partial p}{\partial y} + v\left[\frac{\partial^2 v}{\partial x^2} + \frac{\partial^2 v}{\partial y^2} + \frac{\partial^2 v}{\partial z^2}\right]$$

$$\frac{\partial w}{\partial t} + u\frac{\partial w}{\partial x} + v\frac{\partial w}{\partial y} + w\frac{\partial w}{\partial z} = f_z - \frac{1}{\rho}\frac{\partial p}{\partial z} + v\left[\frac{\partial^2 w}{\partial x^2} + \frac{\partial^2 w}{\partial y^2} + \frac{\partial^2 w}{\partial z^2}\right]$$

The calculation of each spatial point in a flow is not feasible as this would result in an infinite number of calculations. A grid is generated instead and its nodes are calculated. The grid model is then processed further to provide information on the pressure and velocity distribution, which can then be subjected to numerical and/or graphical analysis. In modelling, the distances between individual nodes may partly differ; they depend on the flow velocity gradients.

The calculated nodes lie closer together near walls and corners, which are considered as discontinuities from a fluid dynamics point of view. In areas with low velocity gradients it is not a problem to increase the distances. In addition, assumptions on the distribution of turbulence are made at the nodes. The task of a CFD specialist is to choose the "correct" turbulence model. It takes a lot of experience to be able to create an adequate model and to be able to accurately interpret the results obtained.

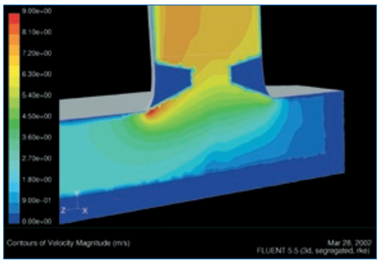


Fig. 2.6-b: Simulation of approach flow to discharge tube

CFD simulation is perfectly suited to evaluating flows in intake structures and pump sumps, especially as it can also be used to make a very exact analysis of the influence single pumps have on the flow pattern in multiple-pump systems.

Problems are more often caused by the fact that surface and submerged vortices and asymmetrical inflows do not always exhibit steady behaviour and are therefore difficult to predict exactly.

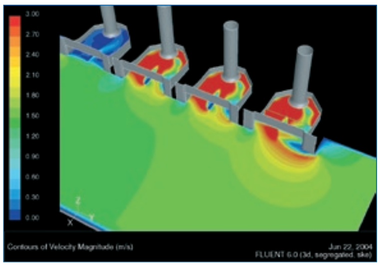


Fig. 2.6-c: Simulation of pump station with several pumps

At KSB CFD simulation is a well-established engineering tool that has been used for years. The fact that CFD calculations have been proven to conform well with model testing in past investigations allows more accurate predictions to be made today on potential flow situations and enables pump stations to be more systematically optimised. In complicated cases, however, physical model testing is to be preferred to CFD calculations for building structure investigations.

In the future the use of both CFD simulations and model testing will significantly reduce the overall costs of pump station investigations.

2.7 Screening equipment

The installation of screening equipment is required for trouble-free pump operation: Depending on the type and origin of the fluid handled it is desirable to install coarse screens (the distance between bars should be between 5 and 30 cm) and/or fine screens (the distance between bars should be between 5 and 20 mm) as well as shingle traps, mounted upstream of the screens, if needed. The screens and traps should be cleaned automatically during pump operation using appropiate mechanical equipment. In applications where surface water from rivers, lakes and channels is pumped or in storm water pumping stations the installation of screening equipment is an absolute must.

Fig. 2.7-a: Coarse screens upstream of an Amacan pump station (water abstraction from a river)

The fact that river water in particular contains shingle and sediment is often overlooked. Under conditions of long-term operation, however, failure to fit the appropriate screening equipment upstream of a pump station will lead to sand accumulation and considerable sedimentation in stagnation zones at and within the building, as well as in increased wear to centrifugal pumps. Also, mechanical damage to the impeller and other pump parts cannot be ruled out.

Where the screens are to be accommodated in the pump station concept is the designer's decision. The screening equipment is either mounted upstream of the pump station or sump to prevent coarse material from entering the building, or single screens are directly integrated into the intake chamber design. Selecting the latter option may necessitate longer chambers due to the slightly reduced flow cross section which results from integrating the screen. Downstream of the screening equipment the velocity distribution developing across the flow cross section should be even and therefore favourable for pump operation, provided the screen is largely free from any trapped material (see Fig. 2.7-b).

When establishing the minimum water level t_1 in the pump sump, it is also necessary to take into account that a screen filled with trapped material creates flow resistance resulting in different water levels up- and downstream of the screen. This means that the water level downstream of the screen must not fall below the permissible minimum water level t_1 for the pump's operating point.

Fig. 2.7-b: Screens with automatic cleaning devices

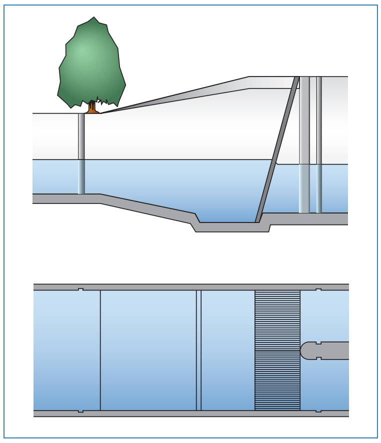


Fig. 2.7-c: Shingle trap upstream of pump station

Half of the impeller free passage should be used as a reference value to determine the permissible maximum distance between the screen bars. This value can be taken from the appropriate pump curve (see the type series booklet or selection software).

Fig. 2.7-d: Wood inside the diffuser casing of an Amacan pump

To evaluate the screen's influence on the water level directly upstream of the pumps it is advisable to use Hager's simplified calculation [10], if a detailed screen selection procedure is not being undertaken.

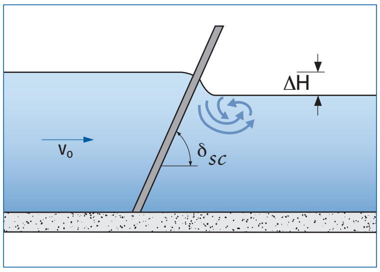


Fig. 2.7-e: Flow through screen, without lowered floor

Applying this calculation will result in the lowering of the water level downstream of the screen as expressed in the equation:

$$\Delta H = \xi_{sc} \times \frac{v_0^2}{2g}$$

Here v_0 is the flow velocity upstream of the screen. The total loss coefficient β_{sc} is a function of the angle of inclination of the screen δ_{sc} in relation to the horizontal position, the correction factor for the cleaning method c_{sc} and the coefficient ζ_{sc}. For a clean screen this correction factor is 1, with mechanical cleaning it ranges between 1.1 and 1.3 and with manual cleaning between 1.5 and 2. The coefficient ζ_{sc} includes the shape of the screen bars and the area ratios between the free flow area $\bar{a}$ and the distance between the bar centrelines $\bar{b}$.

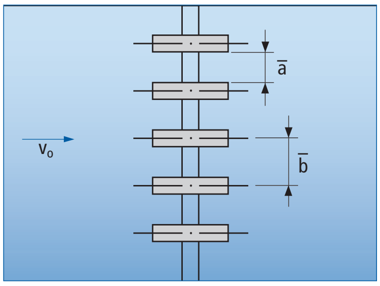


Fig. 2.7-f: Screen layout drawing

Therefore,
$\xi_{sc} = \beta_{sc} \times \zeta_{sc} \times c_{sc} \times \delta_{sc}$

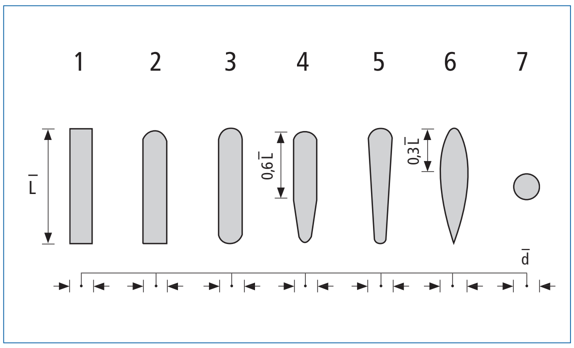


Fig. 2.7-g: Different shapes of screen bars

The following values can be applied for the following different bar shapes:

Shape	1	2	3	4	5	6	7
β_{sc}	1	0.76	0.76	0.43	0.37	0.3	0.74

$\overline{L}$ is the length of the sreen bar profile and $\overline{a}$ the width. If the ratio of $\overline{L}$ / $\overline{a}$ is 5 and the condition $\frac{\overline{b}}{\overline{a}} > 0.5$ is satisfied, the formula for ξ_{sc} can be simplified and expressed as follows:

$$\xi_{sc} = \frac{7}{3}\beta_{sc} \text{ x } \left[\frac{b}{a} - 1\right]^{\frac{3}{4}} \text{x } c_{sc} \text{ x } \sin \delta_{sc}$$

In order to compensate for the losses ΔH occurring as the flow passes the screen, the floor of the intake structure or channel is often lowered by the value Δz downstream of the screen.

$$\Delta H = \Delta z$$

The values usually applied for losses through screens range between approx. 5 cm for mechanical cleaning to approx. 10 cm for manual cleaning.

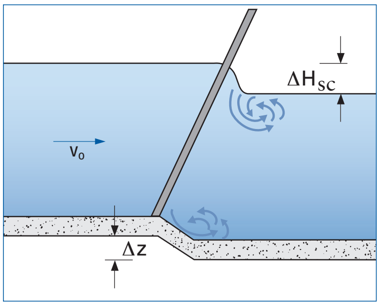


Fig. 2.7-h: Flow through screen with lowered floor

For detailed screen selection, the method according to Idelchik [11, p. 504 ff] is recommended: This method is most appropriate when the influence of oblique flow to the screen is also to be taken into account or if the screen bars are markedly different from what was illustrated in Fig. 2.7-g.

Fig. 2.7-i: Pump station with automatic screens

Screens are often integrated in the direct vicinity of the intake chambers. This means every pump is dedicated with its own screen. The distance between the screening equipment and the pump's discharge tube should be at least 4xD (D being the discharge tube diameter).

If it is assumed that the flow might approach the screen from the side and the influence on the water level downstream of the screen might be difficult to predict, preventive measures are then advisable. Extending the intake chamber wall and positioning the screen in the intake chamber area would then achieve a better defined and even approach flow condition for the pump and screen.

Cleaning of the screen should preferably take place automatically. To activate the cleaning process it is possible to make use of the difference in water levels up- and downstream of the screen. This ensures that the cleaning process is activated as required. Manual cleaning is unfavourable for pump systems in continuous operation, as the water level has to be regularly checked and the screen cleaned by the operating staff. Timer controlled cleaning is also not sufficiently reliable.

3.
Discharge tube designs

The design configuration of Amacan pumps allows a wide variety of installation variants to be chosen with practically no boundaries set on a designer's creativity. Discharge tubes are not only made from metal materials - they can also be constructed with concrete elements. No matter which installation variant is chosen, it is important that the pump's support area in the tube, shaped as a 45-degree slope, is executed accurately.

3.1
Design variants

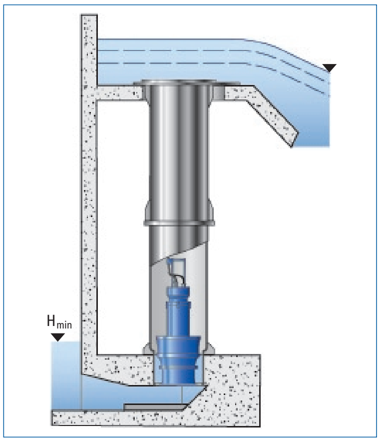


Fig. 3.1-a: Installation type A

The support ring is set in concrete in the intake chamber area, then the concrete tube elements are used to construct the discharge tube. Such a design variant may be suitable for use in simple drainage and irrigation pump stations.

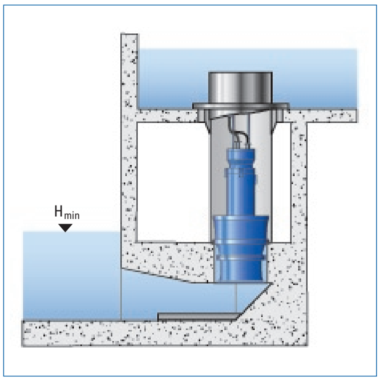


Fig. 3.1-b: Installation type BG

This illustration shows a covered intake chamber.
Here the discharge tube is, however, made from metal.

For this variant it is necessary that at the upper building level the discharge tube is appropriately sealed against the fluid pumped and supported to withstand the mechanical forces. The upper discharge tube edge has to be designed in accordance with the run-off conditions of the discharged fluid and the maximum flow velocities within the tube itself.

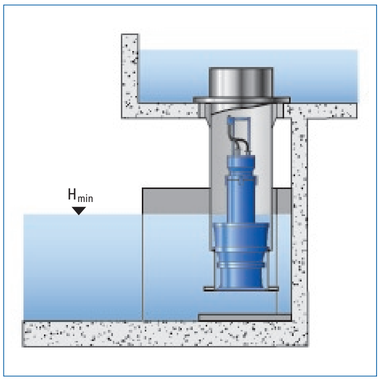


Fig. 3.1-c: Installation type BU

This discharge tube variant can, of course, also be employed in conjunction with open intake chambers. The final decision on the intake chamber design is taken on the basis of the required minimum water level relative to the volume flow rate of the pump and the approach flow direction (see diagram $t_1 = f(Q)$ in the type series booklet or selection software).

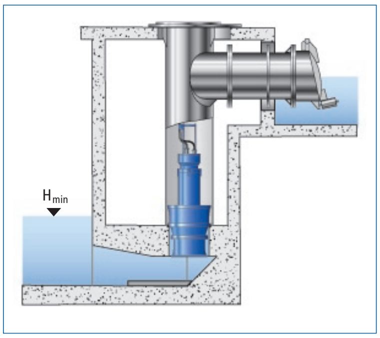


Fig. 3.1-d: Installation type CG

The next type of installation presented here is the underfloor installation. The horizontal discharge pipe outlet is situated below the upper building level. An additional, above-floor building structure, which is necessary in conventional pump stations, is not required here, resulting in a cost advantage.

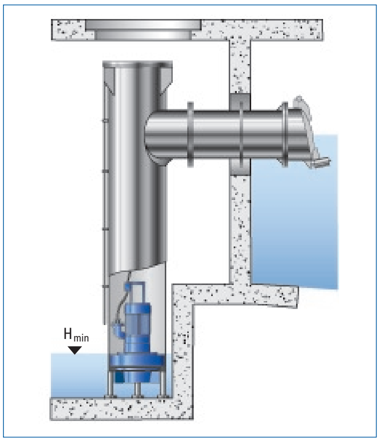


Fig. 3.1-e: Installation type CS

If the area above the pump station is intended for vehicular traffic, the discharge tube can, if necessary, be fitted with support feet resting on the floor underneath the inlet. After the discharge tube has been set up and mounted, the installation area is closed with a cover suitable for vehicles. The electrical cables are routed under the floor to the power supply.

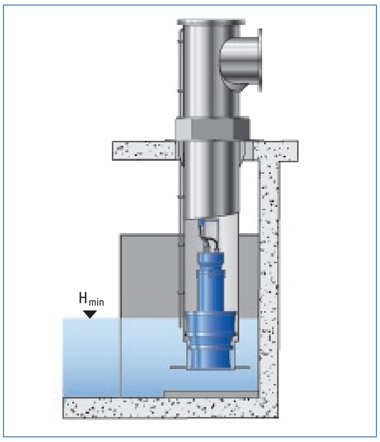


Fig. 3.1-f: Installation type DU

If some systems require the discharge flange to be connected above the floor, the installation type illustrated in Fig. 3.1-f can be chosen. A plate is mounted on the upper building level to accommodate the discharge tube forces. When deciding on the size of this plate it is important to consider the maximum forces developing during pump operation (pump weight, piping forces, torques resulting from pump operation, etc.).

3.2 Details on discharge tube design

The manufacturing quality of the discharge tube is important for the proper functioning of the pump or pump station. As the pump is centered and positioned in the discharge tube on a 45-degree bevel, resting on a rubber ring provided at the pump casing (the pump is seated by its own weight plus the axial thrust developed during pumping), particular attention must be given to this area during manufacturing. Poor concentricity and surface finish may cause the pump to rest on some points but not all of the inclined support area, resulting in inadequate sealing with some flow passing back to the suction side. As a consequence, the pump does not achieve the volume flow rate required for the connected system.

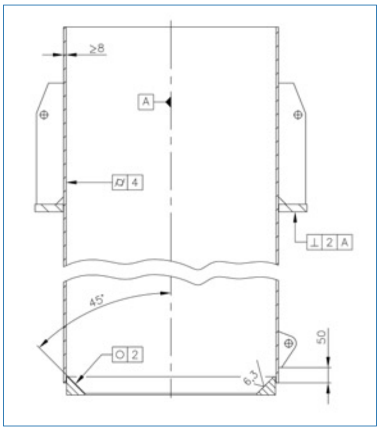


Fig. 3.2-a: Support area of pump in discharge tube for Amacan K

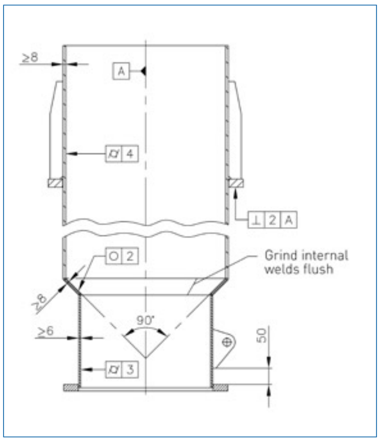


Fig. 3.2-b: Discharge tube in sheet metal construction for Amacan P / S

If the tube is a welded metal sheet construction, it is important to ensure that the welded seams in the 45-degree support area are level and true. The entire discharge tube should additionally be checked for concentricity. As thin metal sheets tend to be deformed by the welding process the metal sheet thickness should not be less than 8 mm.

Alternatively, it is also possible to make this support area as a turned part and to weld it to the discharge tube at the top and bottom. Making long discharge tubes from individual segments bolted together at their respective flanges is recommended to improve concentricity. These tubes are easy to install at site and the flanges provide additional mechanical stability in the radial direction.

For all discharge tubes closed with a cover it is vital to provide an adequate venting device. If this is not provided, a cushion of compressed air will develop in the upper discharge tube section. This has an effect similar to that of a spring and prevents the pump from running steadily. In extreme cases, vibrations may be caused which affect the entire discharge tube. As a remedial measure, a vent pipe is laid from the upper end of the tube down to the sump, or the discharge tube cover is fitted with a venting and aeration device. If a vent pipe is to be fitted, the additional space required must be taken into account when planning the access openings.

Fig. 3.2-c: Discharge tube fitted with valve for venting and aeration

If the installation depth of the discharge tube is more than 4 metres the tube should be centered and/or braced. This is particularly important in the case of stainless steel tubes which are used for their relatively thin walls. Due to these low wall thicknesses the natural frequency of the tubes may quickly reach excitation frequency levels (owing to the working principle of the centrifugal pump). The result is resonance accompanied by extreme vibration effects.

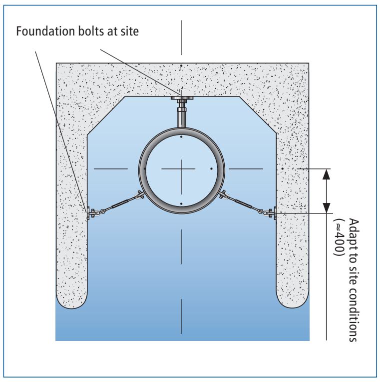


Fig. 3.2-d: Discharge tube bracing with turnbuckles

3.3 Cable connections

The pumps of the Amacan series are all equipped with an absolutely watertight cable entry system. This KSB patented system protects against the pumped fluid penetrating the motor space or terminal box of the pump if the cable insulation has been damaged during assembly or operation. The insulation of the individual cable cores is stripped and the wire ends are tinned. This section is fixed in the cable gland system with spacers and then embedded in synthetic resin. A rubber gland provides additional sealing.

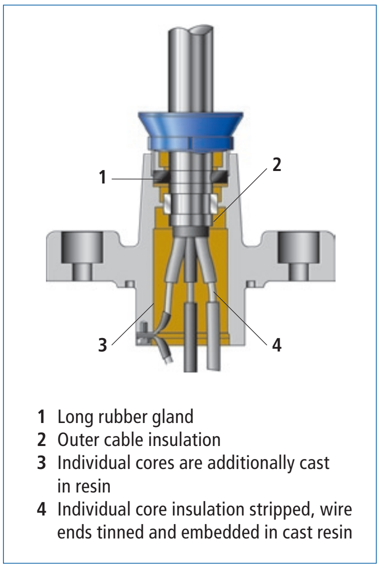


Fig. 3.3-a: Sectional drawing of an absolutely watertight cable entry system on a pump

This sealing principle is used for both power and control cables. When the pump is installed in the discharge tube, it is necessary to mechanically support the cables' own weight and at the same time protect them against flow turbulence. For this purpose KSB has developed a patented cable holder. The cables (power and control cables) are attached to a stainless steel carrier rope using rubber profiles and a clip. The rope is then screwed to the discharge tube cover or to a cross bar in the case of an open discharge tube. This guarantees that the cables have a long service life and the cable entry into the motor housing is absolutely tight.

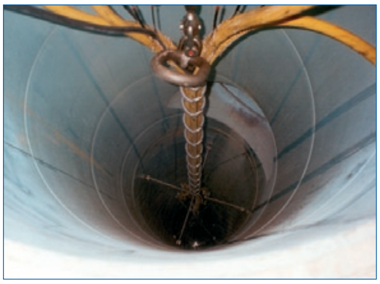


Fig. 3.3-b: Example of a rope with cable holder for an installation depth of 50 m

To ensure the cables are smoothly routed through the discharge tube cover either welded-in sleeves or shaped rubber gromets are used. The choice of cable passage depends in the main on the form of the discharge tube and the system pressure. If the tube variant is one closed with a cover, the cables must be supported by a separate holder underneath the cover to support the cables' own weight and protect them against flow turbulence in the discharge tube, as described above.

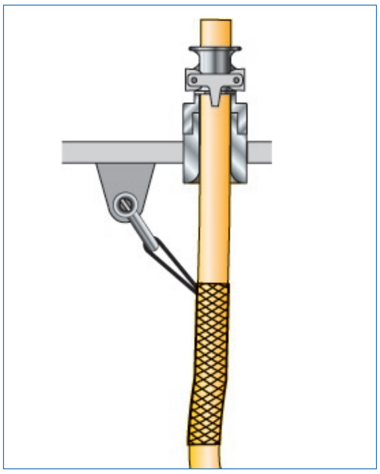


Fig. 3.3-c: Cable suspension and cable entry into discharge tube

If the discharge tube is open, the cables are routed vertically out of the tube and are then attached to a cross bar. If Amacan pumps are installed at greater installation depths, then additional supports should be fitted to hold the cable carrier rope in position. The object of these supports is to reduce the influence of the turbulent flow on the rope. These supports rest against the discharge tube wall.

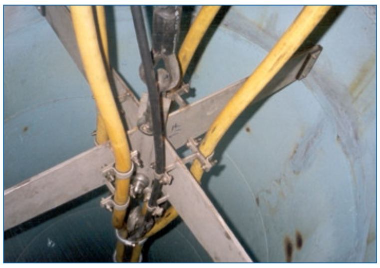


Fig. 3.3-d: Supports for cable guidance in the discharge tube

When ordering the pump it is necessary to specify the exact installation depth so that the precise length of the cables and ropes as well as the number of supports can be determined. If the specifications of both planning and execution stages differ, the following two situations may arise: If the rope is too short, the pump will not be firmly seated in the discharge tube and the reaction moment of the pump may damage the cables during start-up. If the cables are too long or not tight enough, the flow may cause the lifting rings of the cable assembly to hit against the discharge tube thereby damaging discharge tube, rope and cables.

In order to determine the correct number of lifting rings on the rope, it is also important to know the lifting height of the davit, lifting frame or crane.

If the components described above are not ordered along with the pump, other solutions may have a very negative influence on the pump's functioning. Power and control cables are, for instance, very often attached to the rope with simple cable straps; this, however, will lead to the destruction of the cable insulation and/or core breakage inside the cable during pump operation.

Fig. 3.3-e: Cable attachment using simple cable straps

For installation depths greater than 5 m the cable holder and carrier rope design becomes increasingly important for trouble-free pump operation.

4.
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Photographs

Pg. 15 Fig. 2.1-a : KaiserslauternTechnical University, Institute for Fluid Machinery
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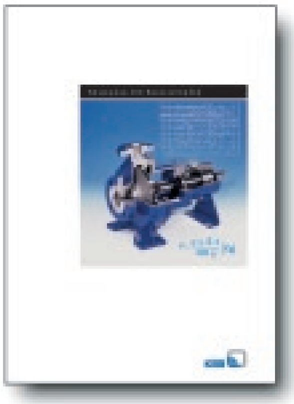

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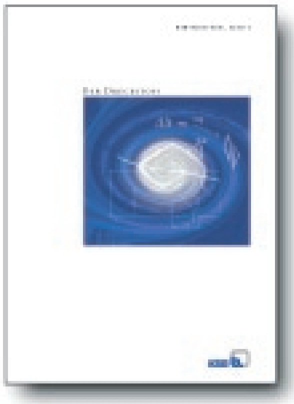

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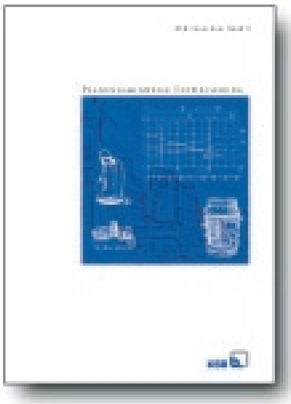

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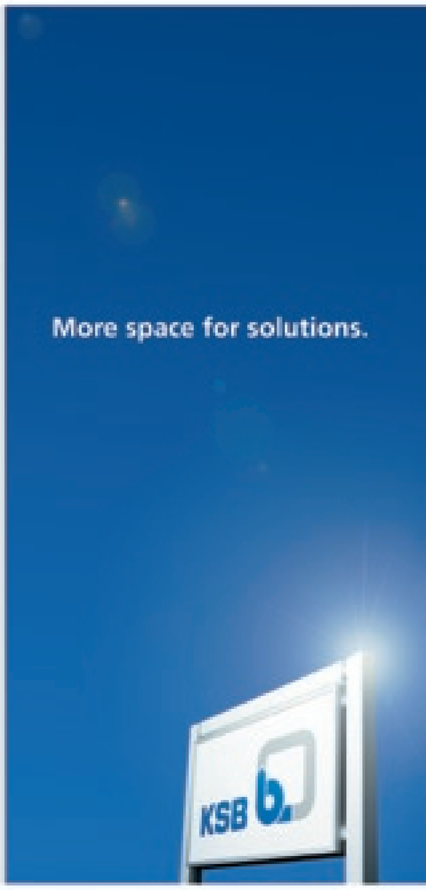

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