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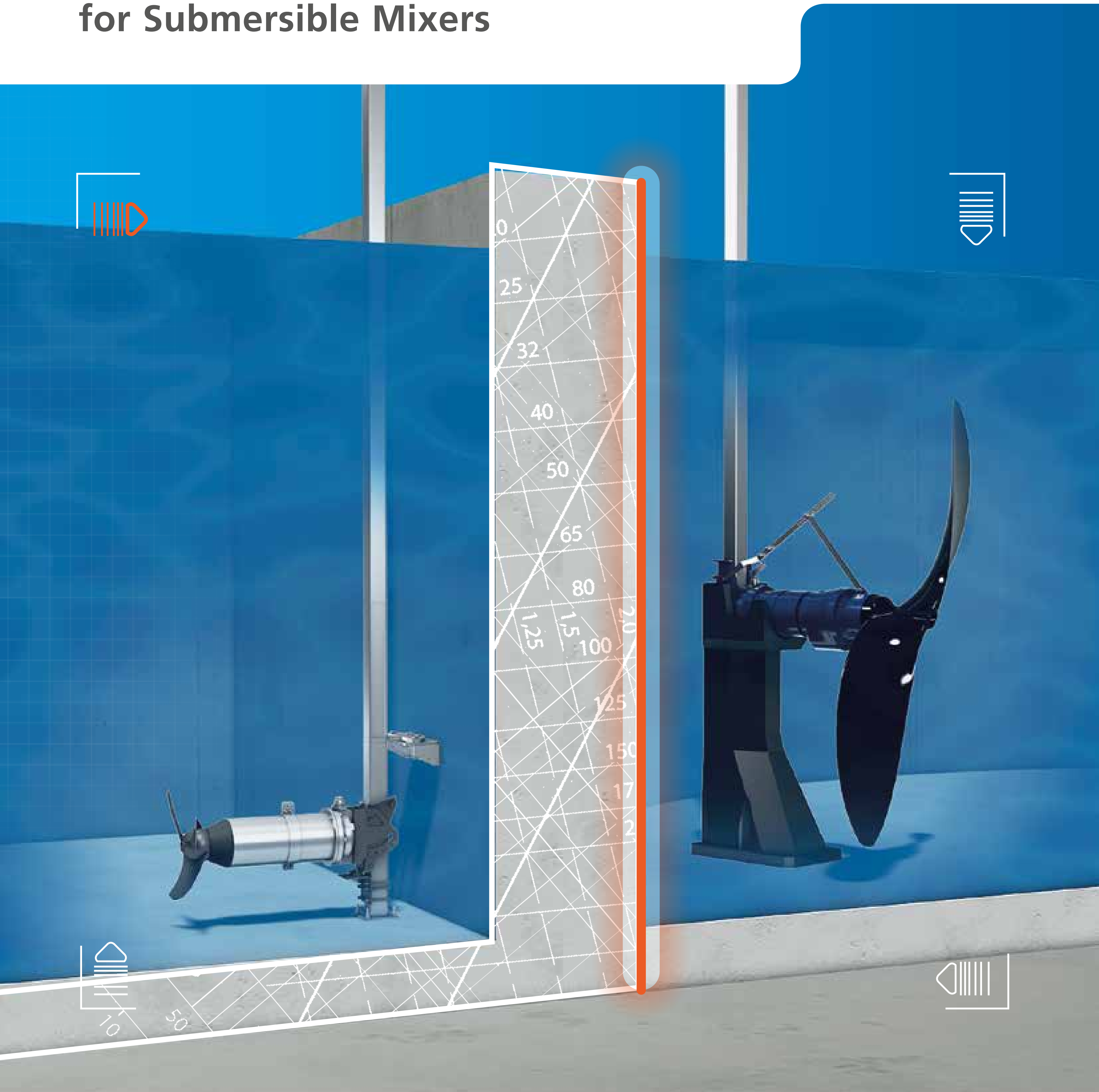
KSB Know-how: Planning Information for Submersible Mixers



Introduction

This planning aid serves to explain the different ways and options of using submersible mixers in municipal waste water treatment plants. It is important to distinguish between mixers used in a simple storage tank and mixers employed in the biological treatment stage.

KSB's mixer range comprises small higher-speed mixers without gears and large low-speed mixers with gears. Both of these variants are designed as compact, close-coupled mixer sets whose submersible motors are cooled by the surrounding fluid.

The large propellers of the Amaprop mixers provide high flow rates and efficient flow acceleration in biological waste water treatment tanks.

The smaller mixers of the Amamix series cover a large range of applications. They are available in grey cast iron as standard or as a robust stainless steel variant for special requirements.
The product range also includes installation accessories for all tank types.

Guide rail installation facilitates access to the mixers; pulling the mixer set up is sufficient for checks and servicing. The three-stage sealing concept, comprising two mechanical seals and a lip seal, allows for long service intervals.

This brochure intends to provide the reader with a basic understanding of submersible mixer applications and of where to position the mixers in a tank, depending on the specified tank size.

The know-how volumes can easily be downloaded or ordered here: www.ksb.com/know-how

Fig. 1: Accessories set 6

Fig. 2: Accessories set 7

1. Amamix submersible mixer

Amamix is a direct-driven, close-coupled, horizontal, fully floodable submersible mixer with self-cleaning ECB (Ever Clean Blades) propeller. An explosion-proof version to ATEX II 2G T4 is available. The mixer is driven by a highly reliable pressure-tight and encapsulated three-phase asynchronous squirrel-cage motor with resin-sealed, absolutely water-tight cable entry and temperature sensors to prevent the motor from overheating. Additional safety is provided by two bi-directional mechanical seals in tandem arrangement with a liquid reservoir. Environmentally friendly white oil is used for the oil fill. The mixer's rolling element bearings are grease-lubricated for life, and its stainless steel screws are easy to undo even after years of operation. It is available in either a grey cast iron or a stainless steel housing, usually with a stainless steel propeller.

Technical data

Fluid temperature	40 °C max. (optional: 60 °C)
Speed	475 to 1400 rpm
Power rating	1.25 to 10 kW
Nominal propeller diameter	225 to 630 mm
Installation depth	30 m max.

Explosion protection to ATEX

Optionally available with jet ring and frequency inverter

Amamix accessory sets

Accessories set 6

- Floor mounting
- With horizontal swivelling option
- Fixed vertical installation height

  Precondition: Place of installation is accessible (e.g. stormwater relief structures)

Accessories set 7

- Mounted on the benching and on the sump/tank wall
- Continuously adjustable installation depth and adjustable jet direction
- The submersible mixer can be lifted out of the tank or sump for maintenance and inspection work.

Accessories set 22

- Mounted on the sump/tank wall and on the inclined tank floor or only on the sump/tank wall
- Continuously adjustable installation depth and adjustable jet direction
- The submersible mixer can be lifted out of the tank or sump for maintenance and inspection work.

Accessories set 22 – Pitch adapter

- For upward or downward pitch adjustment in increments of 10° from 40° upwards to 40° downwards (Amamix 600 G: 15° or 30° upward or downward pitch)

Fig. 3: Accessories set 22

Fig. 4: Pitch adapter

Fig. 5: AmaRoc

Fig. 6: AmaRoc with guide rail

Fig. 7: QR code leading to the "AmaRoc installation" animation

2. Amaprop submersible mixer

The self-cleaning ECB (Ever Clean Blades) of this submersible mixer's propeller are made of glass fibre reinforced epoxy resin with metal hub insert and protective gel coating, which makes them both light and robust. High operating reliability is the outcome of a design with two bi-directional mechanical seals with oil reservoir filled with environmentally friendly oil, a leakage chamber between gear unit and oil reservoir, temperature monitoring of the three-phase asynchronous motor, and an absolutely watertight cable entry. The AmaRoc accessory made of the innovative NoriRoc material ensures a stable mixer position and a very long service life.

Technical data

Speed	24 to 208 rpm
Power rating	1.25 to 20 kW
Propeller diameter	1000 to 2500 mm

ATEX-compliant version available. The mixers are suitable for operation on a frequency inverter.

AmaRoc accessory

AmaRoc is designed for stationary installation on a horizontal tank floor, either free-standing or with an upper guide rail bracket.

The monolithically cast submersible mixer stand is made of NoriRoc.
It has got integrally cast metal bushes for fastening the stand to the tank floor and flexible locating bushes for holding the guide rail.

Fig. 8: AmaRoc installation heights 1450 mm, 1800 mm and 1100 mm

The submersible mixer stand is fastened to the tank floor with chemical anchors.

AmaRoc can be used free-standing, without upper holder (for square guide rails < 7 m) or with upper holder mounted on the tank wall or bridge (generally required for square guide rails ≥ 7 m, optional for square guide rails < 7 m).

Amaprop is available for three different shaft centreline heights:
Shaft centreline height = 1100 mm (Amaprop 1200 ... 1801 only)
Shaft centreline height = 1450 mm
Shaft centreline height = 1800 mm

Fig. 9: Amaprop installation

Propeller mounting/removal

For transporting the Amaprop mixer the propeller should be removed from the shaft.

To do so, the mixer should be in an easily accessible position with suitable supports under the gear unit and guide rail bracket. First, the protective caps are removed from the hub and the outer mechanical seal. To facilitate removal of the propeller, the hub contact surface on the shaft should be cleaned. The nut can then be removed from the shaft, and the propeller can be pulled off. To facilitate mounting the propeller at a later stage the key in the shaft keyway should point upwards. If the propeller is hard to pull off, a forcing screw can be used.

When pulling on the propeller, its seat on the shaft should be clean. A propeller fitting tool can be used for mounting the propeller. When the propeller has reached its final position, the nut can be screwed onto the shaft again, and the protective caps can be fitted.

Given the low weight of the propeller it can also be fitted or removed without using a propeller fitting tool or forcing screw, respectively.

Fig. 10: Amaprop

Fig. 11: QR code leading to the “Amaprop” animation

Fig. 12: Typical tank of a waste water treatment plant (Henderson, NV)

3. Processes and applications

As one of the leading manufacturers of submersible mixers, KSB offers all-in solutions for mixer applications.
Apart from continuously developing its submersible mixers KSB offers in-depth know-how in application and system engineering as well as in the selection of mixer systems.

This know-how is based on comprehensive research, practical experience from thousands of installations and a thorough knowledge of modern mixing technology.

Basics of the mixing process

The movement of liquids (here defined as "flowing fluids") is initiated by a flow-generating system.

To create some awareness of just how significant mixing is, there are very few products that do not require any mixing at all in their production or subsequent refinement processes. The simplest form of mixing can be as elementary as mixing ingredients in the kitchen using a stick blender or wooden spoon. This is still "state of the art" for certain applications.

However, if a larger volume requires mixing, using a suitable mixer set is essential. Applications range from milkshake mixers to large mixer trucks supplying building sites. The present document focusses on submersible mixer technology and its applications.

To be able to optimise a mixing process all parameters influencing that process have to be known. Figure 12 shows a typical activated sludge tank in operation. A simple glance at the surface will not tell us whether this an anoxic, anaerobic or even an SBR tank. In addition, considerable flow obstructions could be located directly underneath the water surface.
Having only information regarding the surface will always jeopardise the success of a mixing process. In contrast, gaining a complete picture will lead to economically advantageous solutions with good process results.

Fig. 13: Rotifers 1

Sludge treatment

Waste water treatment produces primary sludge, secondary sludge and grease.

Fig. 14: Rotifers 2

Primary sludge is mainly composed of faeces.

The terms secondary or excess sludge define excess micro-organisms that are removed from the treated water after the final clarification stage.

All sludges produced in biological waste water treatment in their entirety are referred to as raw sludge. The individual sludges or a mix of them (mixed sludge) can be transferred to sludge treatment.

In sludge treatment, water is removed from the sludges. The sludges thicken. The thickening process reduces the volume of sludge to be treated and increases its dry solids content.
Sludges can essentially be thickened using either static or mechanical dewatering.

In static dewatering the raw sludge is stored in a tank. Gravity causes heavy particles to sink to the tank floor. The clear water occurring at the surface is then withdrawn with a decanter, thus creating new storage volume.
The dry substance content achievable in this process depends on how long the sludge remains in the tank.

Fig. 15: Vorticella

Fig. 16: Thecamoeba

Depending on the size of the sludge storage tank in relation to the size of the waste water treatment plant, dry solids contents of approximately 5 % can be achieved.

As large waste water treatment plants continuously generate large volumes of sludge, the following rule of thumb can be used: The larger the treatment plant, the shorter the time the sludge is stored.

For this reason large waste water treatment plants often opt for mechanical sludge dewatering. In mechanical dewatering the collected sludge is dewatered using a screening drum, centrifuge or belt press. To optimise the mechanical dewatering process polymeric flocculants are often added. Being conducive to the formation of sludge flocs they facilitate dewatering.

Mechanical dewatering is commonly used in large waste water treatment plants. Given the large volume of raw sludge large waste water treatment plants without mechanical dewatering would need very large sludge storage tanks to achieve significant thickening rates.

In addition, large-scale waste water treatment plants also use digestion tanks (digesters). In the digestion tank, thickened raw sludge is heated up to a temperature of 36 - 37 °C and continuously recirculated by special mixers or pumps. The frequently chosen egg shape aids with convection and facilitates recirculation. In the digestion process part of the organic mass (approx. 30 – 50 %) is decomposed and converted into gas (primarily methane).

The digester gas is then used to generate electricity and heat for the treatment plant in combined heat and power stations.

After the digestion process (up to 20 days in the digestion tanks) the so-called digested sludge is removed from the tanks. It is thickened once again (static dewatering by sedimentation) and mechanically dewatered (centrifuges, chamber filter press, travelling screen press). It is then usually burned.

Raw sludge from treatment plants without digestion tanks is either dewatered directly and disposed of, or it is taken to the digestion tanks of another waste water treatment plant.

Mixers can be found in all tanks that are used for storage and thickening. The mixers' task is to homogenise the tank content in order to make its dry solids content as consistent as possible for subsequent treatment processes. In addition, deposits on the tank floors are to be prevented.

To carry out the above mixing task the mixers in these tanks are usually only used in the draining process. The dimensions of mixers required depend on the maximum dry solids content, the type of sludge and any polymeric flocculants used.

Polymeric flocculants not only cause the formation of sludge flocs, they also change the sludge viscosity. Polymer-thickened sewage sludge is much harder to homogenise than statically thickened sewage sludge with the same dry solids content.

The dry solids content of secondary sludge is composed of organic substances (micro-organisms) and mineral substances. The organic dry solids content (ODS / loss on ignition) of regular secondary sludge is 70 - 80 %.

As mentioned before, approx. 30 - 50 % of the organic mass is converted into gas in a digester. This means the digested sludge has a higher mineral percentage than the raw sludge.

A similar effect occurs when the raw sludge remains in the sludge storage tank for a very long time (6 - 12 months). In this case, too, digestion converts some of the organic mass into gas. This gas escapes to the atmosphere without being used.

In either case a higher percentage of minerals has to be taken into account when dimensioning mixers.

Fig. 17: Sludge dewatering

Fig. 18: QR code leading to the "Sludge types" animation

Sludge types and properties

The images show a set-up for determining the sludge volume index (SVI).

The SVI describes the settling characteristics of solids in sludge. The smaller the numerical value, the faster the solids sink down, leading to a clear water zone in the upper part of the container. A small SVI can indicate a high mineral percentage of the solids contained.
These solids are heavier and require a higher flow velocity.

The loss on ignition can also provide information on the percentage of organic matter in the solids.

In general the following applies: Organic solids are easy to mix; mineral substances are hard to mix or cannot be mixed at all. The reason is the difference in density of water and solids.

One of the key characteristics is the dry solids content (DSC) of the sludge. In waste water treatment engineering the DSC can be used to deduce the sludge viscosity.
This is important for the flow behaviour of the sludge and for selecting the right mixer.

Exceptions are the polymeric flocculants required for mechanical thickening, which can drastically increase the viscosity of the sludge. In this case, the flow behaviour as well as sufficient motor power reserves must be taken into account.

Biological treatment stage

Basics:

Most impurities in waste water are of an organic nature and are purified by micro-organisms in combination with dissolved oxygen and in the absence of oxygen, respectively. Conversion processes essentially break down the compounds listed below.

Fig. 19: Activated sludge tank

For optimum metabolism and for the sewage plant to work efficiently, the bacteria require a nutrient ratio of C : N : P = 100 : 5 : 1.

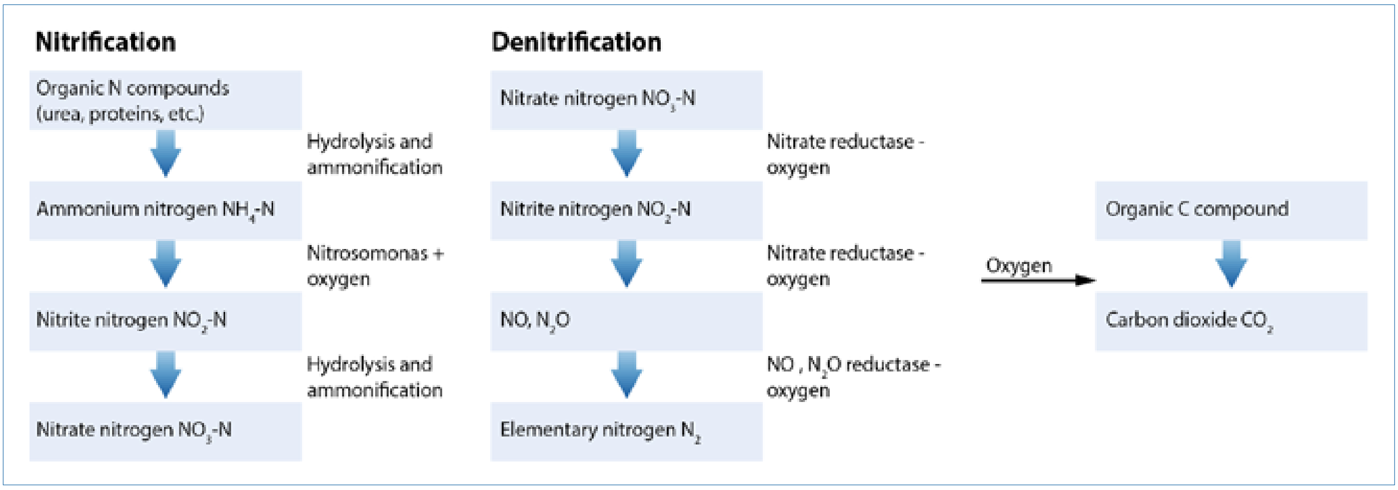


Fig. 20: Breakdown processes during nitrification and denitrification

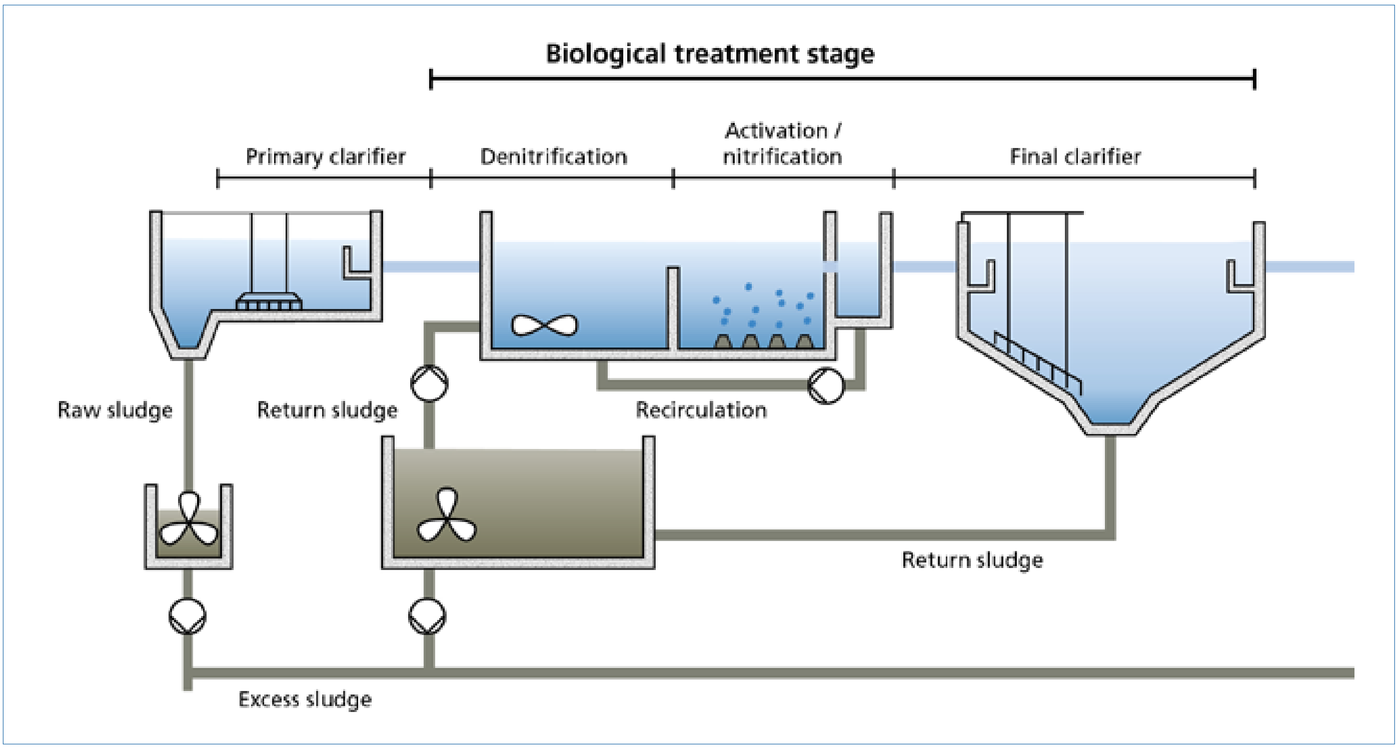


Fig. 21: Processes of the biological treatment stage

Primary clarifier

In primary clarifiers, the finest mechanical particles are separated using sedimentation.
The substances deposited on the bottom of the tank form the primary sludge. This raw sludge is conveyed to the digester via the pre-thickener.

Nitrification

Nitrogen is oxidised into nitrate in two stages by the microbes Nitrosomonas and Nitrobacter.
This process happens in two stages:

$$2NH_4^+ + 3O_2 \xrightarrow{\text{Nitrosomonas}} 2NO_2^- + 2H_2O + 4H^+$$ Formula (1)

$$2NO_2^- + O_2 \xrightarrow{\text{Nitrobacter}} 2NO_3^-$$ Formula (2)

Key:
NH_4^+ = Ammonium
O_2 = Oxygen
NO_2^- = Nitrite
H_2O = Water
H^+ = Acidic hydrogen
NO_3^- = Nitrate

Denitrification

Aerobic micro-organisms break down carbon and produce molecular nitrogen that is released into the atmosphere.

$$4H^+ + 4NO_3^- + 5C \xrightarrow{\text{heterotrophic bacteria}} 5CO_2 + 2N_2 + 2H_2O$$ Formula (3)

Key:
H^+ = Acidic hydrogen
NO_3^- = Nitrate
C = Carbon
CO_2 = Carbon dioxide
N_2 = Nitrogen
H_2O = Water

Final clarifier

The final clarifier is the last stage of biological treatment.
Treated water flows continuously from the activated sludge tank into the final clarifier. Here, the sludge and the micro-organisms sink to the bottom and the clarified water flows out via the tank's drain channel.
The sludge is evacuated from the bottom of the tank and either fed back into the activated sludge tank or pumped into the sludge lagoons.

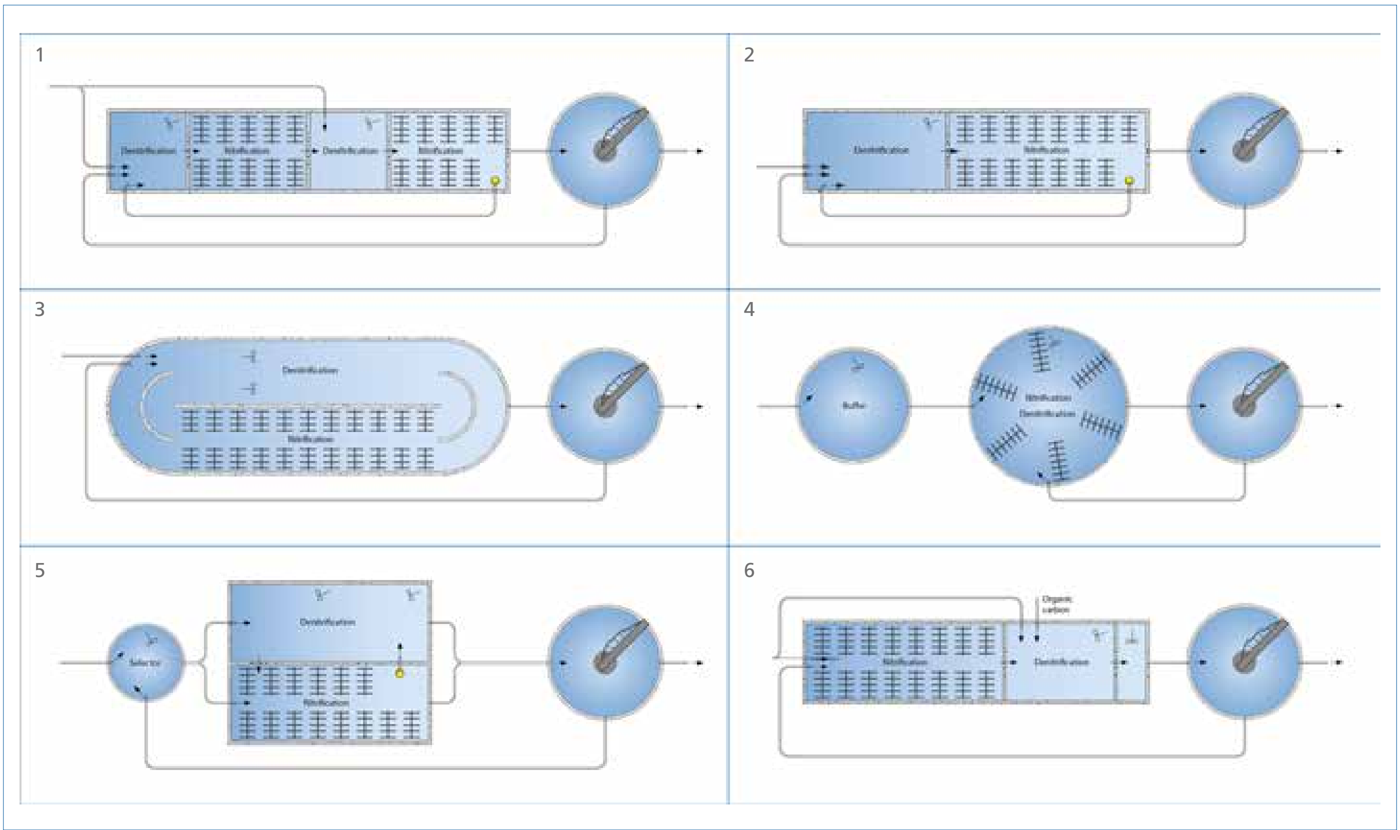


Fig. 22: Different tank arrangements in the biological treatment stage

1. Cascade denitrification
In the first tank the return sludge is denitrified.
In further denitrification tanks, the nitrate formed in upstream nitrification tanks is denitrified. Internal circulation is not required.

2. Upstream denitrification
In the upstream denitrification stage sufficient carbon is fed into the denitrification tank from the oxygen-rich nitrification tank via recirculation pumps.
Additional carbon dosing, as in the downstream denitrification stage, is not necessary.

3. Aeration (systems) in activated sludge tanks
According to DIN 4046, aeration generally refers to the gas exchange between water and air to introduce oxygen and, if applicable, remove dissolved gases.

Waste water can be supplied with air:

- For the chemical oxidation of inorganic compounds; and
- To supply micro-organisms with sufficient oxygen.

Aeration systems cause friction losses depending on their operating mode (simultaneous or intermittent operation).
Generally, these losses can be divided into:

- Constant losses: Flow losses are caused by the aeration type (disk, plate or tube-type air diffusers) and the area covered.
- Variable losses: These vary depending on the air input.

The losses listed above must be considered when selecting mixers suitable for achieving a flow velocity of 0.3 m/s in activated sludge tanks in line with VDMA 24656.

Over the past few years, KSB has created selection algorithms, validated in flow measurements, for the different mixer sizes installed in various tank geometries.

Simultaneous denitrification
In the tanks with circulating flow, nitrification takes place in the zones supplied with oxygen while, at the same time, denitrification takes place in the zones without oxygen. The oxygen content is controlled in such a way that certain areas of the tank contain no dissolved oxygen.

4. Intermittent denitrification
In this case, nitrification and denitrification occur in the same tank, one after the other (sequence batch reactor).
The activated sludge tank is usually designed as a round tank with fine-bubble aeration from the floor and a submersible mixer.
The processes either run separately via a timer or are controlled by oxygen and redox potential.

5. Alternating denitrification
Alternating denitrification systems consist of two activated sludge tanks that are alternately filled with waste water and aerated. Waste water and nitrate-loaded return sludge from the pre-clarification stage are mixed in tank 1 without aeration – denitrification takes place. At the same time, tank 2 is aerated – nitrification takes place. As soon as the sensors in tank 1 show that all nitrate has been removed, both tanks are briefly aerated. Subsequently, the process is performed in reverse: nitrification in tank 1, denitrification in tank 2.

6. Downstream denitrification
Most of the carbon contained in the waste water is broken down in upstream nitrification. The nitrate formed in the process is then broken down in the downstream denitrification stage. In this procedure, nitrate respiration is not sufficient for complete denitrification due to a lack of carbon. Therefore, organic carbon must be added from an external source. For example, waste water from breweries or dairies is ideal for use as an external source.

Physical fundamentals:

- Without any external forces acting on it an air bubble or gas bubble in a liquid can only rise vertically.
- Without any external forces acting on it a swarm of bubbles in a liquid can only rise vertically.
- Existing vertical flows (forces) influence the rising velocity positively or negatively, depending on their direction. In other words, a vertical flow directed downwards towards the tank floor reduces the rising velocity and a flow directed upwards towards the surface increases it.
- Existing horizontal flows (forces) do not influence the rising velocity of gas bubbles.
- Flows are vectors.

When looking at an individual air or gas bubble, we can see that the rise of a bubble can be defined as a function of its expansion and that it will rise to the surface at the corresponding velocity.

Figure 23
The illustration shows bubbles that were injected into the liquid at equal time intervals, rising to the surface.

S ==> Distance travelled by the air in cm
v_{Air} ==> Rise velocity in cm/s
t ==> Time in the liquid in s

According to the laws of physics, the time the bubbles spend in the liquid will not change if a horizontal flow is introduced into the system.
Figure 24 shows a horizontal laminar flow into which bubbles are injected at equal time intervals and rise to the surface.

When looking at the flowing liquid in volume sections per time unit, we can see that the bubbles in this segment rise vertically to the surface at the rise velocity.

At the same time we can see that the bubbles seem to follow a diagonal movement along the resultant force of rise velocity and horizontal flow.

V ==> Volume section per time unit in m^3

The distance travelled by the bubble is equal to the distance it travelled in figure 23.

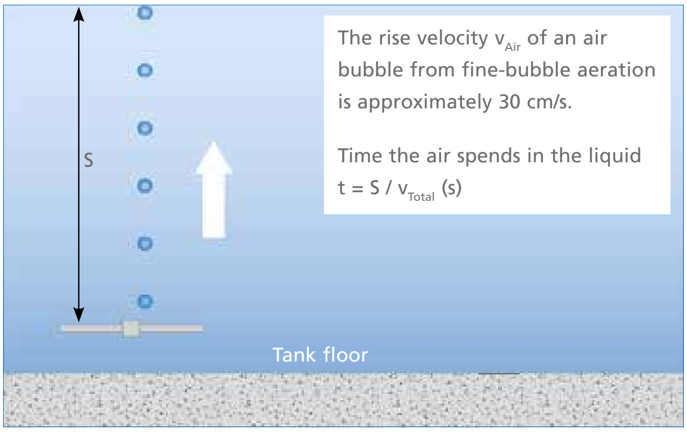


Fig. 23: Rise of an air bubble

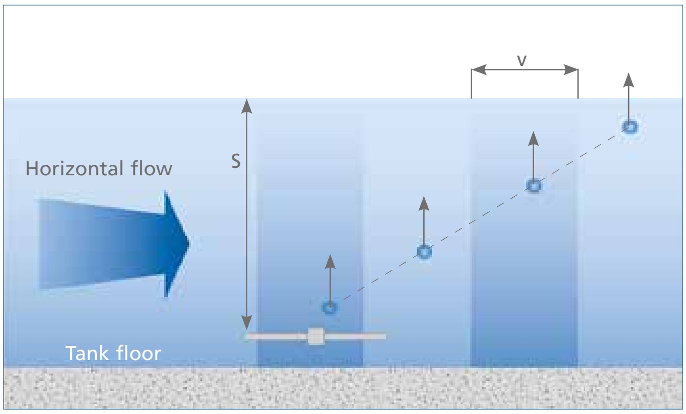


Fig. 24: Rise of an air bubble in a horizontal flow

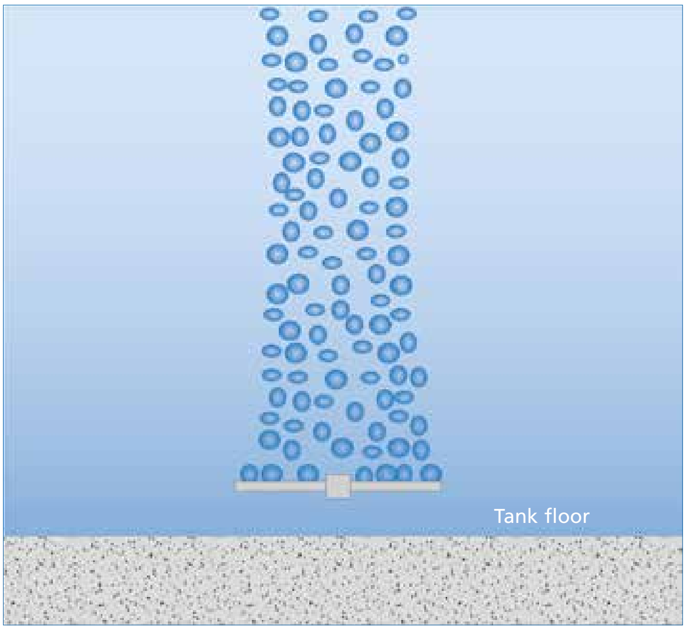


Fig. 25: Aeration jet

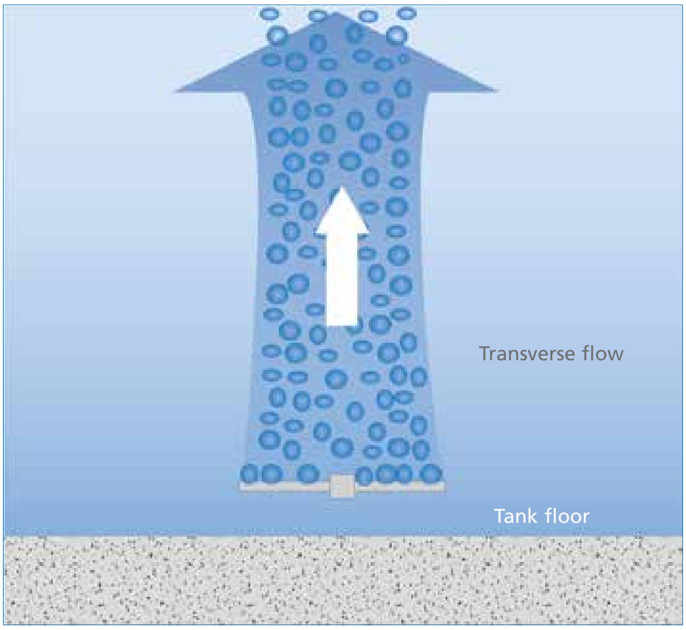


Fig. 26: Aeration jet with induced vertical flow

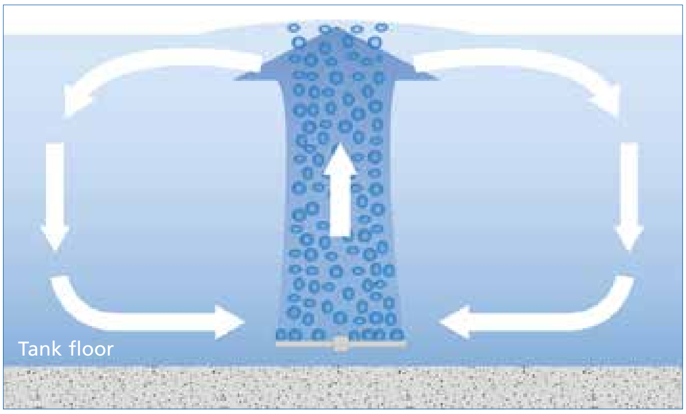


Fig. 27: Aeration jet with swirl-type flows

As the flow is turbulent in real-life applications, studying a laminar flow can only serve to prove the theoretical knowledge that a horizontal flow does not influence the time bubbles spend in a liquid.

From the point of view of process technology, are there any advantages of adding horizontal flows?

1. Solids and sludge are kept in suspension.
2. Bacteria are supplied with new substrate.
3. The time the bubbles spend in the liquid is longer.

Points 1 and 2 shall not be discussed any further.

Why do the bubbles actually spend more time in the liquid?

In practical applications, an individual bubble must be evaluated in conjunction with entire swarms of bubbles and the flow generated by the rising air itself.

Figure 25

Figure 25 shows a single aeration jet in an activated sludge tank.

The rising air creates a flow towards the surface.
At the surface the water-air mixture expands in the form of a swell. The liquid is moved towards the surface along with the rising air and equivalent liquid flow is sucked up from the bottom of the tank.

Figure 27

A swirl-type flow is present on both sides, which makes the air rise to the surface faster.
These swirl-type flows can reach a flow velocity of up to 60 cm/s.

Flows are vectors. This means the flow velocities can be added up.

	Rise velocity of air	30	cm/s
+	Flow velocity of swirl-type flows	60	cm/s
=	Total flow velocity	90	cm/s

Time the air spends in the liquid

$t = S / v_{Total}$ (s) Formula (4)

Key:
t = Time spent in the liquid
S = Length of floor aerator
v_{Total} = Velocity

The time the air bubbles spend in the liquid is reduced by the proportion of the flow velocity of the swirl-type flow to the total flow velocity.

Figure 29
Now if a horizontal flow is added to these fluid mechanics, the shape of the swirl-type flows changes. Or in the ideal case, swirl-type flow will be completely neutralised and fluid dynamic conditions will arise which are similar to those of laminar flows.

Without the swirl-type flow, the time the bubbles spend in the liquid is increased by the proportion of the flow velocity of the swirl-type flow to the total flow velocity.

This condition depends on the buoyancy energy of the air bubbles and the transverse flow generated by the mixers.

The flow within the aeration field is very turbulent. Turbulence eddies are increased by the aeration, resulting in a substantial increase in both macro and micro turbulence.

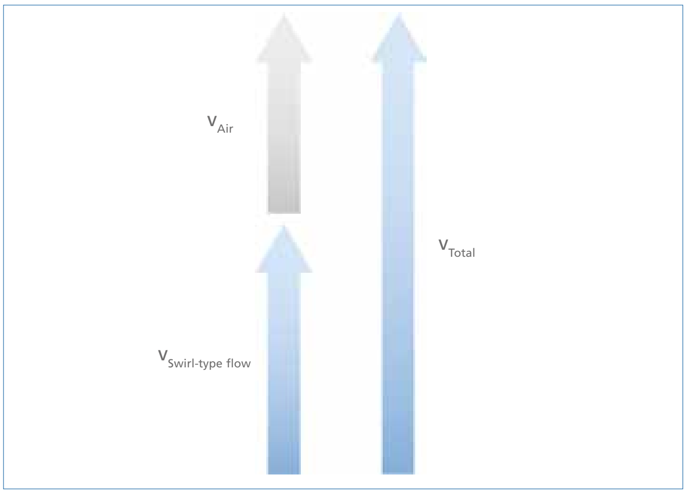


Fig. 28: Rise velocity of air

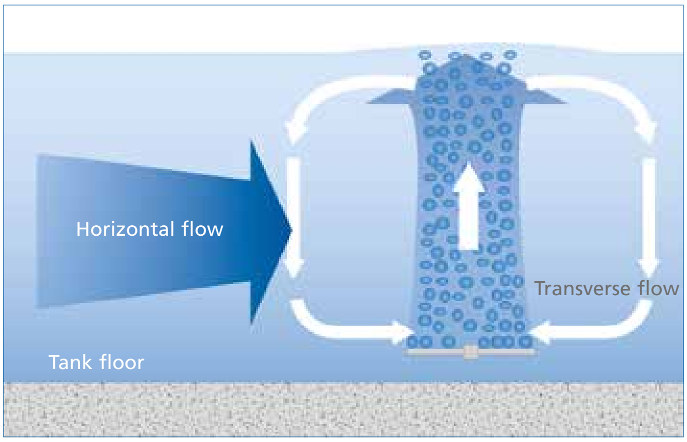


Fig. 29: Flow superposition

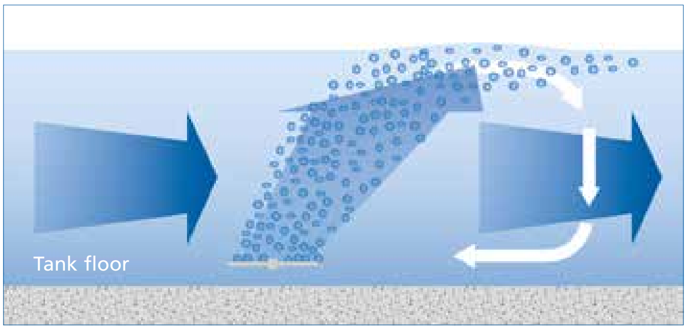


Fig. 30: Formation of a dipolar flow

Fig. 31: Tube-type diffuser

Fig. 32: Supratec plate diffuser

Fig. 33: Disk diffuser

Figure 30
The horizontal flow causes the swarm of bubbles to drift away with the flow. On the front, the swirl-type flow is neutralised or nearly neutralised. On the rear side, the swirl-type flow continues but changes its shape and expansion.

The time the bubbles spend in the liquid increases due to the reduced vertical flow.

Aeration systems

Depending on the design of the waste water treatment plant it is possible for nitrification and denitrification to take place in the same tank. These processes can be alternating or in parallel.

KSB does not manufacture aerators but has many years of experience of using its mixers in combination with the most diverse of aeration systems.
Primarily, aerators can be divided into two different designs: surface aerators and subsurface fine-bubble diffusers.

Surface aerators introduce air via rotating aeration elements (vertical shaft / horizontal shaft / brushes). They are used to push the mixture of activated sludge and water up into the air, creating a mist of droplets.
Given their function such aeration systems are usually employed in tanks of a relatively low depth (2.5 m to 4 m).

The flows caused at the surface depend on the surface aeration system selected. If parallel operation is planned, these flows must be taken into account when positioning the mixers.
Depending on the propeller diameter a turbulent approach flow subjects the mixer set to a higher load, which will have a negative impact on its service life.

In the case of subsurface aeration, oxygen is supplied by disk, tube or plate type air diffusers. Compressors supply these diffusers with compressed air.
The diffuser elements are usually fitted with membranes designed to generate bubbles as fine as possible to increase the efficiency of the diffuser.

The reason is the favourable ratio of surface to enclosed air volume. In other words; the smaller the bubble generated, the better the oxygen transfer.
As the diffuser elements are mounted on the tank floor, the air bubble can only transfer oxygen to the surrounding mixture of activated sludge and water while it is travelling upwards towards the surface.
This leads to the conclusion: The deeper the tank, the higher the oxygen intake.

The parallel operation of mixers and fine-bubble air diffusers is challenging for several reasons:

Unlike water, air is compressible. When operating mixers and diffusers in parallel a certain safety distance to the diffuser field must therefore be observed.

Otherwise air bubbles could enter the propeller area and be compressed on the discharge side. Depending on the quantity of air bubbles this would reduce the mixing energy generated by the mixer. Logically, it would also subject the propeller to alternating stress. Depending on the propeller diameter this increases the load on the mixer set and will have a negative impact on its service life.

The tractive force of a rising air bubble takes water up to the surface along with the bubble. At the same time water has to flow down to the diffuser to displace the volume of the air injected. Due to this principle, a vertical swirl-type flow forms above the diffuser field during operation. The strength of this swirl-type flow depends on the aeration density (m^3 air / m^2 tank / hour).

As soon as the flow jet of the mixer hits the swirl-type flow described, increased local turbulences occur.
There is no evidence of bubbles “shearing” above the diffuser. Analyses have shown that, in the ideal case, the flow generated by the mixer is diverted to the surface and passes the field there.

This requires a suitable, unaerated distance for the flow to travel, so the flow jet can expand as much as possible, transmitting as much mixing energy as possible to the mixture of activated sludge and water by means of horizontal thrust.
Otherwise a large share of the mixing energy would be dissipated as strong local turbulence (friction).

In this context it has to be pointed out that subsurface fine-bubble aeration uses many times the energy of mixers.

Given the above facts we recommend not to use mixers and subsurface aeration in parallel.

If this is unavoidable the above facts must be taken into account. The mixer manufacturer should be involved as early as possible in the planning phase.

We would like to conclude this section by explaining a few general issues.

Given the described differences, conversion from surface aeration to subsurface air diffusion can be very difficult.

As has been explained, an air bubble can only transfer oxygen to the surrounding fluid while the air bubble is rising. If the tank is not deep enough, oxygen intake will be low.
This problem can only be partly countered by increasing the aeration density.

A higher aeration density will logically generate a larger number of bubbles. However, the larger number of bubbles will lead to a collision of bubbles, creating large bubbles, which decrease the quality of oxygen input.

Also, high aeration loads per unit area cause a strong vertical flow above the aeration field as described. This can lead to a sufficiently aerated mixture of activated sludge and water being “trapped” in the swirl-like flow with hardly any oxygen being transferred. To reiterate:
The nitrification process is carried out by micro-organisms that need oxygen for the conversion process.

Although mixers can be slightly beneficial to the oxygen transfer, they cannot accelerate the metabolism of micro-organisms.

Fig. 34: Installation preventing floating sludge

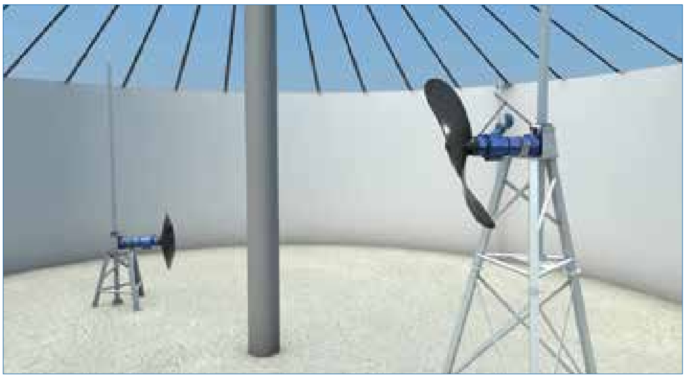


Fig. 35: Typical installation in a digester

Fig. 36: QR code leading to the “Biogas” animation

Biogas

Application and use of mixers

Biogas is produced by organic non-toxic material being biochemically digested by micro-organisms in the absence of oxygen. As this is a continuous process large quantities of the substrates used must be added to the reactors every day. To achieve favourable reaction conditions for the micro-organisms mixers take on a multitude of different tasks in biogas plants.

As one of the market leaders for energy-efficient low-speed submersible mixers, KSB has been actively involved in the biogas business for many years. To be able to serve this market even better, KSB works together with a distributor.

Drawing on KSB's experience, our partner selects optimum mixers and their positions for each plant and continuously develops the mixer technology further.

KSB distributor

As a specialised manufacturer for high-quality mixer technology with many years of experience in the toughest of applications PTM GmbH Halle (Saale) knows the requirements on advanced engineering in biogas plants inside out. Based on this application knowledge a mixer series was developed that combines maximum efficiency with a very long service life.

Behind this achievement are many years of experience, the best of materials and continuous product quality control.

In-house development – Propeller made of polyamide 12

Mixers in biogas plants are subjected to very particular requirements. In practice, especially long fibres and mineral substances such as sand and stones frequently damage propellers after a short time, leading to a short service life and high costs for mixer repairs or replacements. In response, a new propeller generation has been developed, made of highly wear-resistant polyamide 12 (PA12). This material is far superior to both metals and glass fibre materials and has solved the general issue of propeller longevity. This propeller easily outlasts its counter-parts on the market. In addition the hydraulic system ensures efficient and effective mixing results, also for the toughest of requirements. This is particularly interesting for simple retrofitting on installed mixers in order to further extend the mixers' service life.

PHANTOM – The mixer

PHANTOM is the most efficient submersible mixer of its class. In demanding applications this mixer is clearly superior to higher-speed or conventional low-speed mixers. Its unsurpassed service life and its high thrust/power ratio are not surprising. They are the result of many optimised components interacting.

Fig. 37: Propeller made of polyamide 12

Benefits of PHANTOM mixers at a glance

- Extremely wear-resistant propeller made of PA12 offers resistance to abrasion and corrosion at the highest thrust/ power ratio.
- Hardened mating ring carrier protects the mechanical seal from fibres.
- Double mechanical seal with covered spring is resistant to solids and fibres.
- Guide bracket with movable multiple rollers ensures free movability also in the case of contamination.
- Motor with high reserve provides full power also in high-temperature operation.
- Large cable cross-section markedly extends the cable life.
- Precision bearing ensures smooth operation also in the event of frequent load changes.

Applications of PHANTOM mixers

Suitable for all heavy-duty applications, e.g. in biogas plants (digester, post-digester, digestate storage) and/or for drilling fluid.

Product overview

PHANTOM 1000 horizontal submersible mixer

Applications:	**Mixing tank, digester, post-digester, digestate storage**
Fluid handled:	Digestion substrate
Maximum permissible temperature:	60 °C
Propeller speed:	166–204 rpm
Motor power P_2:	11–20 kW
Propeller material:	Polyamide 12
Propeller diameter:	1000 mm
Maximum axial thrust:	4500 N
Explosion protection:	II2G Ex d IIB T3

PHANTOM 1400 horizontal submersible mixer

Applications:	**Mixing tank, digester, post-digester, digestate storage**
Fluid handled:	Digestion substrate
Maximum permissible temperature:	60 °C
Propeller speed:	88–114 rpm
Motor power P_2:	6–20 kW
Propeller material:	Polyamide 12
Propeller diameter:	1400 mm
Maximum axial thrust:	5500 N
Explosion protection:	II2G Ex d IIB T3

PHANTOM 2500 horizontal submersible mixer

Applications:	**Mixing tank, digester, post-digester**
Fluid handled:	Digestion substrate
Maximum permissible temperature:	60 °C
Propeller speed:	42–46 rpm
Motor power P_2:	6–10 kW
Propeller material:	Polyamide 12
Propeller diameter:	2500 mm
Maximum axial thrust:	6000 N
Explosion protection:	II2G Ex d IIB T3

The compact TYPHOON mixer is the perfect solution for mixing applications with high turbulences in low-viscosity fluids containing abrasive substances.

Its propeller, made of highly wear-resistant polyamide 12, has been developed with state-of-the-art computer-assisted simulation methods and perfected in empirical practical tests.
Like the Phantom type series, TYPHOON mixers are equipped with a double mechanical seal and grease-lubricated bearings that are sealed for life. With its direct, gear-less drive the TYPHOON mixer is compact in design and can be operated without a soft starter or frequency inverter. This makes the TYPHOON mixer the optimum choice for digestate storage or mixing tanks.

Benefits of TYPHOON at a glance

- Propeller made of PA12 – Optimised propeller made of wear-resistant high-performance plastics for a perfect mixing result
- Double sealed – Two mechanical seals made of wear-resistant silicon carbide
- Direct drive – Compact design without gear wear
- Low-maintenance – No oil change required for up to 16,000 operating hours
- Explosion protection – ATEX-compliant as standard
- Monitoring – Three temperature and leakage sensors for motor monitoring
- Perfect protection – Absolutely watertight resin-sealed cable entry protecting the motor against moisture; simple replacement of cables during servicing without special tools

TYPHOON horizontal submersible mixer

Application:	Special design for digestate storage tanks
Fluid handled:	Digestion substrate
Maximum permissible temperature:	40 °C
Propeller speed:	475 rpm
Motor power P_2:	13 kW
Propeller material:	Polyamide 12
Propeller diameter:	650 mm
Maximum axial thrust:	2710 N
Explosion protection:	II2G Ex d IIB T4

Biogas portfolio

- Complete technical and commercial know-how for mixer selection and installation
- Feasibility studies and concept creation for new installations and plant repowering
- Computational Fluid Dynamics (CFD) flow simulations
- Rheological investigations
- Design and static verification of structures installed in the tank for special applications
- Large number of mixers on stock, enabling short delivery times

Ice prevention

In certain cases bodies of water or the inflow areas of pumping stations have to be prevented from freezing over in the winter months. This may be required to maintain access to ports or ship locks or to continue operating pumping stations, such as low-lift pumping stations used in flood control. Mixers can help with this task by making water from lower, warmer layers flow to the surface. Another positive mixing effect is the water movement on the surface, which also prevents it from freezing over.

Generally, even low flow velocities are sufficient for ice to be prevented. As ice prevention measures are usually employed in open waters, contact guards for the mixer propellers are often essential.

The losses caused by wire cages, pipes or similar protective guards should be taken into account during selection.

MBBR

MBBR stands for Moving Bed Biological Reactor. This is a tank with a high pollution load, which is used in the biological stage of a waste water treatment plant.
To achieve as high a density of biologically active substance as possible, so-called "carriers" are used. They are usually made of polyethylene and float just beneath the water surface.

The carriers, which are available in different shapes and sizes, should have as large a surface as possible. To enhance the exchange of nutrients the carriers must be kept moving by mixers.
Higher-speed Amamix mixers are not suitable as their stainless steel propellers would damage the carriers.
As the carriers impede the flow of the activated sludge, a flow velocity of more than 30 cm/s must be provided.

For thorough mixing the mixer propeller needs to force the carriers down into the depth of the tank, so they can slowly rise again in a different part of the tank.
For this reason an MBBR often requires a special variant of installation parts.

MBBR should not be confused with MBR, a Membrane Biological Reactor whose membrane holds back molecules larger than water. An MBR helps pollution loads to be reduced, similar to the MBBR.

Stormwater tank cleaning

When stormwater retention tanks are filled, a certain contamination load has to be expected. This contamination load should be removed when the tanks are drained.
Several options are available to remove contamination from stormwater retention tanks and clean the tanks. Apart from conventional methods of cleaning stormwater retention tanks with flush buckets / flush cleaning, mechanical removal, flushing devices or pump-operated jet aeration systems, using mixers with an axial propeller is also an option.
Mixers should primarily be used in round stormwater retention tanks as the mixer thrust will rotate the water, stirring up the solid particles and keeping them in suspension (tea cup effect). Another precondition for a good cleaning effect is a high drainage velocity for removing the waste water from the tank. Disadvantages of using mixers for cleaning are the poor cleaning effect at the walls and having to stop the mixers before the water level falls too low. However, the decisive benefits of using mixers are their low investment and operating costs. Refer to the following table for a comparison of different cleaning options for stormwater retention tanks.

	Flushing device	**Mechanical removal device**	**Flush buckets / flush cleaning**	**Jet aeration systems**	**Mixers with axial propeller**
Structural adjustment required	Yes, permanently laid piping with flushing nozzles	No	Yes, the tank must be deeper than normal; supportive walls are required for larger tanks.	Yes, the tank floor slope must oppose the cleaning direction.	No
External water supply required	Yes, drinking water or service water	No	Yes, drinking water or service water	No	No
Special tank shape required	No	Yes, open tank with smooth floor required	Yes, only rectangular tank possible	No	Yes, optimal only for round tank with high drain velocity
Depending on the water level	Yes, cleaning only possible when the tank is drained	Yes, cleaning only possible when the tank is drained	Yes, cleaning only possible when the tank is drained	No	Yes, limited cleaning effect at low water level
Digestion and odour nuisance if the stormwater is left in tank for a long time	Yes, digestion possible	Yes, digestion possible	Yes, digestion possible	No, actively countered by oxygen input	Yes, digestion possible
Even degree of contamination	No	No, danger of sludge compaction; mechanical manual cleaning required in this case	No, system-related contamination surge, high contamination of residual drainage	Yes	Yes, if water level sufficiently high
Cleaning of sides included	No	No	No	Yes	No
Complete cleaning including problematic zones	No, drain channel becomes blocked	No, risk of sludge thickening	No, drain channel becomes blocked; several flushing cycles required for high pollution loads	Yes	No, residual contamination possible at low water level
Evaluation	High investment costs, high water consumption, nozzles may become blocked, low cleaning performance	High procurement and maintenance costs, low cleaning performance	High investment costs due to special structure; additional cleaning of drain channel required	Economic solution; individual solutions possible for every tank geometry, excellent cleaning performance	Economic solution with relatively good cleaning results in round tanks

Table 1: Comparison of cleaning options for stormwater tanks

Mixer applications in fun parks

Apart from many types of pumps, mixers can also be employed to generate horizontal flows in fun parks, whitewater parks or similar applications. Mixers can move boats, rubber dinghies or rafts round water-filled loop courses, for example. They can also generate waves. Another mixer application is that of recirculating artificial lakes or other stagnant waters to prevent the formation of algae, digestion and the associated odour nuisance.

In all of these cases individual solutions have to be tailored to the specific requirements. Please don't hesitate to contact us if you need any assistance with such applications.

Mixing up pump sump contents

In waste water pumping stations or in pumping stations with a high solids content, e.g. sand, there is a risk of solids depositing on the floor or sedimentation during prolonged pump standstill. To prevent deposits and stir up the solids prior to the next pumping process, so they can be transported out of the pumping station together with the water, one or several higher-speed mixers can be installed in the pump sump. The same mixers can also serve to remove or prevent floating sludge. The mixers should be operated before the drainage pumps are started up, allowing the mixers to create a swirl in the pump sump for about 10 to 15 minutes, depending on the sump size. The mixers should be switched off shortly before the pumps are started up, so the turbulences in the pump sump cannot lead to vortices with a negative effect on the pumps' operation. The mixer or mixers should be installed in the pump sump without hindering the approach flow to the pumping station and should allow access for service and repair work to be carried out.

4. Mixer positioning

General information

The positioning of submersible mixers can largely contribute to good mixing results and trouble-free operation.

Correct mixer positioning is always based on a system analysis. The factors to be taken into account are the tank shape, tank size, inlets, outlets, fitted structures, any aeration systems and the mixer type.

For optimum mixing of the tank contents the mixers should be evenly spaced and symmetrically arranged.

Figure 38 shows the simulation of a rectangular tank with one mixer (1 x 2000 N / power input 2.5 kW).
Figure 39 shows the same rectangular tank fitted with two mixers (2 x 1000 N / power input 1.0 kW each).

In a direct comparison the velocity distribution in the tank with two mixers is clearly more homogeneous.
The number and size of low-flow areas in the tank is visibly reduced.

Depending on the tank size and shape, a single mixer can be sufficient to achieve the desired mixing results.
However, a larger number of mixers generally provides redundancy and mixes the tank contents more evenly.
Especially in activated sludge tanks using a larger number of mixers can save energy.

Ideally, this should already be considered in the planning phase. Generally speaking, the highest energy savings can be made by selecting a favourable tank shape.

The positioning of a submersible mixer will considerably influence its mixing performance and, with that, the trouble-free operation of the mixer and the overall system.
Given the different characteristics we once again need to distinguish between mixers with a small propeller and high propeller speed (KSB Amamix) and mixers with a large propeller and low propeller speed (KSB Amaprop).

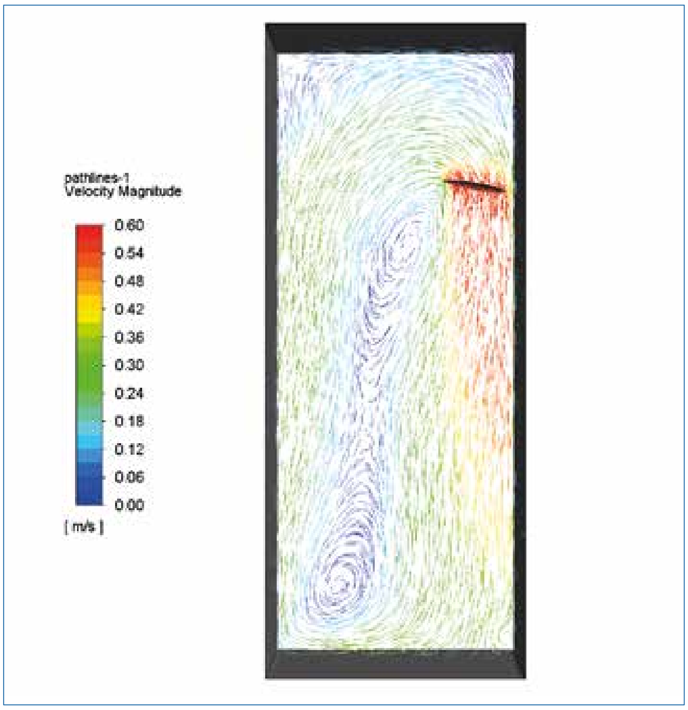


Fig. 38: Rectangular tank with one mixer

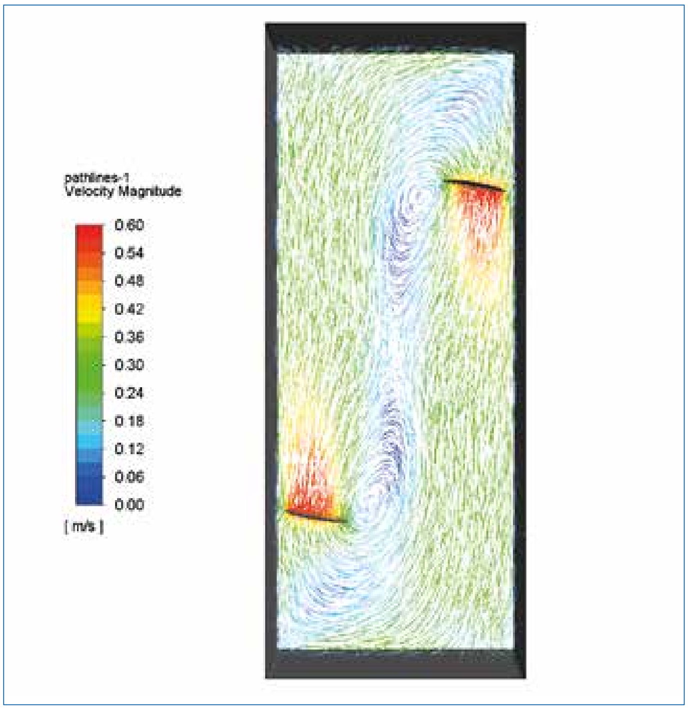


Fig. 39: Rectangular tank with two mixers

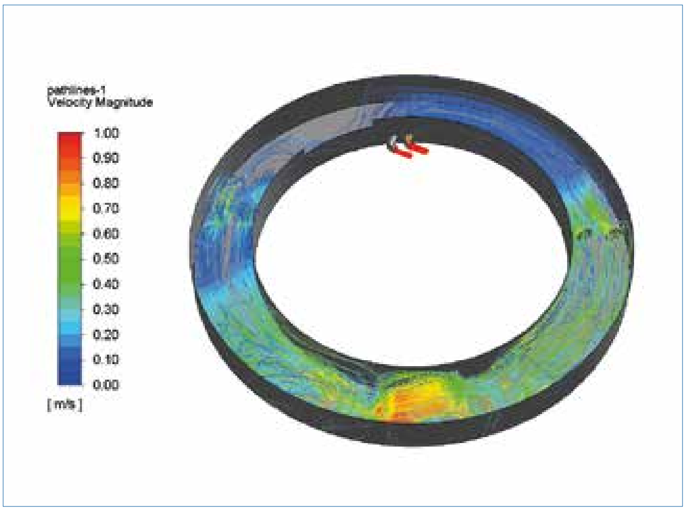


Fig. 40: Annular tank system

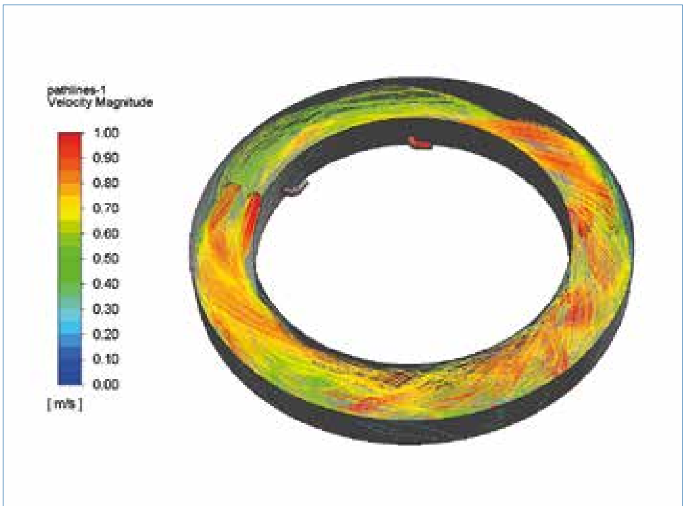


Fig. 41: Optimised annular tank system

High-efficiency flow accelerators are characterised by large, relatively slow-running propellers. This configuration leads to a comparatively high flow rate (0.8 - 5 m^3/s, depending on the propeller diameter and speed) and, at the same time, a relatively low flow outlet velocity (0.4 - 0.8 m/s, depending on the propeller diameter and speed).
The large propeller diameter also makes the load arm at the shaft relatively long. In practice, this means that high-efficiency mixers need to be positioned very carefully.

Shear flows and increased turbulence will increase the load acting on the mixer, due to the mixer design principle. Unfavourable positioning can have a negative impact on the mixing result and on the service life of mixer sets.

Figure 40 demonstrates the example of an annular tank with four mixers, two recirculation pumps and subsurface fine-bubble aeration being operated at the same time.

It illustrates the influence of the aeration field and of the recirculation pumps on the flow velocity.
As can clearly be seen, the desired even flow around the annular tank has not been established. This is due to poorly positioned and over-dimensioned recirculation pumps.

Figure 41 shows a simulation of the same tank with recirculation pumps of a lower capacity that have been positioned in a better place. Marked improvements can be seen.

The thrust generated by this mixer type with its low outlet velocity at the propeller is strongly influenced by any approach flow from the rear. This circumstance must be taken into account when positioning the mixer.

Direct-driven mixers with a small propeller and high speed are characterised by a comparatively low flow rate (0.06 - 1.2 m^3/s, depending on the propeller diameter and speed) at a relatively high outlet velocity (2 - 2.5 m/s).
Its comparatively small propeller makes this mixer type clearly less sensitive to unfavourable positioning. However, poor positioning will lead to a higher load on the installation accessories.

For the above-mentioned reasons, mixer positioning has to be considered already in the early planning stage; the combination of tank shape and size, aeration and mixer has to be seen as a functional unit (DIN 19596-3).
Servicing and access openings as well as the required platforms and bridges must be provided for the planned tank geometry.
If the fill levels are high, guide rails might have to be protected against vibrations by fitting middle supports.

The following positioning information serves to generate an optimum flow and maximise the mixers' service life.

Installation types in the tank

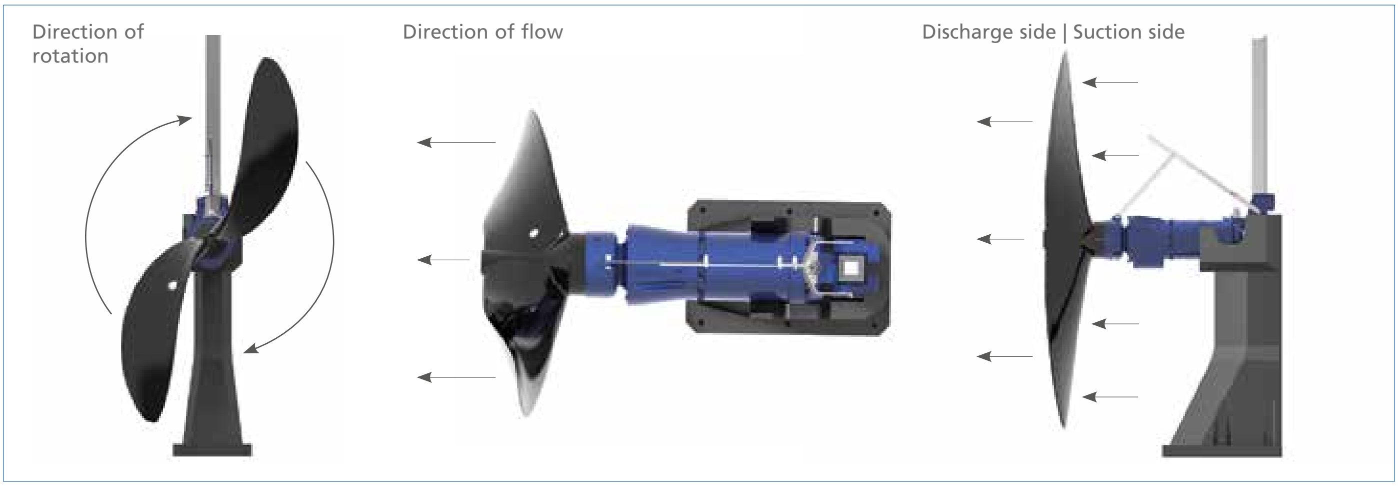


Fig. 42: Direction of rotation and direction of flow

Round tanks

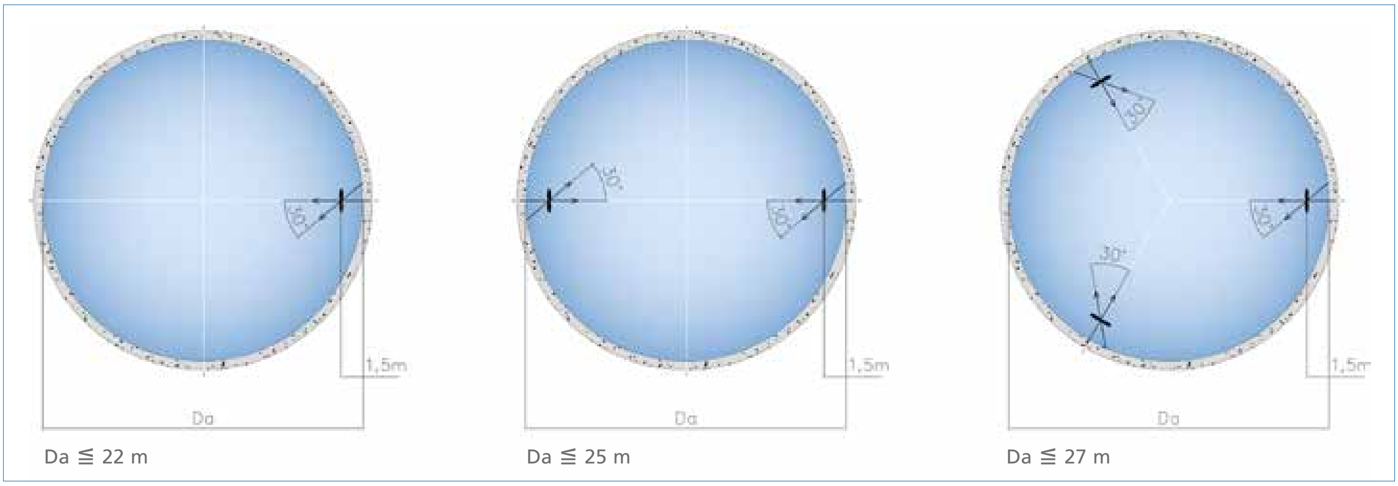
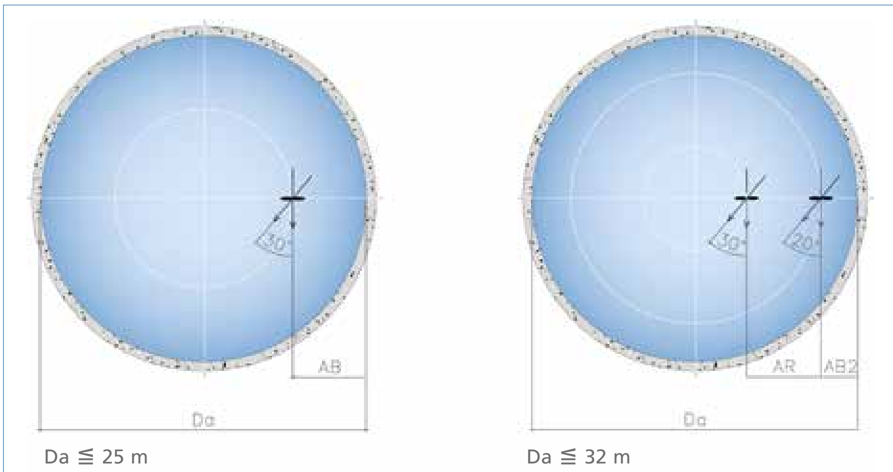


Fig. 43: Round tanks | General positioning



AB = Da/4 (minimum distance from tip of blade to tank wall 0.3 m)

AB2 = Da/8 (minimum distance from tip of blade to tank wall 0.3 m)

AR = Da/4 (minimum distance from tip of blade to tank wall 0.6 m)

Fig. 44: Round tanks | General positioning

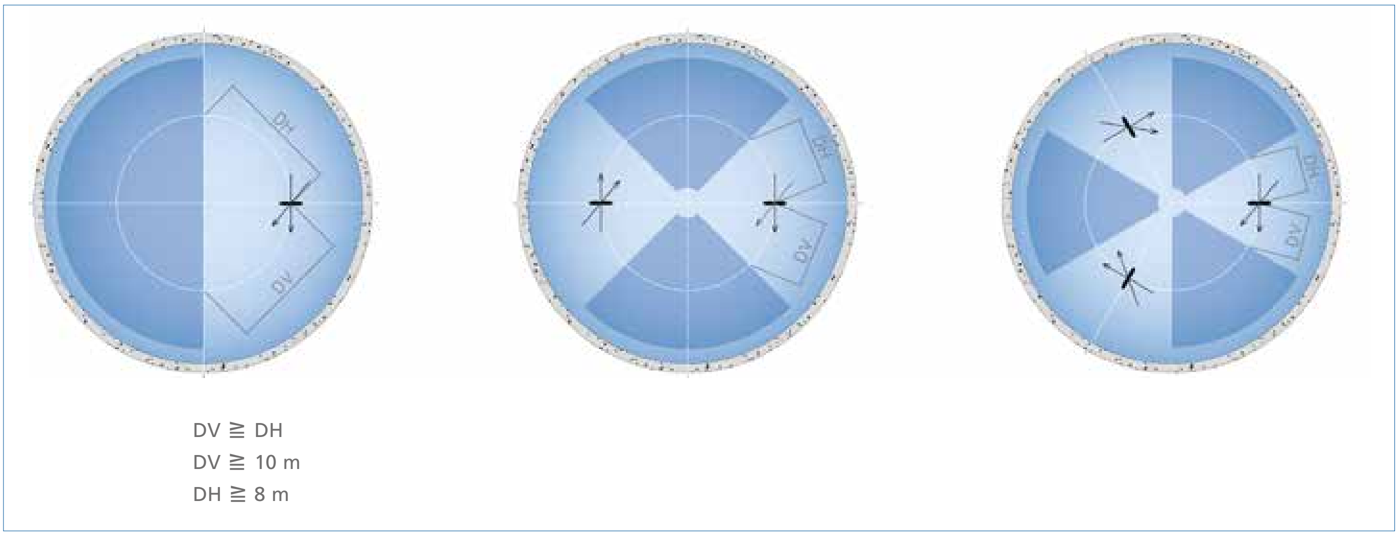


Fig. 45: Round tanks | Positioning of aeration fields in parallel operation

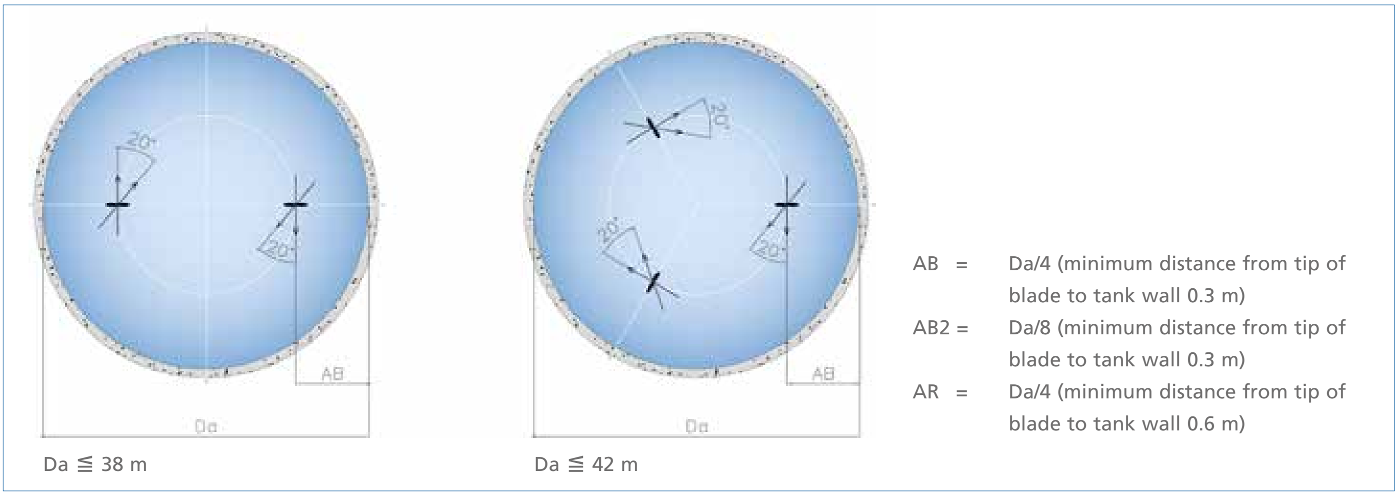


Fig. 46: Round tanks | Positioning of aeration fields in parallel operation

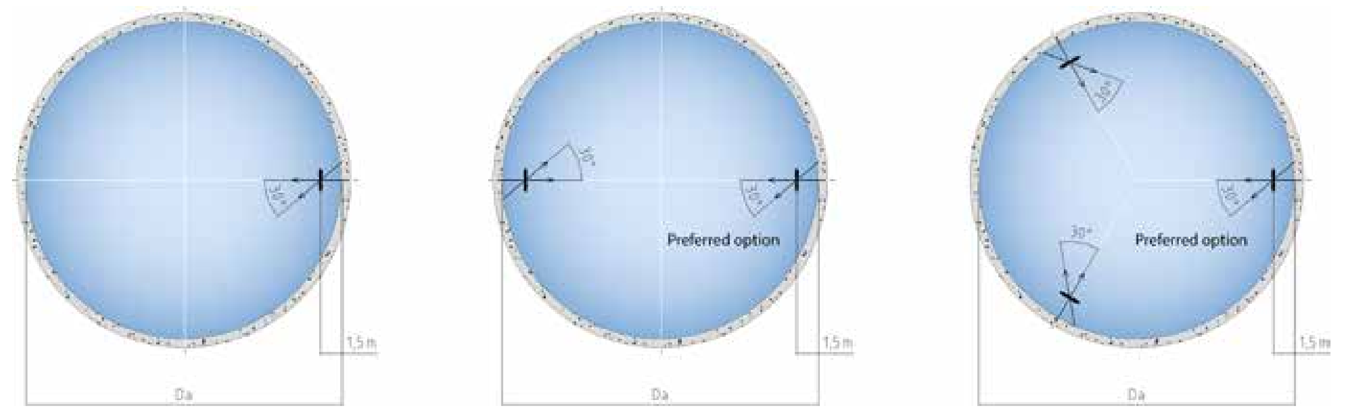
AB – Distance to side wall of the tank
AB2 – Distance to side wall of the tank for parallel installation

W – Racetrack width
Da – Tank diameter / outer ring diameter
Di – Diameter of inner tank structure / central structure

AR – Distance between two mixers installed in parallel

DV – Discharge-side safety distance to the aeration field in parallel operation
DH – Suction-side safety distance to the aeration field in parallel operation

The safety / minimum distances indicated should always be adhered to when operating flow accelerators.

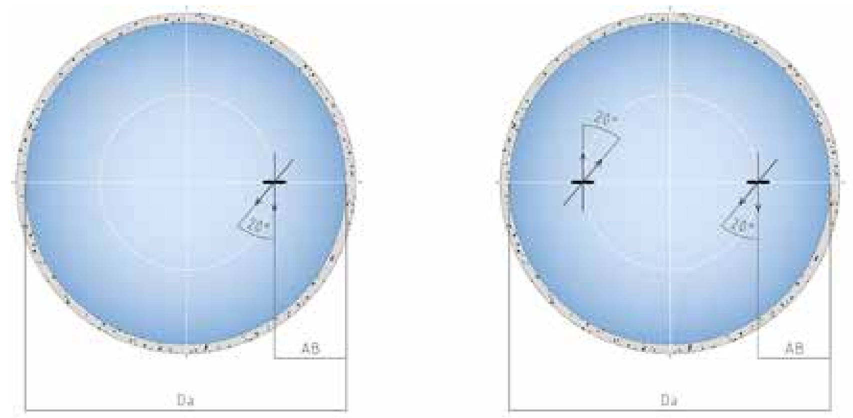


Da ≦ 16 m

Da ≦ 20 m

Da ≦ 24 m

Fig. 47: Round tanks | Sludge storage tanks (DS max. 8 % without polymers)



Da ≦ 10 m

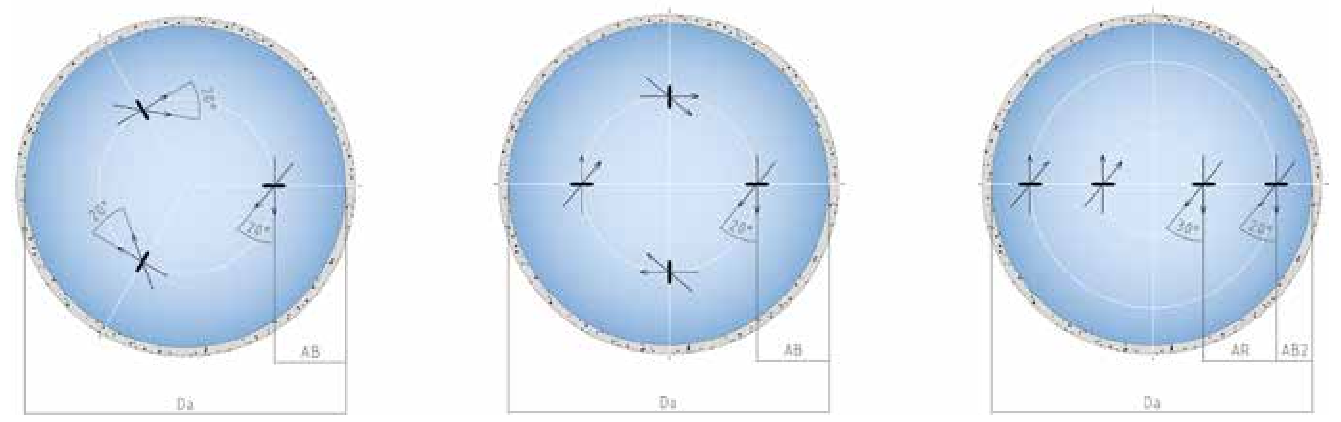
Da ≦ 15 m

AB = Da/4 (minimum distance from tip of blade to tank wall 0.3 m)

AB2 = Da/8 (minimum distance from tip of blade to tank wall 0.3 m)

AR = Da/4 (minimum distance from tip of blade to tank wall 0.6 m)

Fig. 48: Round tanks | Stormwater overflow tanks (floor drainage in the middle of the tank)



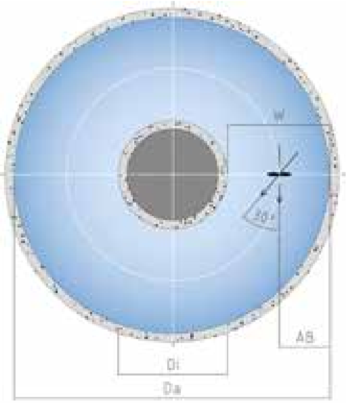
Da ≦ 18 m

Da ≦ 22 m

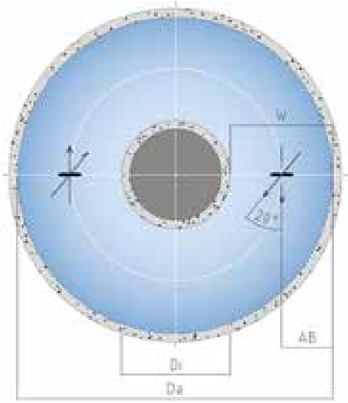
Da ≦ 22 m

Fig. 49: Round tanks | Stormwater overflow tanks (floor drainage in the middle of the tank)

Annular tanks



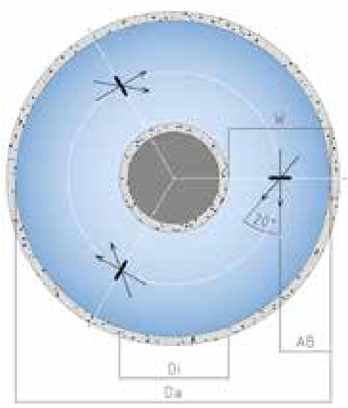
Da ≦ 10 m



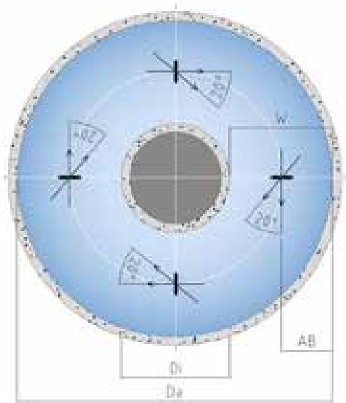
Da ≦ 15 m

W = (Da-Di) / 2
AB = W/2 (minimum distance from tip of blade to tank wall 0.3 m)
AB2 = W/4 (minimum distance from tip of blade to tank wall 0.3 m)
AR = W/2 (minimum distance from tip of blade to tank wall 0.6 m)
Di = 0.05 x Da (otherwise round tank)

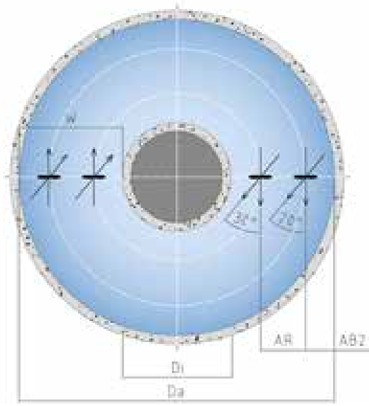
Fig. 50: Annular tanks | Stormwater overflow tanks (floor drainage via drain channel around the circumference of the central structure)



Da ≦ 18 m



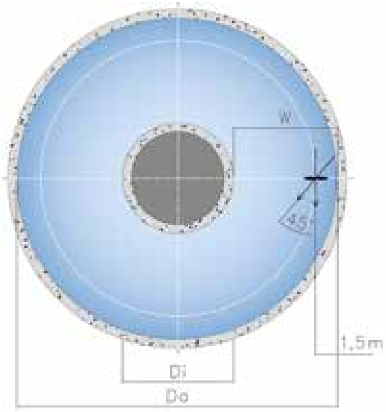
Da ≦ 22 m



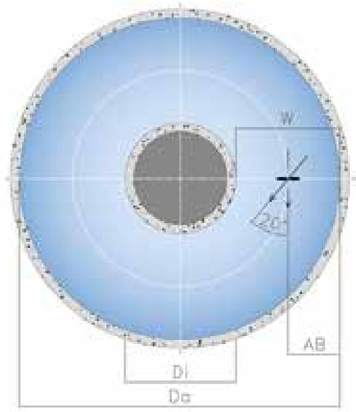
Da ≦ 22 m

W = (Da-Di) / 2
AB = W/2 (minimum distance from tip of blade to tank wall 0.3 m)
Di = 0.05 x Da (otherwise round tank)

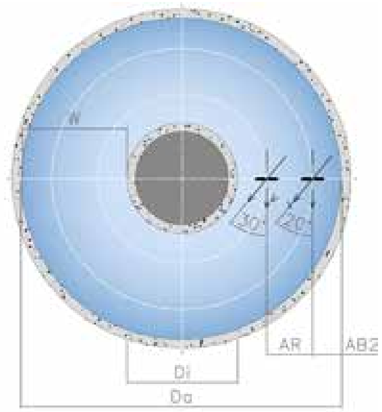
Fig. 51: Annular tanks



Da ≦ 15 m



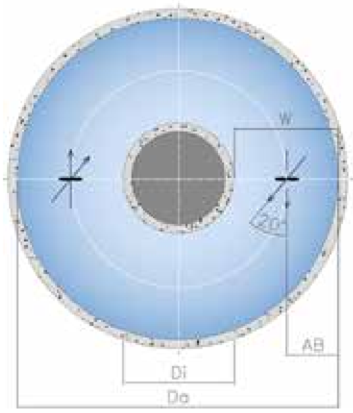
Da ≦ 22 m



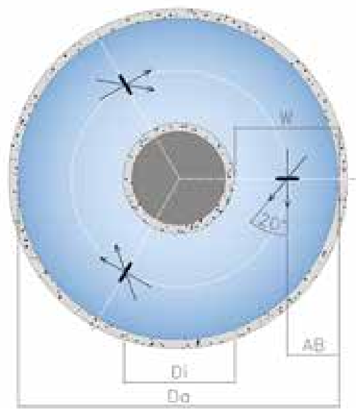
Da ≦ 27 m

W = (Da-Di)/2
AB = W/2 (minimum distance from tip of blade to tank wall 0.3 m)
AB2 = W/4 (minimum distance from tip of blade to tank wall 0.3 m)
AR = W/2 (minimum distance from tip of blade to tank wall 0.3 m)
Di > 0.05 x Da (otherwise round tanks)

Fig. 52: Annular tanks | General positioning



Da > 22 m < 39 m



Da > 39 m < 45 m

W = (Da-Di)/2
AB = W/2 (minimum distance from tip of blade to tank wall 0.3 m)
Di > 0.05 x Da (otherwise round tanks)

Fig. 53: Annular tanks

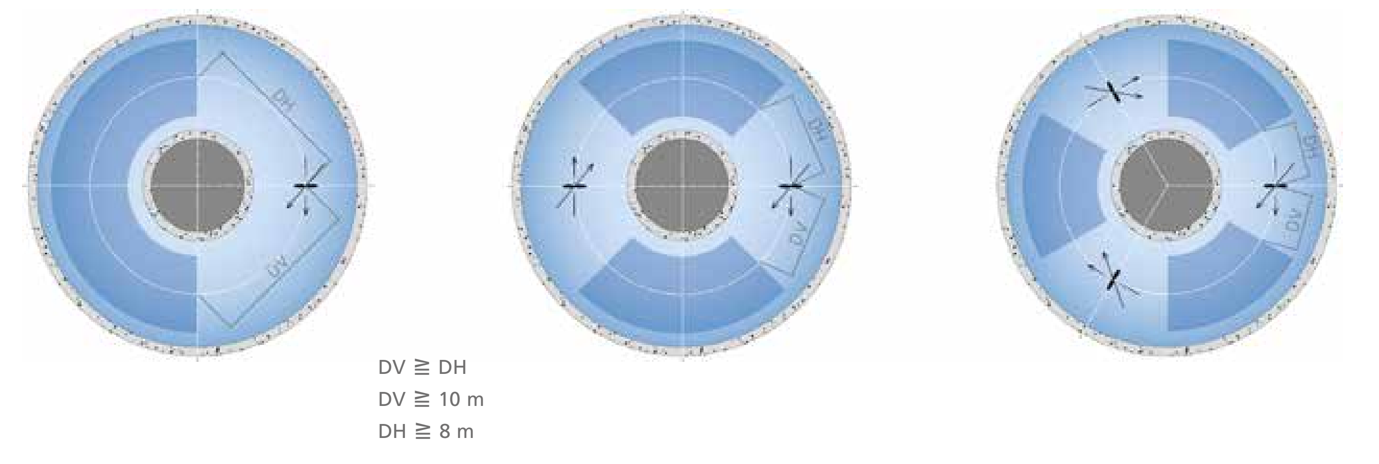


Fig. 54: Annular tanks | Positioning of aeration fields in parallel operation

AB – Distance to side wall of the tank
AB2 – Distance to side wall of the tank for parallel installation

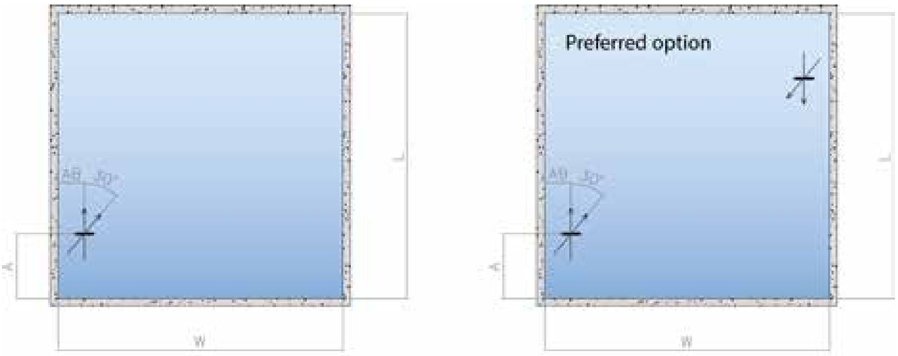
W – Racetrack width
Da – Tank diameter / outer ring diameter
Di – Diameter of inner tank structure / central structure

AR – Distance between two mixers installed in parallel

DV – Discharge-side safety distance to the aeration field in parallel operation
DH – Suction-side safety distance to the aeration field in parallel operation

The safety / minimum distances indicated should always be adhered to when operating flow accelerators.

Square tanks

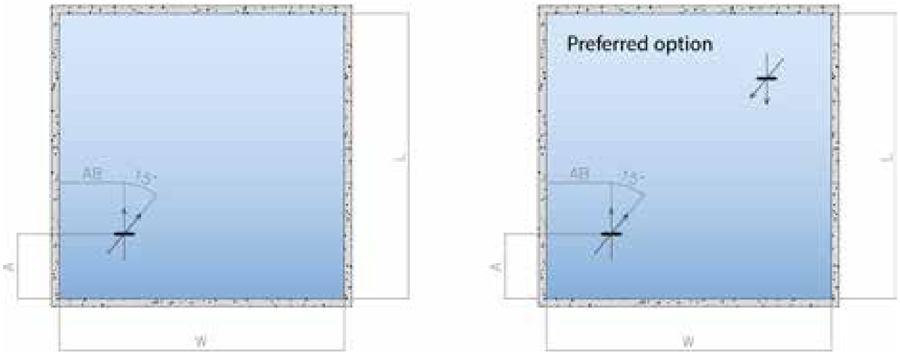


L ≦ 20 m

L ≦ 24 m

A = L/6 to L/3 (minimum distance to front wall 2 x propeller diameter)
AB = 1.5 m (minimum distance from tip of blade to tank wall 0.3 m)
L = W

Fig. 55: Square tanks | General positioning

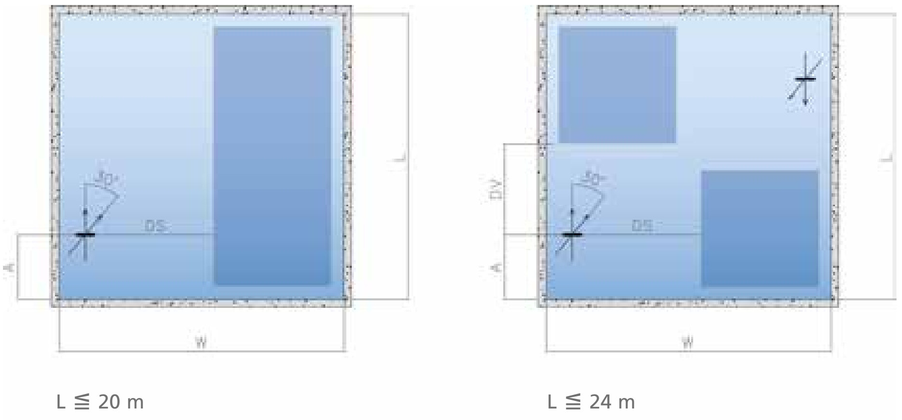


L > 20 m ≦ 24 m

L > 24 m ≦ 28 m

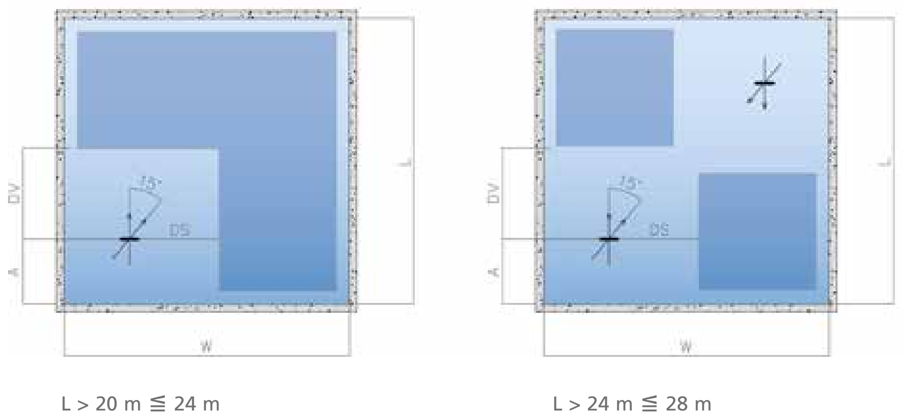
A = L/6 to L/3 (minimum distance to front wall 2 x propeller diameter)
AB = L/4
L = W

Fig. 56: Square tanks



A = L/6 to L/4 (minimum distance to front wall 2 x propeller diameter)
DV = 7.5 m
DS ≧ 2 x propeller diameter

Fig. 57: Square tanks | Positioning of aeration fields in parallel operation



A = L/6 to L/4 (minimum distance to front wall 2 x propeller diameter)
DV = 7.5 m
DS ≧ 2 x propeller diameter

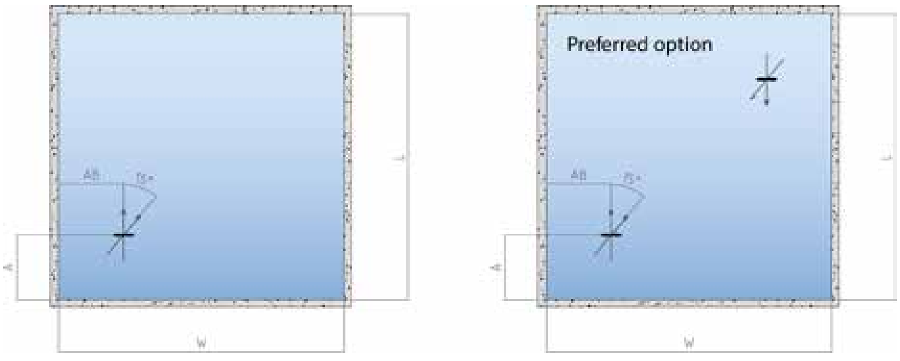
Fig. 58: Square tanks | Positioning of aeration fields in parallel operation

A – Suction-side safety distance to tank wall
AB – Distance to side wall of the tank
B1 – Distance between mixers installed in series

W – Racetrack width
L – Tank length

DS – Sideways safety distance to the aeration field in parallel operation
DV – Discharge-side safety distance to the aeration field in parallel operation
DH – Suction-side safety distance to the aeration field in parallel operation

The safety / minimum distances indicated should always be adhered to when operating flow accelerators.



L ≦ 8 m

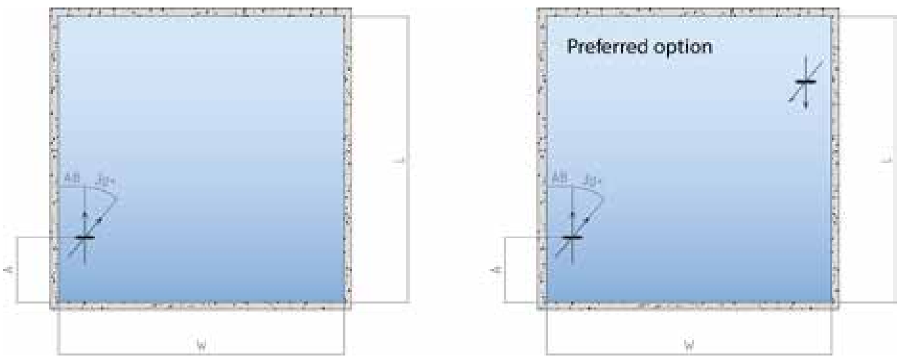
L ≦ 12 m

A = L/6 to L/3 (minimum distance to front wall 2 x propeller diameter)

AB = L/4

L = W

Fig. 59: Square tanks | Stormwater overflow tanks (floor drainage in the middle of the tank)



L ≦ 16 m

L ≦ 20 m

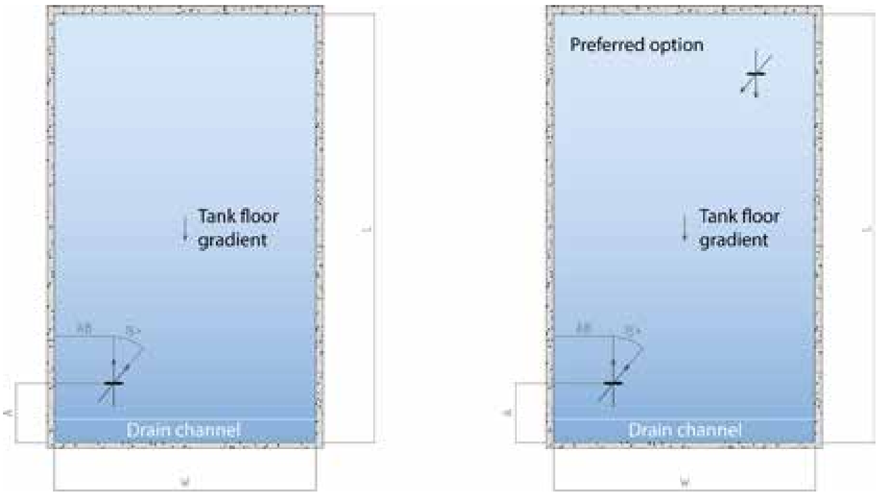
A = L/6 to L/3 (minimum distance to front wall 2 x propeller diameter)

AB = 1.5 m (minimum distance from tip of blade to tank wall 0.3 m)

L = W

Fig. 60: Square tanks | Sludge storage tanks (DS max. 8 % without polymers)

Rectangular tanks



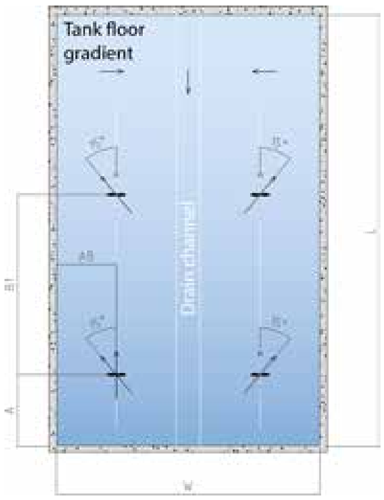
L/W ≦ 2 - W ≦ 6

L/W ≦ 2 - W ≦ 8

A = L/6 to L/4 (minimum distance to front wall 2 x propeller diameter)

AB = W / 4

Fig. 61: Rectangular tanks | Stormwater overflow tanks



L/W > 2.5

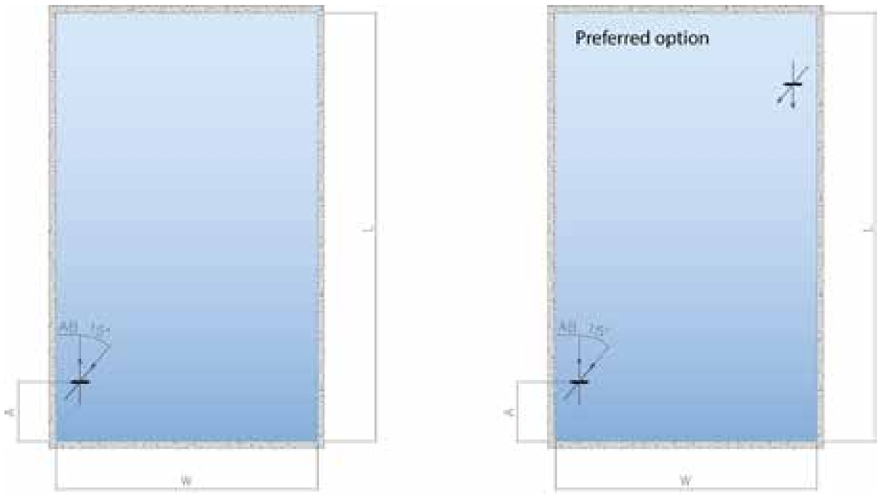
W ≦ 18

A = L/6 to L/4 (minimum distance to front wall 2 x propeller diameter)

B1 = (L-A) / number of mixers

AB = W/4

Fig. 62: Rectangular tanks | Stormwater overflow tanks



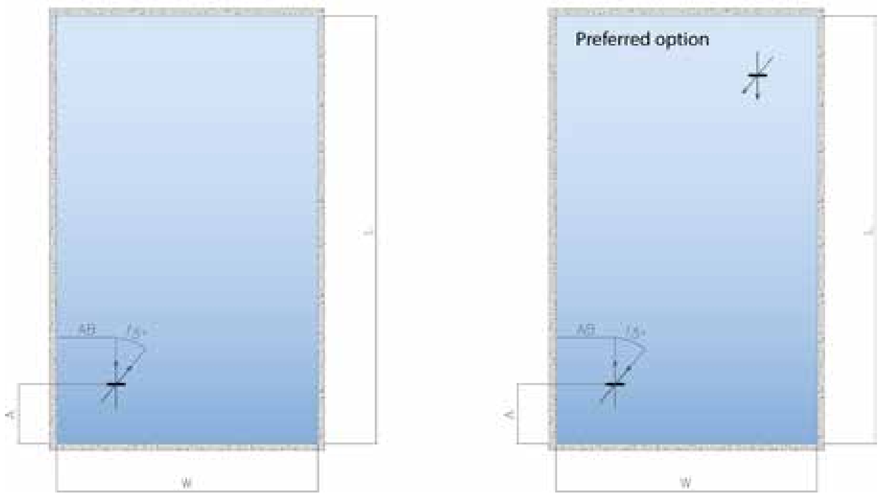
L/W ≦ 2.5 - W ≦ 15

L/W ≦ 2.5 - W ≦ 20

A = L/6 to L/4 (minimum distance to front wall 2 x propeller diameter)

AB = 1.5 m (minimum distance from tip of blade to tank wall 0.3 m)

Fig. 63: Rectangular tanks | General positioning



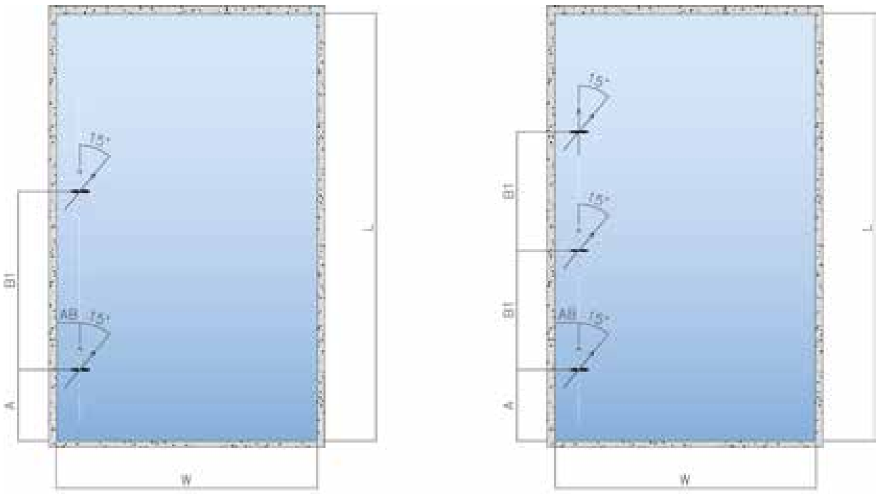
L/W ≦ 2 - W ≦ 18

L/W ≦ 2 - W ≦ 25

A = L/6 to L/4 (minimum distance to front wall 2 x propeller diameter)

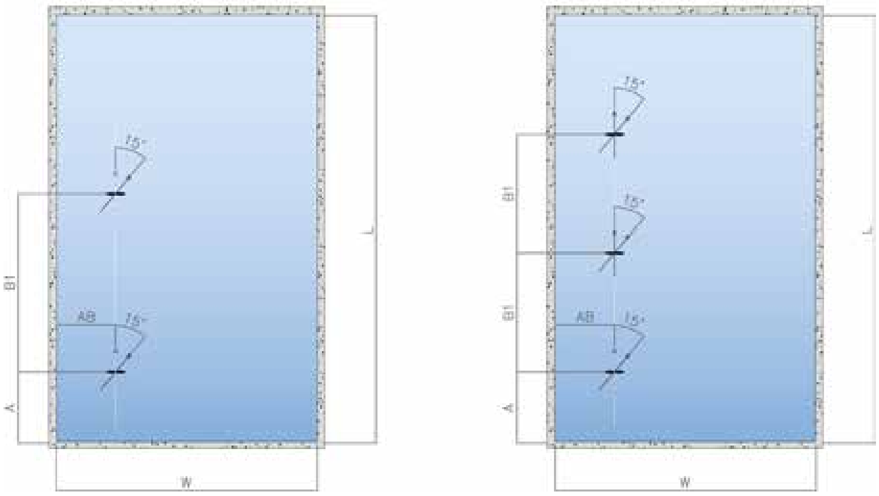
AB = W/4

Fig. 64: Rectangular tanks



A = L/6 to L/4 (minimum distance to front wall 2 x propeller diameter)
B1 = (L-A) / number of mixers
AB = 1.5 m (minimum distance from tip of blade to tank wall 0.3 m)

Fig. 65: Rectangular tanks | General positioning



A = L/6 to L/4 (minimum distance to front wall 2 x propeller diameter)
B1 = (L-A) / number of mixers
AB = W/4

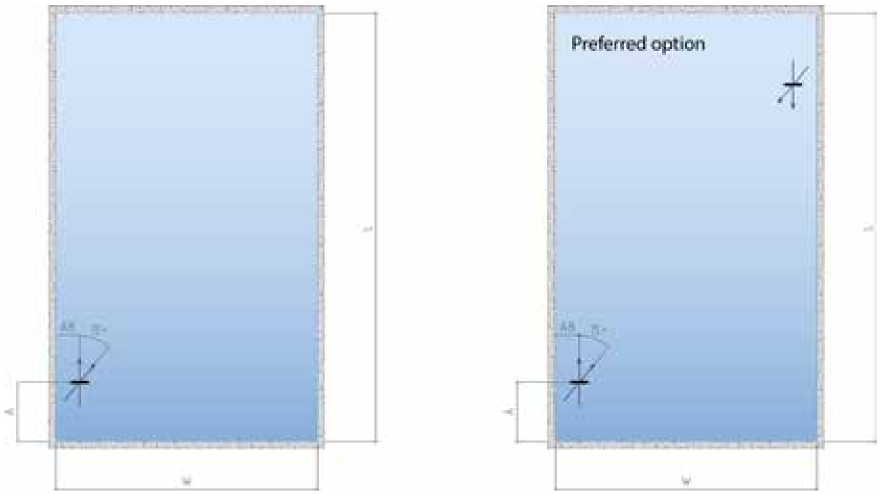
Fig. 66: Rectangular tanks

A – Suction-side safety distance to tank wall
AB – Distance to side wall of the tank
B1 – Distance between mixers installed in series

W – Racetrack width
L – Tank length

DS – Sideways safety distance to the aeration field in parallel operation
DV – Discharge-side safety distance to the aeration field in parallel operation
DH – Suction-side safety distance to the aeration field in parallel operation

The safety / minimum distances indicated should always be adhered to when operating flow accelerators.

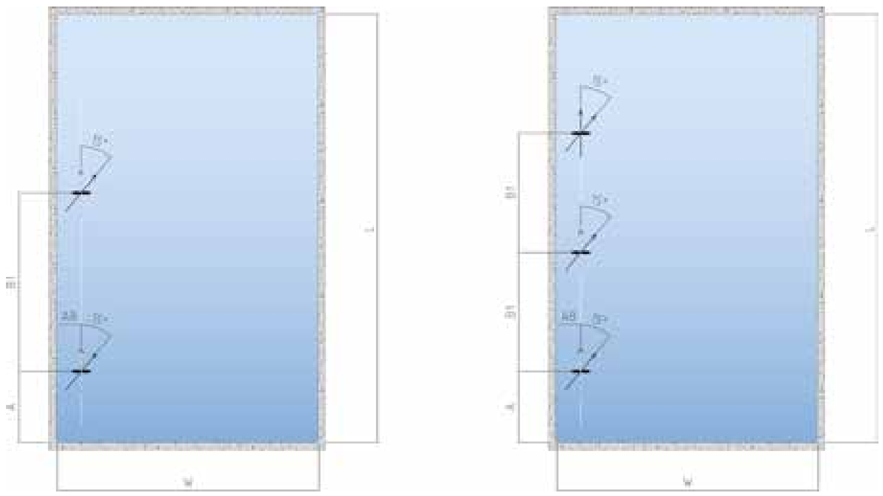


L/W ≦ 2.5 - W ≦ 8

L/W ≦ 2.5 - W ≦ 10

A = L/6 to L/4 (minimum distance to front wall 2 x propeller diameter)
AB = 1.5 m (minimum distance from tip of blade to tank wall 0.3 m)

Fig. 67: Rectangular tanks | Sludge storage tanks (DS max. 8 % without polymers)

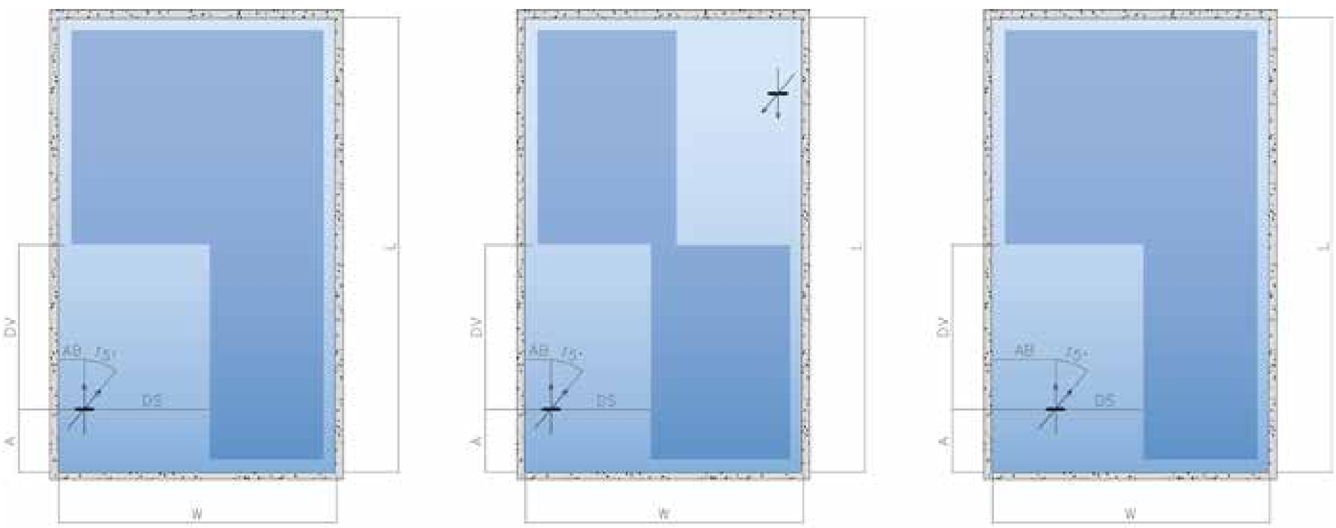


L/W > 2.5 ≦ 5
W ≦ 6

L/W > 5 ≦ 7.5
W ≦ 6

A = L/6 to L/4 (minimum distance to front wall 2 x propeller diameter)
B1 = (L-A) / number of mixers
AB = 1.5 m (minimum distance from tip of blade to tank wall 0.3 m)

Fig. 68: Rectangular tanks | Sludge storage tanks (DS max. 8 % without polymers)



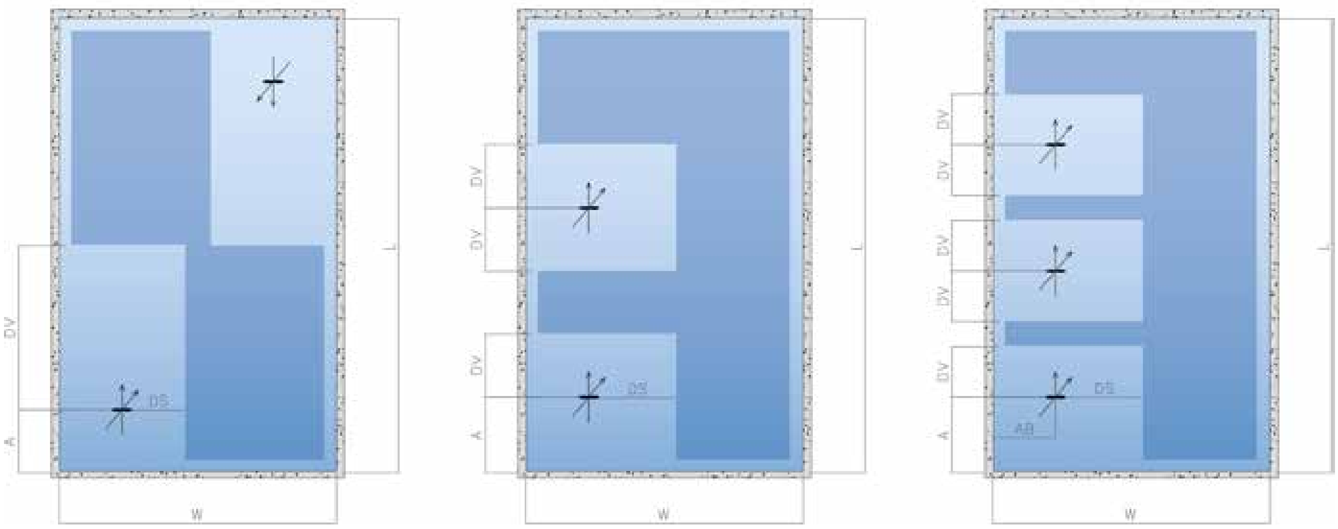
L/W ≦ 2.5 - W ≦ 15

L/W ≦ 2.5 - W ≦ 20

L/W ≦ 2.5 - W ≦ 18

DV = 7.5 m
DS = 2 x propeller diameter
A = L/6 to L/4 (minimum distance to front wall 2 x propeller diameter)

Fig. 69: Rectangular tanks | Positioning of aeration fields in parallel operation



L/W ≦ 2 - W ≦ 25

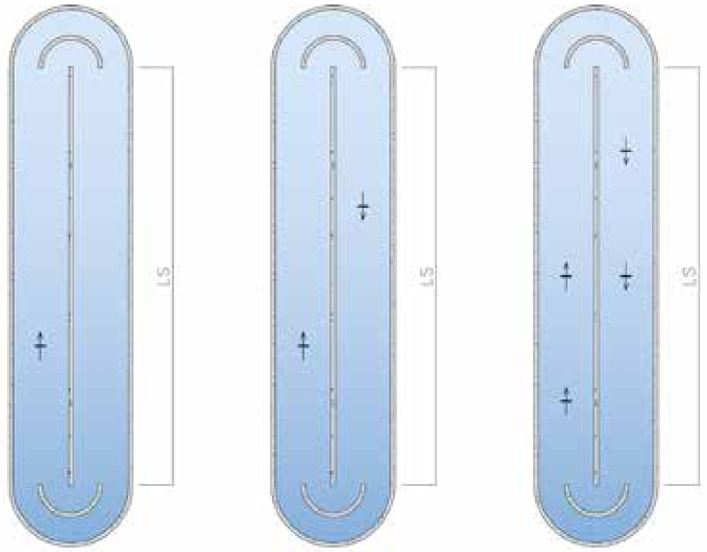
L/W ≦ 2.5 ≦ 5
W ≦ 15

L/W ≦ 2.5 ≦ 5
W ≦ 15

DV = 7.5 m
DS = 2 x propeller diameter
A = L/6 to L/4 (minimum distance to front wall 2 x propeller diameter)

Fig. 70: Rectangular tanks | Positioning of aeration fields in parallel operation

Tank with circulating flow

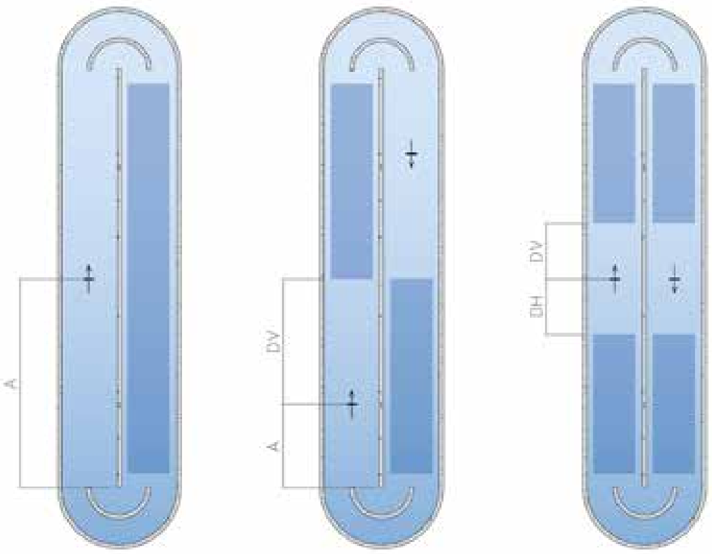


LS ≦ 50 m

LS ≧ 50 m
LS ≧ 90 m

LS ≧ 90 m
On request

Fig. 71: Tanks with circulating flow | Number of mixer installation points



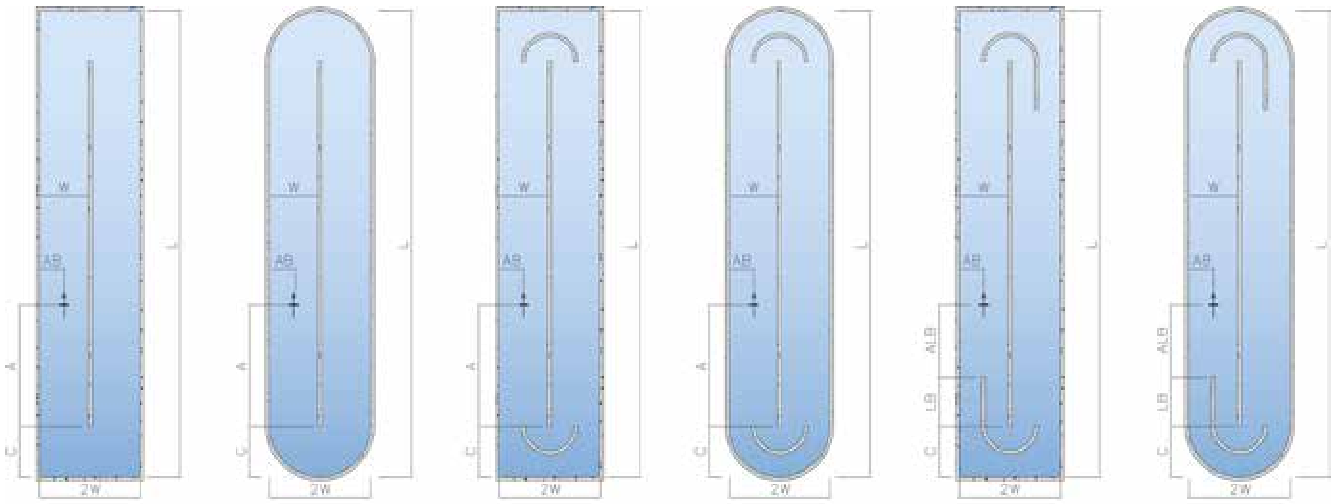
1 field

2 fields

4 fields

A ≧ 1.5 x W (≦ A/2)
DV ≧ 10 m
DH ≧ 8 m

Fig. 72: Tanks with circulating flow | Positioning of aeration fields in parallel operation



A ≧ 1.5 x W (≦ A/2)
AB = W/2 (minimum distance from tip of blade to tank wall 0.3 m)
LB ≧ W
ALB ≧ 1 x W
C = W

AW2 = W/4 (minimum distance from tip of blade to tank wall 0.3 m)
AR2 = W/2 (minimum distance from tip of blade to tank wall 0.6 m)

AW3 = W/6 (minimum distance from tip of blade to tank wall 0.3 m)
AR3 = 2 x AW3 (minimum distance from tip of blade to tank wall 0.6 m)

Fig. 73: Tanks with circulating flow | General

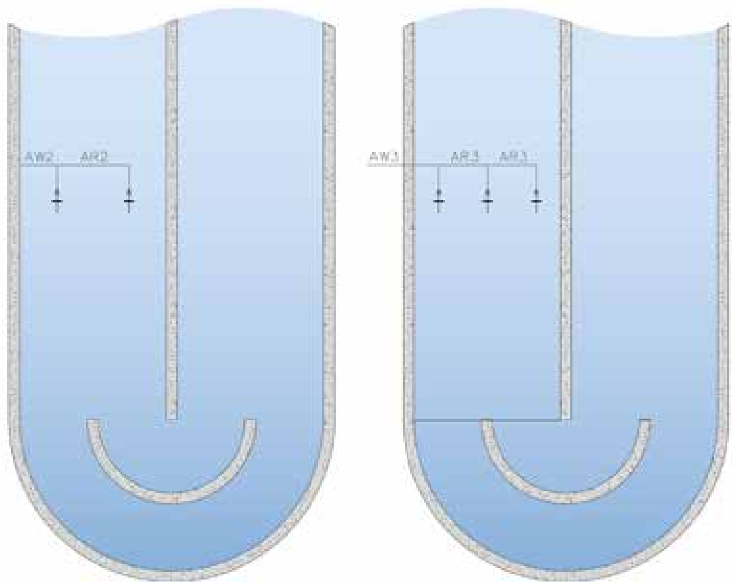
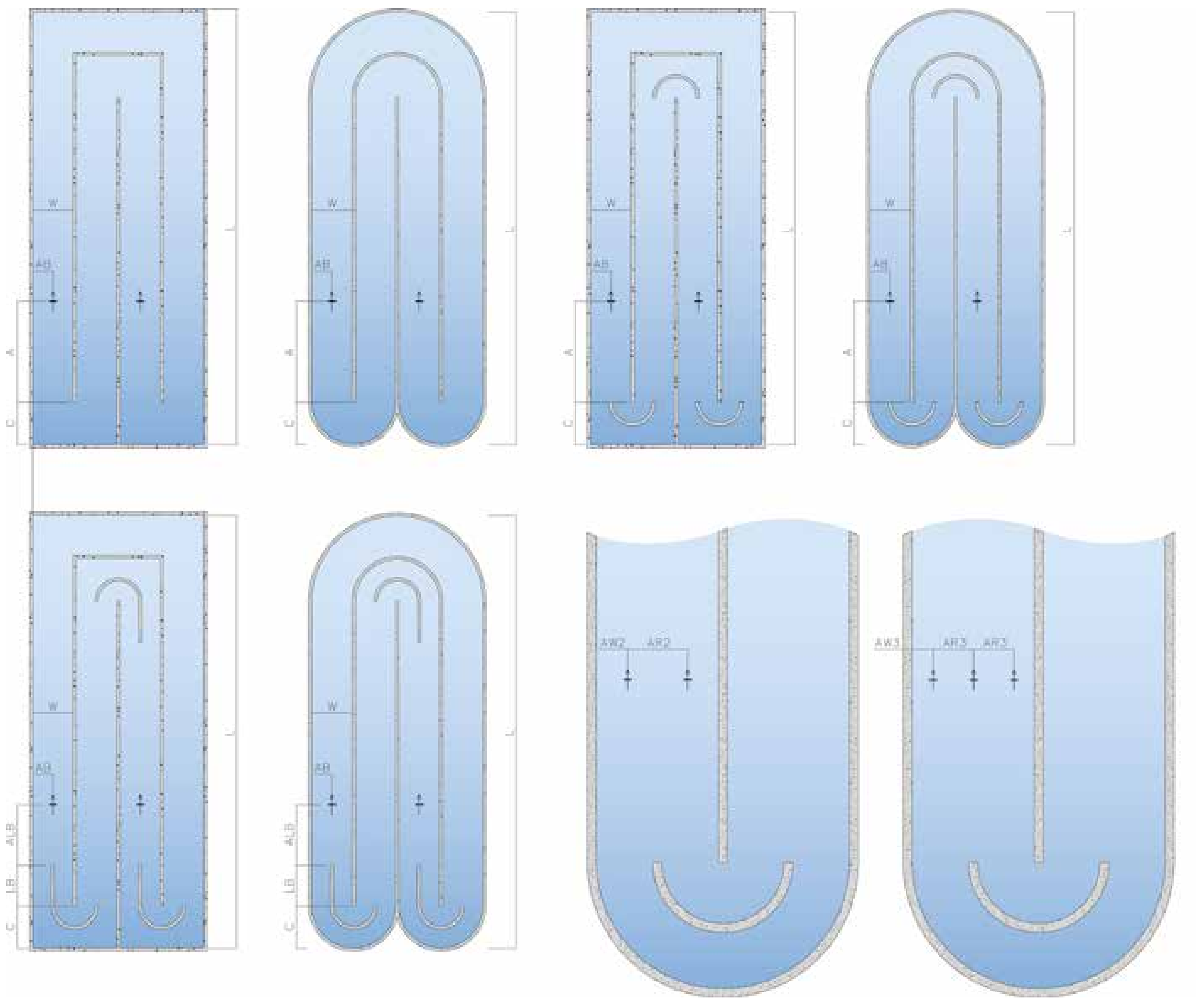


Fig. 74: Tanks with circulating flow

Tanks with meandering flow



A ≧ 1.5 x W (≦ A/2)
AB = W/2 (minimum distance from tip of blade to tank wall 0.3 m)
LB ≧ W
ALB ≧ 1 x W
C = W

AW2 = W/4 (minimum distance from tip of blade to tank wall 0.3 m)
AR2 = W/2 (minimum distance from tip of blade to tank wall 0.6 m)
AW3 = W/6 (minimum distance from tip of blade to tank wall 0.3 m)
AR3 = 2 x AW3 (minimum distance from tip of blade to tank wall 0.6 m)

Fig. 75: Tanks with meandering flow | Positioning of aeration fields in parallel operation

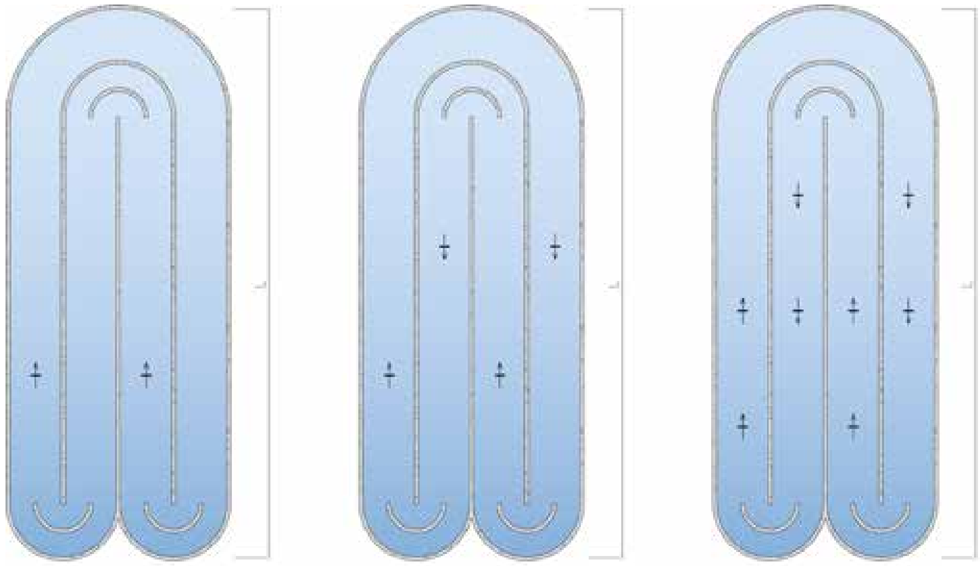


Fig. 76: Tanks with meandering flow | Number of mixer installation points

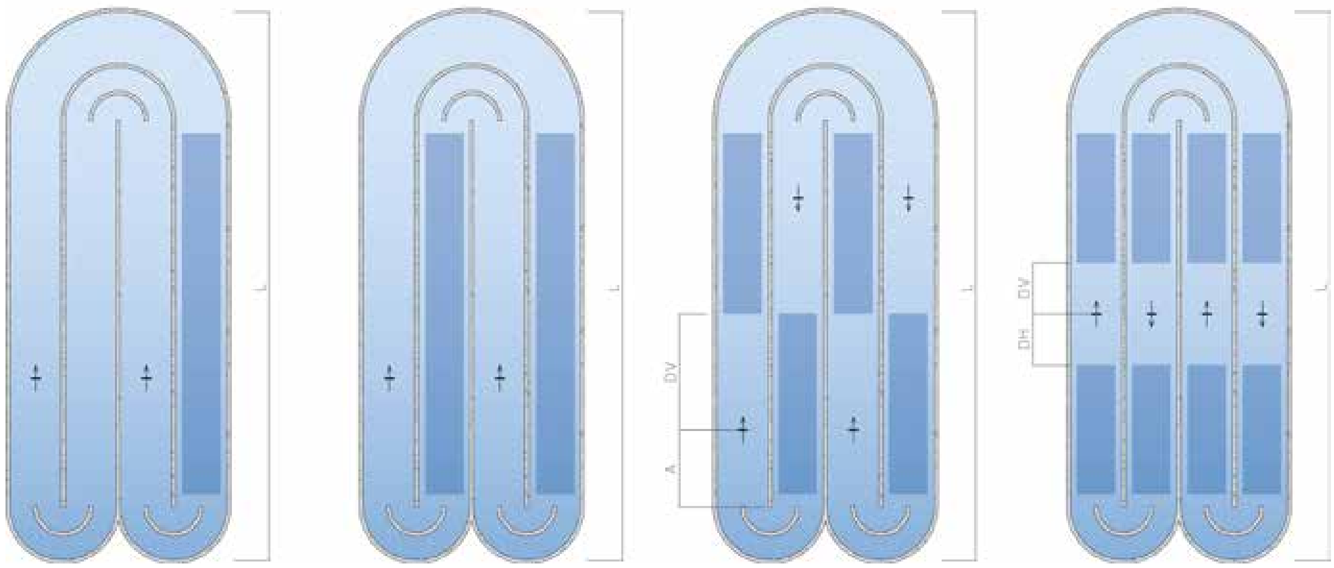


Fig. 77: Tanks with meandering flow | Positioning of aeration fields in parallel operation

Mixing radius

As described in the previous section, submersible mixers are selected based on their function and on the tank parameters.

Another factor to be looked at can be the predicted mixing radius. To do so, isotachs (lines of equal velocity) are determined and displayed, for example by means of a CFD simulation (see illustration). On request a specific mixing radius diagram can be created for each submersible mixer.

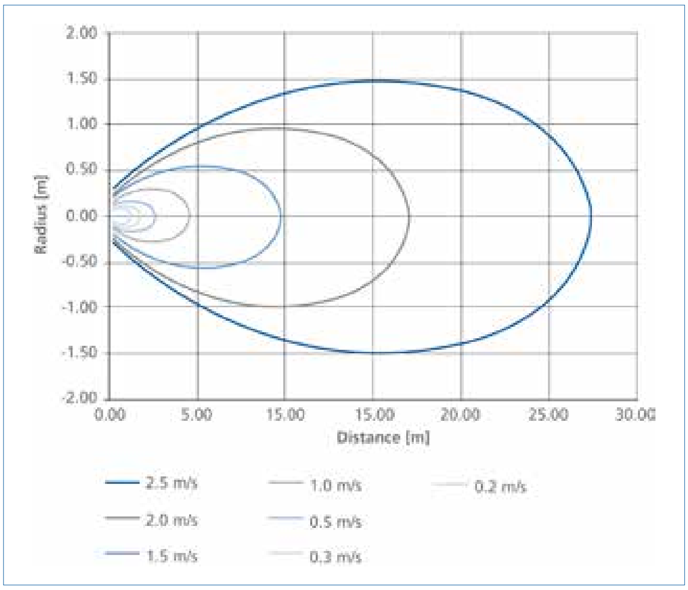


Fig. 78: Mixing radius diagram of Amamix C 3231

5. CFD

Mixing processes in waste water engineering are realised with free-running propellers. The propeller size is small compared to the tank volume. The actual mixing process is effected by the impulse of a free jet generated by the propeller. This impulse is measured via the propeller thrust force, with thrust F being the most important characteristic for describing a mixer. The free jet can be used in different ways. One of them employs the kinetic impulse force of the jet to maintain a circulating flow; the other uses the energy transferred by the propeller to homogenise and disperse (mix) the tank content. KSB offers two mixer types, which are referred to below as low-speed mixers and higher-speed mixers.

Low-speed mixers serve to maintain a channel-type flow.
If a minimum flow velocity in the channel is ensured, sludge flakes will be kept suspended and deposits will be prevented. Any flow resistance in the channel has to be compensated by the impulse force of the low-speed mixer (gradient substitution).

Higher-speed mixers are designed to homogenise a specified tank content volume and suspend any solid particles by means of the flow generated and the entrainment of the free jet.

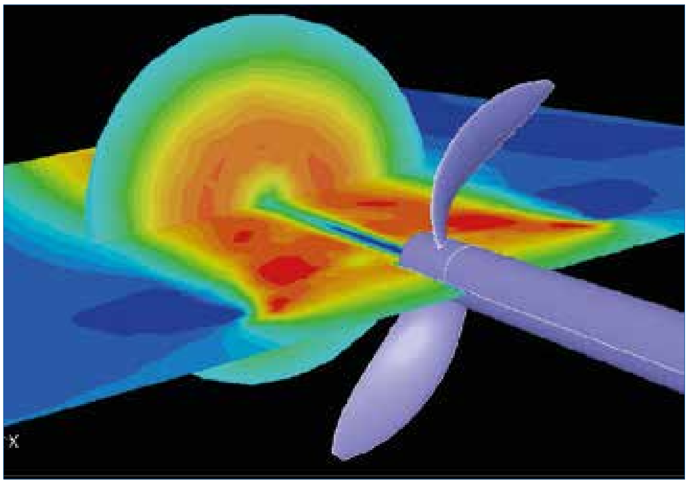


Fig. 79: Mixer with free-running propeller

Thrust from impulse:

$$F = \rho \cdot A_S \cdot v_S \cdot (v_4 - v_1)$$ Formula (5)

Key:
F = Thrust [N]
ρ = Density [$^{kg}/_{m^3}$]
A_S = Cross-section of propeller plane [m^2]
v_S = Flow velocity in propeller plane [$^m/_s$]
v_4 = Flow velocity at the rear of the propeller [$^m/_s$]
v_1 = Flow velocity in front of the propeller [$^m/_s$]

Thrust from pressure:

$$F = A_S \cdot \rho /2 \cdot (v_{42} - v_{12})$$ Formula (6)

$$v_S = (v_4 + v_1) / 2$$ Formula (7)

Key:
F = Thrust [N]
ρ = Density
A_S = Cross-section of propeller plane [m^2]
v_{42} = Velocity difference [$^m/_s$]
v_{12} = Velocity difference [$^m/_s$]
v_S = Flow velocity in propeller plane [$^m/_s$]
v_4 = Flow velocity at the rear of the propeller [$^m/_s$]
v_1 = Flow velocity in front of the propeller [$^m/_s$]

The reduction of the jet diameter from A_S to A_4 is referred to as jet contraction.

Effective power of mixers:

$$P_N = F \cdot v_1$$ Formula (8)

Key:
P_N = Effective power [W]
F = Thrust [N]
v_1 = Flow velocity in front of the propeller [$^m/_s$]

Calculation of tank flow

CFD software is a successful means of providing qualitative evidence of hydraulic performance parameters for mixers.
The pressure loss **$\Delta p = g \cdot \Delta h \cdot \rho$** is caused by friction and shape losses.

Pressure loss:

$$\Delta p = \left(\frac{\lambda \cdot L}{D_h} + \sum_i \zeta_i\right) \cdot \rho \cdot \frac{V_B^2}{2}$$ Formula (9)

Key:
Δp = Pressure loss [Pa]
λ = Pipe friction factor
L = Length
D_h = Equivalent diameter in fluid-mechanical terms [m]
ρ = Density
ζ = Loss coefficient
V_B = Flow velocity [$^m/_s$]

Resistance force:

$$F_W = \Delta p \cdot A_F = \left(\frac{\lambda \cdot L}{D_h} + \sum_i \zeta_i\right) \cdot \rho \cdot \frac{V_B^2}{2}$$ Formula (10)

$$F_W = \text{const.} \cdot V_B^2 \rightarrow V_B \sim \sqrt{F_W}$$ Formula (11)

Key:

- F_W = Resistance force [N]
- Δp = Pressure loss [Pa]
- A_F = Cross-section [m²]
- λ = Pipe friction factor
- L = Length
- D_h = Equivalent diameter in fluid-mechanical terms [m]
- ρ = Density
- ζ = Loss coefficient
- V_B = Flow velocity [m/s]

Resistance force:

$$F_{Mixer} = - F_W$$ Formula (12)

The mixer compensates flow resistances with thrust. In our experience the numerical approach is successful when the following framework conditions are given:

- The physical calculation has been verified in practical experience.
- The calculation model meets the requirements.
- The qualitative calculation results have been verified in simple approaches.
- A larger number of different variants has been calculated to create a matrix as part of the product development.
- The results have been analysed and an optimisation strategy has been developed.
- The strategy has been verified in model testing and product implementation (measurement).

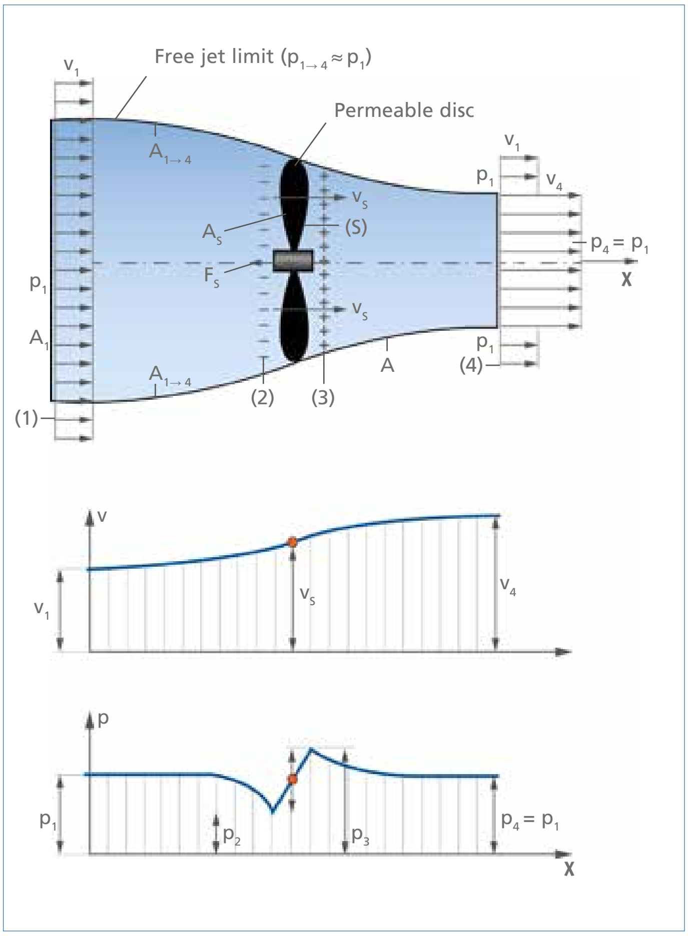


Fig. 80: Jet contraction

Aeration

Aeration systems are part of the tank geometry.
The resistance of both the aeration systems and the air introduced must be taken into account.

This is a UDF module that considers the effects of aeration field buoyancy forces in a single-phase calculation. The introduction of air and the resulting secondary flows are modelled by solving an additional transport equation. Depending on the air content, source and sink terms are generated that represent the flow resistance of the air bubbles and the buoyancy forces.

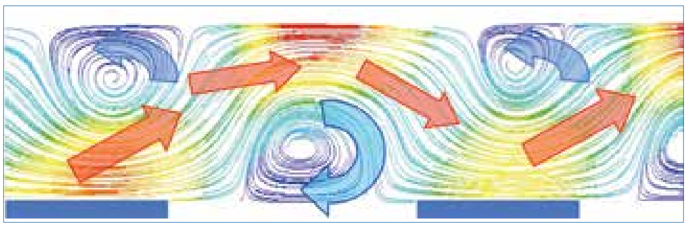


Fig. 81: Streamlines along several aeration fields

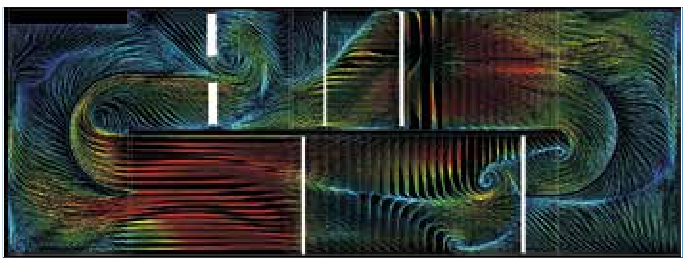


Fig. 82: Streamlines at the surface

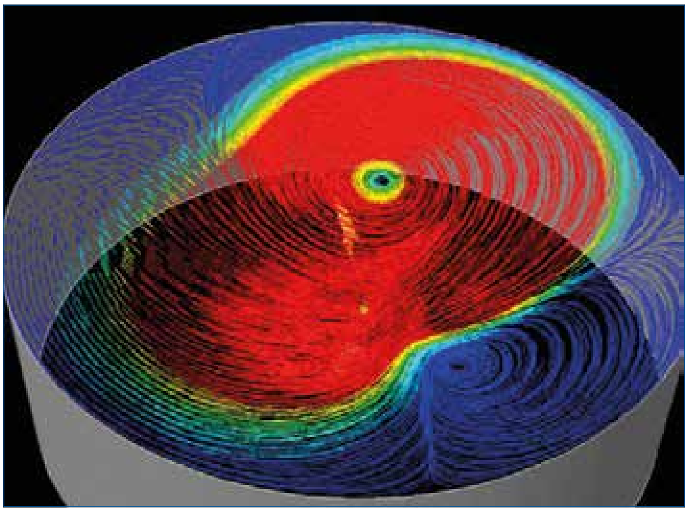


Fig. 83: Streamlines at the surface

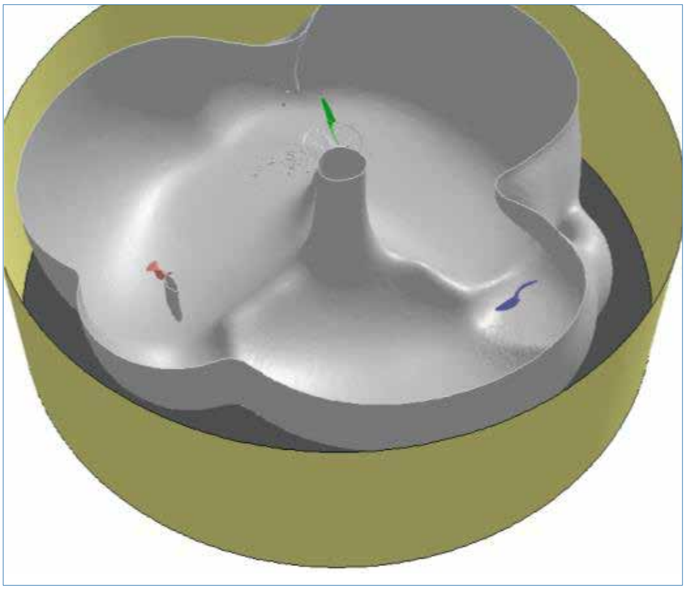


Fig. 84: Mixing volume

Based on the combination of comprehensive tank calculations and experiences a reliable selection tool has been developed. Its reliable results have been verified in velocity measurements and surface observations.

Higher-viscosity fluids – Biogas

For non-Newtonian fluids (e.g. in biogas applications) the dependence of viscosity on the shear rate must be considered by approximation.

The mixer quality, reactor flow and surface flow as well as the substrate transport are examined using CFD. Pseudoplastic fluids have an optimum mixing volume that depends on the mixer type, position, number of mixers and mixer speed.

The task is to create a mixing volume $v > v_{Limit}$ at minimum energy input.

Calculation models for pseudoplastic fluids:

- The viscosity η depends on the shear rate.
- $\eta = f(\gamma)$ is determined in a rotational viscometer.
- Approximation for $\eta = f(\gamma)$ programmable as UDF

The model approach was verified by analysing a large number of calculations with variable geometries (round, annular and racetrack tanks) of various dimensions, various rheology (K, m), various mixers and by comparing CFD calculations with matching measurements. Based on the model observations a procedure for estimating the mixing volumes has been derived.

Objectives of CFD calculations

- Determining characteristic flow patterns
- Qualitative and quantitative simulation of velocities
- Estimating the size and energy content of a mixing zone (cavern) in biogas reactors
- Analysing mixers regarding their application and positioning
- Verifying dead water zones
- Possibly estimating the mixer load
- Verifying potential surface vortices

Photo credits

Figs. 13 – 16	öko-control GmbH
Fig. 37	PTM GmbH Halle (Saale)

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