



Engineering & Expertise Designing pump sumps

LARGE SUBMERSIBLE PROPELLER PUMPS

FLYGT
a xylem brand

Total solution engineering increases operational efficiency

Introduction

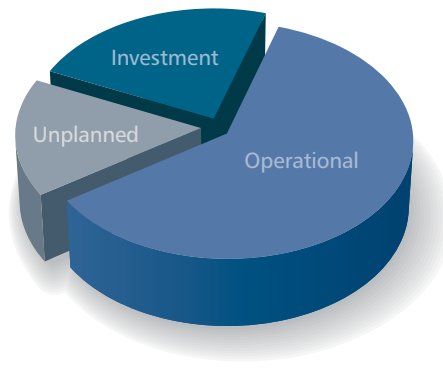
The proper design of the pump sump is critical in order to optimize pump inflow and, thereby, pump station efficiency. The number, type and arrangement of pumps, variable flow conditions in the approach area, the geometry of the structure itself and other site-specific factors must be evaluated on a case-by-case basis to identify their influence on the pump sump design.

Determining the best pump sump for a site therefore requires engineering and expertise. We will provide guidance for the design of pump sumps using large propeller pumps. Methods and procedures are given for handling various inflow conditions, avoiding solids buildup and arranging multiple pumping units in order to achieve an efficient, well-designed pump sump.

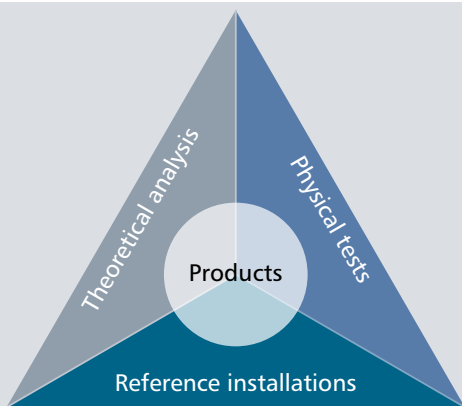
For more detailed information and design requirements, please read our engineering brochure. "Design recommendations for pump stations with vertically installed Flygt axial and mixed flow pumps"

Achieving lowest total cost of ownership

When providing pumping solutions, Flygt prefers to take the total cost of ownership into consideration.



- **Investment costs**
Costs associated with design, excavation, civil work, product purchases, installation and commissioning.
- **Operational costs**
Over time, energy usage and maintenance costs are often the major contributors to the overall costs along with the cost of labor required to run the system.
- **Unplanned costs**
When things go wrong, such as pump failures stemming from problematic station design, costs can skyrocket. Unexpected downtime can cause sewer backups, overflows, basement flooding and untreated effluent. On top of that, you have to repair pumps and take corrective measures regarding the station design.



Engineering & Expertise

Engineering & Expertise

Thanks to our engineering expertise, we can lower your total cost of ownership. We can analyze your system using state-of-the-art computational programs. We can test your pump station using scale models if required. We can also provide you with reference installations that are similar to your project. All of this together with our premium products provides you with an optimized design.

Reliable pump station design

Flygt large propeller pumps are designed to transport large volumes of fluid at low heads. These submersible pumps operate directly in the pumped liquid, making them a smart, economic alternative to non-submersible pumps. In addition, their slim profile enables a considerably smaller pump station footprint than that of non-submersible pumps. Key features are:

- Sustained high efficiency
- Self-cleaning capabilities
- Compact, modular design
- No separate lubrication system
- Low noise and vibration levels
- Flood-proof pump stations
- Quick and easy installation
- Minimal station superstructure

Flygt propeller pumps are usually installed in a discharge tube on a support flange that is incorporated in the lower end of the tube. No anchoring is required because the weight of the pump is sufficient to keep it in place. The pumps are equipped with an anti-rotation gusset. This arrangement provides the simplest possible installation. The pump is simply lowered into the discharge tube by hoist or crane; retrieval of the pump is equally simple.

Flygt large propeller pumps operate in various applications such as:

- Stormwater pumping
- Flood control
- Wastewater pumping
- Irrigation systems
- Cooling water
- Water parks and surfing attractions
- Irrigation



Achieving lowest total cost of ownership

Correctly designed stations will ensure minimal sedimentation and/or floating debris, thereby reducing planned services and maintenance. A well-designed pump station optimizes the hydraulic conditions for the pump, thus ensuring reliable pump operation and specified performance. We assure optimal sump size, making it as small as feasibly possible without compromising on reliability or efficiency.

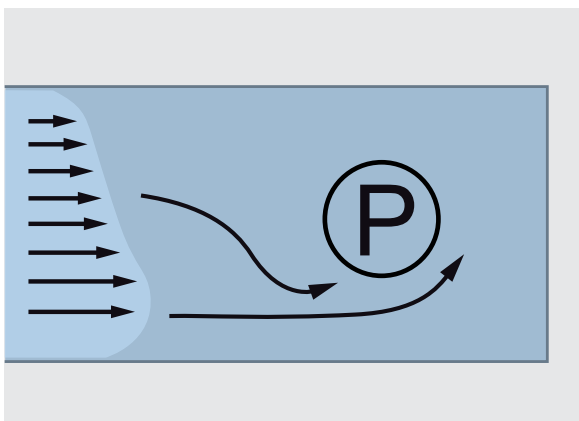
Adverse hydraulic phenomena

According to the Hydraulic Institute: “Ideally, the flow of water into any pump should be uniform, steady and free from swirl and entrained air. Lack of uniformity can cause the pump to operate away from the optimum design condition, and at a lower hydraulic efficiency. Unsteady flow causes the load on the impeller to fluctuate, which can lead to noise, vibration, bearing problems and fatigue failures of pump shafts.”

To ensure the expected pump performance and long service intervals, it is important to design the pump sump to prevent adverse hydraulic phenomena at pump intakes.

Excessive pre-swirl

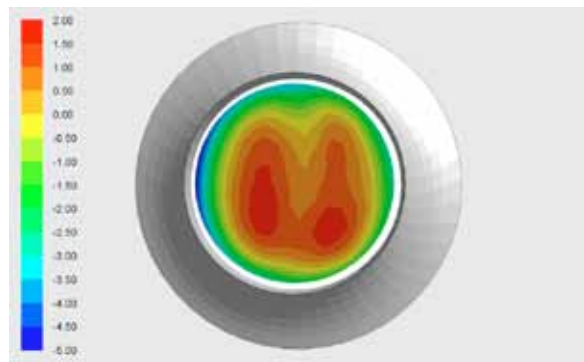
Pre-swirl changes the flow conditions at the pump inlet, which results in a change in the relative impeller speed. This, in turn, causes a change in pump performance, which can lead to overloading the motor or reduced pump performance. Excessive pre-swirl can also result in bearing wear and cavitation across the impeller area. Pre-swirl usually originates from an asymmetric velocity distribution in the approach channels, which evolves into a pre-swirl at the pump inlet. The Hydraulic Institute recommends a pre-swirl angle that does not exceed 5°, calculated from the ratio between the tangential velocity and axial velocity.



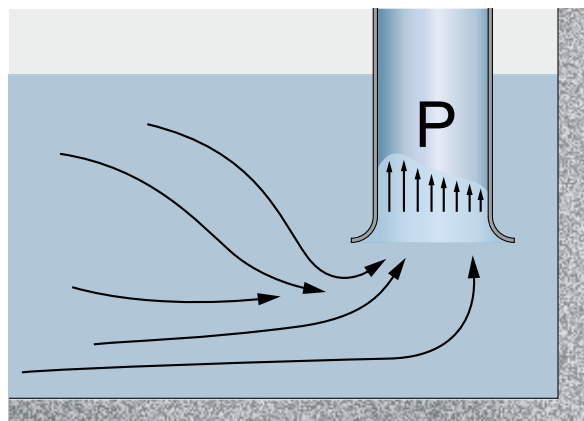
A non-uniform approach flow leads to pre-swirl, which can overload the motor or reduce pump performance.

Uneven velocity distribution at the pump intake

Uneven velocity distribution can result from different types of phenomena and disturbances. While some unevenness in velocity distribution is inevitable and does not harm the pump, variations that are greater than 10% at the pump intake can have severe consequences and should be avoided. A large variation of velocity results in an uneven load on the impeller and bearings. Unsteady flow causes the load on the impeller to fluctuate, which leads to noise, vibration, bearing loads and increased risk of fatigue failures.



CFD simulation of the flow distribution at the impeller plane.



Uneven velocity into the pump inlet leads to noise, vibration and bearing loads and increased risk of fatigue failure.

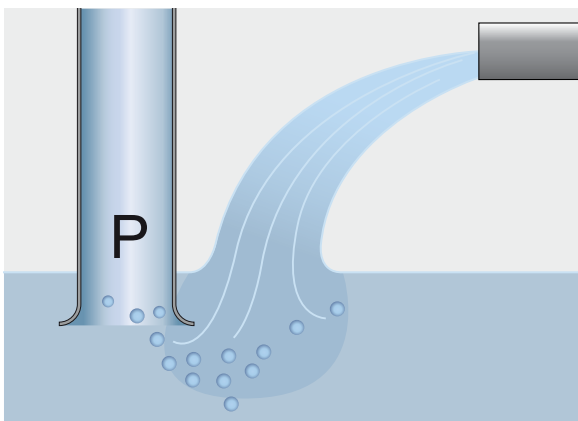
Entrained air

It is widely known that even minor air entrainment, of some 3.4% of the volume, will lead to a clear reduction in pump performance and loss of efficiency; the severity depends upon the quantity of air entrained and the pump type. The expansion of ingested air bubbles within the impeller may result in mechanical imbalance, vibration and acceleration of mechanical wear. Normal design practices recommend the exclusion of any air entrainment in the approach flow to the pump intake. In addition, entrained air leads to increased corrosion.

While air bubbles may be present in the liquid for a variety of reasons, their presence is usually due to cascading of the water as it enters the sump from a weir, culvert or incoming pipe located above the surface water level in the sump.



Entrained air and vortex shown in scale model test.



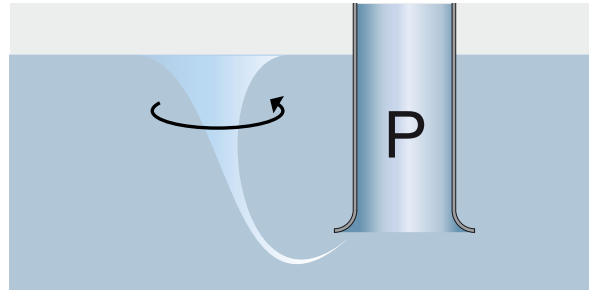
Entrained air can cause reduction in discharge and loss of efficiency.

Vortices

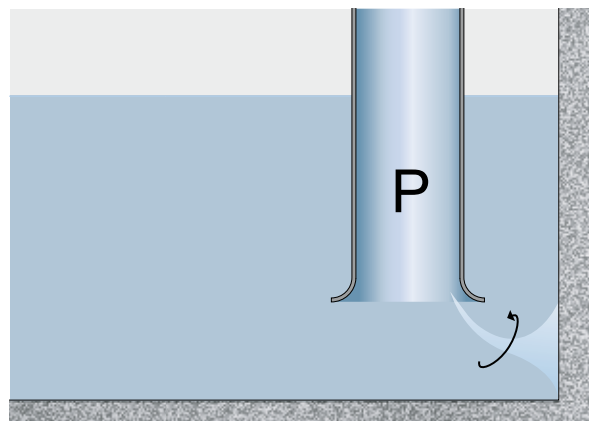
Unlike excessive pre-swirl, vortices appear locally with higher intensity and are a major hindrance to proper pump operation, resulting in cavitation, uneven load, noise and vibration. There are several different types of vortices.

The most commonly known type is the free surface vortex, which can have varying degrees of intensity - from weak surface vortices to fully developed vortices with a continuous air core that extends from the surface into the pump.

Less well known, but just as common is the vortex that originates under the surface from the sump bottom, walls or between two pumps, and extends to the pump inlet. This type of vortex can achieve high rotational speed with high subpressures and cavitations.



Strong surface vortex with an air core will result in cavitation, uneven load, noise and vibration.



Strong submerged vortex.

Sediment, floating debris and clogging problems

In addition to preventing the occurrence of adverse hydraulic phenomena, it is also important to design the station to minimize build up of sediment at the bottom of the sump and accumulation of floating debris.

Bottom sediments

Too low a velocity will result in low shear stresses on the bottom floor and build up of sediments. Cleaning bottom sediments is a costly and time consuming process. In addition, problems with odors are likely to occur when sediments build up.

When designing a sump, it is important to avoid any low flow regions within the sump. This can be achieved through the use of benching and a sloping floor to direct the bottom sediments toward the pump inlet.

If the bottom sediments are evenly distributed over time into the pump, no clogging problems will arise in the pumps.

Floating debris

Low flow regions also create floating debris on the surface of the sump. Again, cleaning is costly and time-consuming.

Floating debris can be avoided with good station design by ensuring that the velocities in sump are maintained and by not making the sump too large. It is also important to use a "wastewater" control philosophy, such as alternation between all pumps.

Clogging

If large mats of floating debris accumulate on the surface in the sump, significant increases in the flow rate can release huge portions of the mats, which may clog the pump or system components.



Bottom sediment buildup shown in a scale model test.



Pump station with accumulation of floating debris.

Verified design

We have designed, developed and verified standard Flygt branded pump stations. Extensive physical tests, applications expertise and years of experience have been utilized to optimize the design of Flygt pump stations.

Proven installations

Today there are thousands of pump stations in accordance to the Flygt standard in operation all over the world. These have a proven track record of preventing sedimentation, clogging, floating debris and adverse hydraulics. Experience from existing Flygt pump stations is also a critical success factor when designing new pump stations.

Scale model testing

When there is little or no prior experience, we use physical model testing to ensure the reliability of the design. A model is built to scale, typically at a 1:10 scale, on the basis of Froude number similarity, to preserve the laws of physics, and operated as a real installation. Analysis from the physical tests will show if the design is reliable and effective, and provides a solution to ensure safe pumping operation.

Computational fluid dynamics

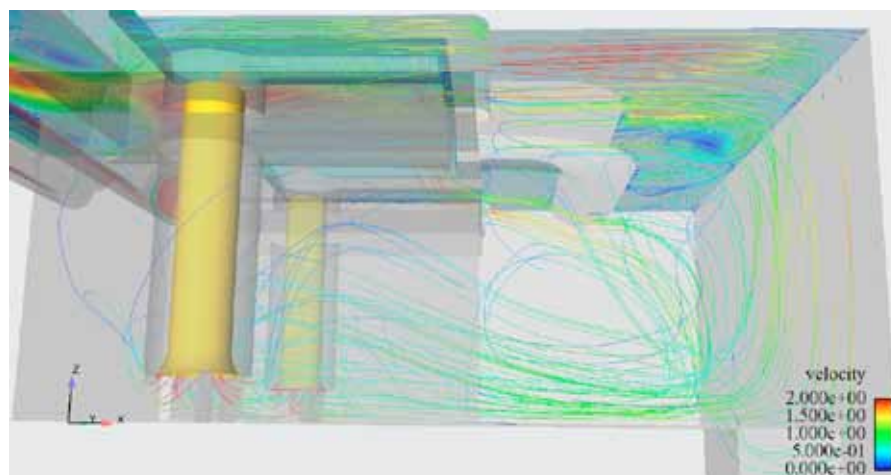
Another method we use to verify design is computational fluid dynamics (CFD), a mathematical modeling of the design where the flow pattern can be observed. Flygt pioneered the use of CFD to verify



Propeller pump sump design verified by a scale model test.

sump design, and we have been using CFD for many years. Depending on the complexity of the installation, CFD can complement physical model testing or replace it entirely.

We have a number of standard Flygt sump designs, all of which have been tested extensively through physical model testing, verified through CFD and proven through installations in use around the world. These sump designs have proven to minimize accumulation of sediments and debris and prevent adverse hydraulic conditions. When using standard Flygt designs, within the limits of our recommendations, there is no need for additional physical model testing or CFD.



Propeller pump sump design verified through computational fluid dynamics (CFD).



Reliable, cost-effective pumping

Our engineering expertise and vast experience contributes to pump station designs that together with Flygt equipment ensure reliable and cost-effective pumping. Because the pump station is a complex system, it is important to consider every critical aspect during the design phase. Pumping system efficiency depends not only on the efficiency of the pumping units, but also on the prevention of adverse hydraulic phenomena as well as sedimentation, floating debris and clogging problems.

Objectives

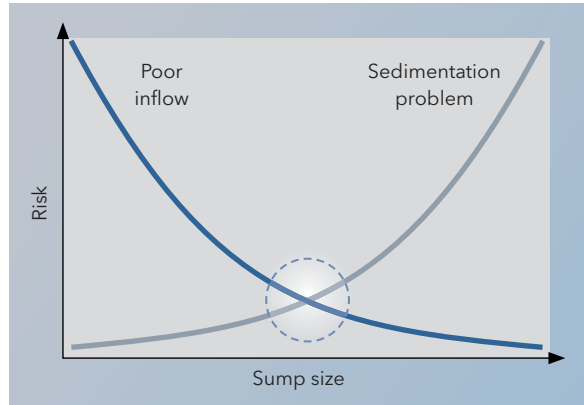
Ideally, the design of a pump station aims to achieve:

- Smallest possible footprint with the lowest possible cost
- Elimination of sedimentation and buildup of other debris
- Reliable handling of variable inflow
- Necessary conditions for optimal pumping
- Ease of installation, maintenance and repair

When designing a station it is also important to consider other factors that can have an impact on operations, such as site conditions, type of media and local regulations and practices.

Optimal sump sizing criteria

Other important factors to consider are the dimensions and capacity of a sump. Designing a sump that is too small carries a low risk of sedimentation problems but a high risk of poor inflow. In contrast, designing a sump that is too large will create low flow regions, which implies a high risk of sedimentation problems, while at the same time a low risk of poor inflow. These criteria must be taken into consideration to determine the optimal sump size.

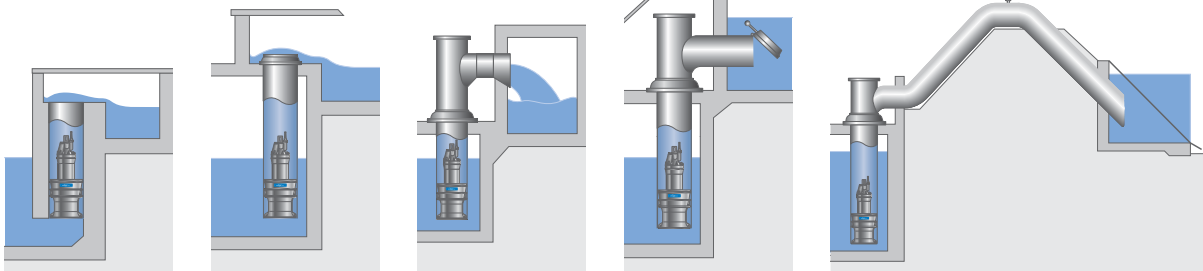


Optimal sump size depends on criteria, such as poor inflow and sedimentation problems.

Methods of installation

To reduce installation costs, standard Flygt pump packages with key pump station components are available to facilitate site-specific installation. We

have all the accessories and components required to meet your specific needs.



In concrete structure for pumping to channel.

In manufactured column for pumping to channel.

With a discharge pipe and free outlet.

With submerged outlet and flap valve.

With a siphon.

(Note: The different discharges are illustrated as manufactured columns, but all of them can be used with concrete structures as well.)

Pump sump design

The proper design of the pump sump is crucial in order to achieve an optimal inflow to the pumps. We can provide you with standard solutions for sump design based on our engineering expertise and experience. Typical components of a pump sump that uses large propeller pumps include an inlet area, forebay and pump bay.

Typical sump design

Inlet area

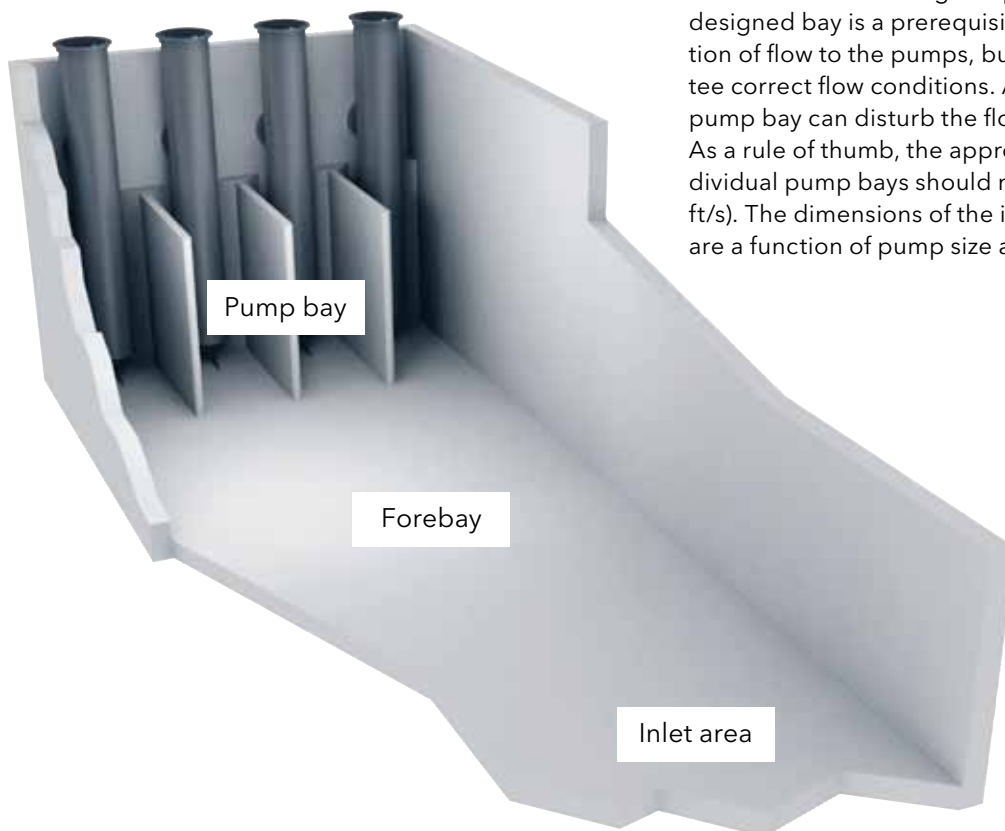
An inlet conveys water to the pump station from a supply source such as a culvert, canal or river. Usually, the inlet has a control structure such as a weir or gate.

Forebay

The forebay guides the flow to the pump bay in such a way that it is steady and uniform. Because the inflow to each individual pump bay should also be steady and uniform, the design of the forebay is critical and should follow our "Design recommendations for large propeller pumps". The design of the forebay is dependent upon the pump station's approach flow conditions. The most common approach condition is one that is parallel to the sump centerline, which is the preferred layout. The other approach condition is one that is perpendicular to the sump centerline.

Pump bay

In practice, only the design of the pump bay can be standardized for a given pump type. A properly designed bay is a prerequisite for correct presentation of flow to the pumps, but it does not guarantee correct flow conditions. A poor approach to the pump bay can disturb the flow in the pump intake. As a rule of thumb, the approach velocity to the individual pump bays should not exceed 0.5 m/s (1.6 ft/s). The dimensions of the individual pump bays are a function of pump size and flow rate.



Achieving uniform inflow

The use of propeller pumps puts high demand on the inflow. To achieve satisfactory homogeneous flow into the propeller pump, there are two major types of pump station designs: the open sump intake and the formed suction intake.

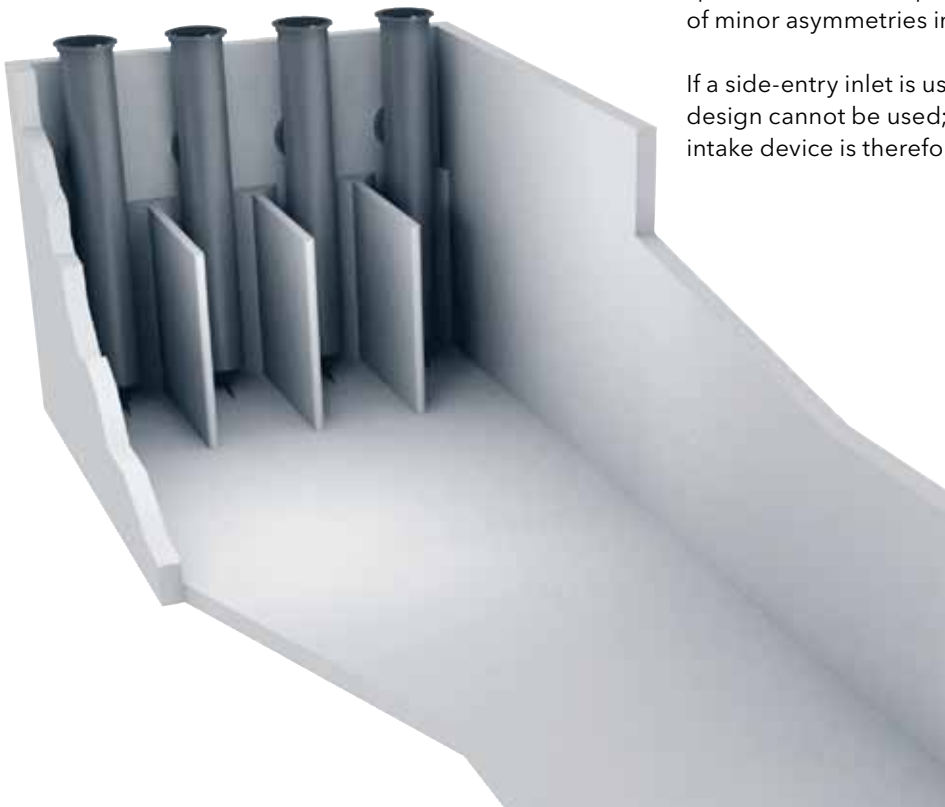
Open sump intake design

The most commonly used approach is the open sump intake design with open channels into the pumps. This design is the most sensitive to non-uniform approach flows; therefore, it requires the use of a longer forebay and longer dividing walls between the individual pump bays than the formed suction intake design.

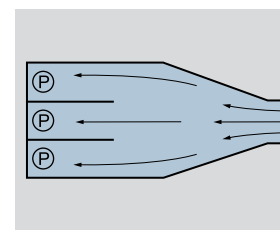
To achieve a steady, uniform flow towards each pump, the flow into the pump should be parallel to the pump channel. Ideally, the inlet to the sump is placed directly opposite the pumps and is directed towards these, but in many cases this is not possible due to angled inflow or lack of space.

Open sump intake design includes devices such as splitters and divider plates that alleviate the effects of minor asymmetries in the approach flow.

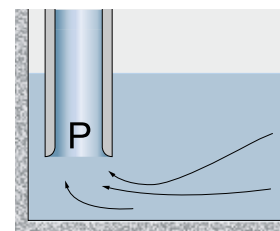
If a side-entry inlet is used, the open sump intake design cannot be used; the use of some type of intake device is therefore required.



Pump station with open channels to the pumps.



Schematic plan of a pump station with open channels to the pumps.



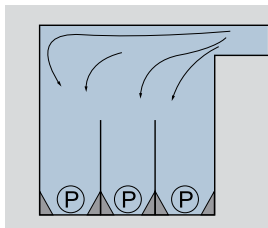
Cross-section of a pump station with open channels to the pumps.

Formed suction intake design

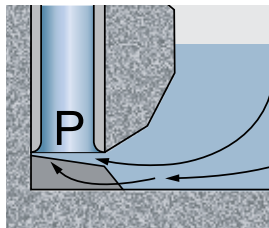
In situations with adverse flow conditions or limited space, the use of a formed suction intake design may be more appropriate. Its main function is to normalize the flow by means of acceleration and redirect the flow vertically into the pump inlet.



Pump station with formed suction intake in concrete.



Schematic of a formed suction intake design with side inlet.



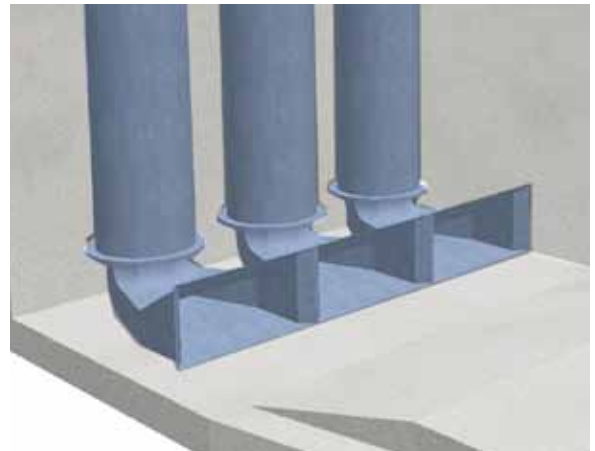
Cross-section of a formed suction intake design.

The formed suction intake design can be constructed either of concrete or steel. The intake reduces disturbances and swirl in the approach flow. The inclined front wall is designed to prevent stagnation of the surface flow. The geometrical features of this intake provide smooth acceleration and smooth turns as the flow enters the pump. This design is recommended for stations with multiple pumps with various operating conditions.

Flygt Formed Suction Intake

An alternative to a formed suction intake design is the Flygt Formed Suction Intake device. This specially engineered device for propeller pump intakes provides optimal inflow by gradually accelerating and redirecting the flow towards the pump inlet. Its primary function is to condition the incoming flow into a uniform profile and redirect the flow. It is ideal for use if highly adverse inflow conditions exist or the space available for the pump station is limited.

With the Flygt Formed Suction Intake device, it is possible to design an even more compact station. Compared to the already compact Flygt standard



The Flygt Formed Suction Intake device.

open sump intake design, the Flygt Formed Suction Intake device helps reduce the footprint of the sump by up to 60 percent. The Flygt Formed Suction Intake device is capable of normalizing even higher flows than those handled by a formed suction intake design.

By providing a reliable pump intake device in limited space, the Flygt Formed Suction Intake device is able to achieve a more economical pump station solution with a smaller footprint and good hydraulic performance.

Proven worldwide

Flygt has designed propeller pump stations for thousands of installations around the world. Engineering expertise and years of experience have resulted in the success of these installations. Three such installations are described below.



Belgium: Pump station

Challenge

To provide a cost-efficient pump station fed by three independent inlets, resulting in a potential maximum inflow of 7.8 m³/s (123,000 US gpm) combined. Air entrainment into the pumps due to the three independent inlets presented challenges.

Solution

We designed a solution using four Flygt PL 7101 propeller pumps with a total capacity of 8 m³/s (127,000 US gpm). This solution is shallower than competitors' solutions and has a lower height for lifting the water, which reduces energy consumption. The design was verified through physical hydraulic scale model tests to ensure the reliability of the solution.



Spain: White water ride

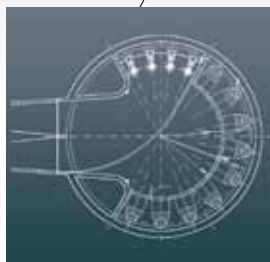
Challenge

Creating an artificial white water channel for water sports such as kayaking, canoeing and rafting by pumping 3 m³/s (48,000 US gpm) per pump at a height of 7 m (24 ft).

Solution

The operating mode provided the simultaneous use of three or four pumps with a fifth as a backup. We supplied five Flygt PL 7101 pumps rated at 300 kW each. When the channel was not used for racing, two Flygt LL 3300 pumps rated at 27 kW each handled a flow of 0.25 m³/s (4,000 US gpm). Due to the complexity of maneuvering the system and controlling pumps in conjunction with other equipment in the water channel, we also provided a Flygt pump controller to manage all these devices.





China: Circular stormwater and wastewater pump station

Challenge

Situated on an estuary of a major river, one of the largest cities in China has an average annual rainfall of 1100 mm (43 in). The three-month typhoon season, usually with heavy rains from the Pacific Ocean, leaves behind long-term seepage of water on the streets and/or floods households due to inadequate drainage systems and an obsolete pump station from the 1950s. Drainage is important to the city's downtown district, which are comprised of high-end residential complexes, municipal administrative buildings, foreign consulates and bustling shopping centers.

Solution

The city's largest pump station for combined sewage and rain/stormwater handling underwent

an major upgrade, which includes nine Flygt PL 7121/965 propeller pumps and four Flygt CP 3501/835 wastewater pumps. All pumps are arranged in a circular chamber and share the same water sump. The effective inside diameter of the sump is 39 m (128 ft).

Used for rain/stormwater handling, the Flygt propeller pumps have an operating range of between 2.5 and 3.5 m³/s (40,000 to 55,000 US gpm) and a head of 8 to 13 m (26 to 43 ft); the highest efficiency of 83% is obtained at a head of 10.2 m (34 ft). The sewage pumps have an operating range of between 1.0 and 1.4 m³/s (16,000 to 22,000 US gpm) and a head of 7.8 to 12.5 m (26 to 41 ft); the best efficiency of 84% is obtained at 11 m (36 ft).

Engineering & Expertise



To ensure reliable and highly efficient operation, we offer comprehensive support and service for pump station design, system analysis, installation, commissioning, operation and maintenance.

Design tools

When you design pump stations, we can offer advanced engineering tools to generate sump designs. Our design recommendations give you essential information regarding dimensions and layout. In short, we assist you every step of the way to make sure you optimize performance and achieve energy-efficient operations.

Theoretical analysis

Computational fluid dynamics (CFD) can provide far more detailed information about the flow field in a fraction of the time required to get the same information through physical hydraulic scale model testing. Using CFD in combination with computer-aided design (CAD) tools, it is possible to obtain a more efficient method of numerical simulation for pump station design.

To obtain a reliable, energy-efficient pumping system, it is important to analyze all modes of operation. To analyze the transient effects at pump start and stop with respect to flow and head as well as the electrical parameters such as current and torque, it is also important to have an accurate mathematical description of the pump and motor, which is gained, in part, from extensive testing in our laboratories.

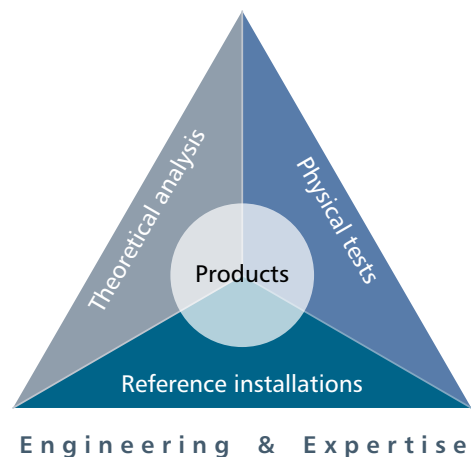


Physical testing

Physical hydraulic scale model testing can provide reliable, cost-effective solutions to complex hydraulic problems. This is particularly true for pump stations in which the geometry departs from recommended standards or where no prior experience with the application exists. Scale model testing can also be employed to identify solutions for existing installations and has proven to be a far less expensive way to determine the viability of possible solutions than through trial and error at full scale.

When our standard design recommendations are not met, we can assist in determining the need for physical testing as well as planning and arranging the testing and evaluating the results.

We have conducted system analysis and designed pump stations for thousands of installations around the world. Engineering expertise and years of experience gained from the design and operation of these installations have been a critical success factor when analyzing, testing and commissioning new pump installations.



Xylem ['zīləm]

- 1) The tissue in plants that brings water upward from the roots
- 2) A leading global water technology company

We're 12,000 people unified in a common purpose: creating innovative solutions to meet our world's water needs. Developing new technologies that will improve the way water is used, conserved, and re-used in the future is central to our work. We move, treat, analyze, and return water to the environment, and we help people use water efficiently, in their homes, buildings, factories and farms. In more than 150 countries, we have strong, long-standing relationships with customers who know us for our powerful combination of leading product brands and applications expertise, backed by a legacy of innovation.

For more information on how Xylem can help you, go to xylem.com.



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