Design Recommendations

FOR PUMP STATIONS WITH LARGE CENTRIFUGAL FLYGT WASTEWATER PUMPS

FLYGT
a xylem brand

Contents

This brochure is intended to help application engineers, designers, planners, and users of sewage and stormwater systems who are incorporating submerged submersible and dry installed Flygt pumps into their design.

A proper design of the pump sump in such installations is crucial. Two important design requirements to be met are: the prevention of significant quantities of air from reaching the impeller, and disposal of settled and floating solids. The Flygt standard pump sump can be used as it is, or with appropriate variations to meet the requirements of most installations.

The pump and sump are parts of an overall system that also includes a variety of structures and other elements such as ventilation systems and handling equipment.

Operating costs can be reduced with the help of effective planning and suitable operation schedules.

Xylem personnel and publications are available to offer guidance in these areas. Transient analysis such as air chamber dimensioning, valve selection, etc. should also be considered in wastewater pump station design. These matters are not addressed in this brochure, but we can offer advice on these topics.

Please consult with our engineers to achieve optimum pump performance, maximum pump life, and a guarantee that product warranties are met. The design recommendations are only valid for Flygt products. Xylem assumes no liability for non-Xylem equipment.

Flygt large centrifugal pumps introduction

Flygt large centrifugal submersible pumps have been used in a variety of applications all over the world. Pumps can be either submerged or dry installed. Applications include wastewater pumping stations in a variety of sizes as well as intake stations to treatment plants, storm water pumping, irrigation, mine applications, shipyards, and more.

Flygt submersible centrifugal pumps offer important advantages such as:

- A compact motor and pump unit
- No separate lubrication system
- Low operating sound level
- N impellers which provide sustained efficiency and enhanced reliability due to a unique hydraulic design
- Flood proof pumping stations even for dry installed pumps
- Automatic connection and disconnection for submerged installations. This allows for fast and easy installation, inspection, and service.
- Minimal station superstructure

Our submerged pumps are installed on a discharge connection bolted to the pit floor. The pump is guided to its position with double permanently installed 3” pipes. The connection is automatic and needs no visibility. The pump is just lowered onto the discharge connection and is held in position by its own weight. Retrieval of the pump is just as simple.

Flygt dry installed pumps are easy to maintain. The motor and impeller assembly can easily be lifted out of the pump volute for overhaul and repair. The submersible pump/motor unit also provides the possibility of a flood proof pumping station for safe operation at all times.

General considerations for sump design

Ideally, the flow of fluid into any pump should be uniform, steady, and free from swirl and entrained air. Lack of uniformity can cause a pump to operate at a lower efficiency. Unsteady flow causes the load on the impeller to fluctuate, which can lead to noise, vibration, and bearing problems.

Swirl in the pump intake can cause a significant change in the operating conditions for a pump, and can produce changes in the flow capacity, power requirements, and efficiency. It can also result in local vortex-type pressure reductions that induce air cores extending into the pump. This, and any other air ingestion, can cause reductions in pump flow and fluctuations of impeller load which result in noise and vibration with consequent physical damage. Additionally, these fluctuations can impact process loads in other parts of the system.

The design of a sump should not only provide proper approach flow to the pumps, it should also prevent the accumulation of sediments and surface scum in the sump. The following points must be considered:

- Flow of water from the sump entrance should be directed toward the pump inlets in such a way that the flow reaches the inlets with a minimum of swirl and energy loss.
- In order to prevent the formation of air-entraining surface vortices in the sump, the walls must be designed and built to avoid stagnation regions in the flow. A properly placed wall close to the inlet can reduce the tendency toward localized swirl and vorticity. The water depth must also be great enough to suppress surface vortices.
- Although excessive turbulence or large eddies should be avoided, some turbulence does help to prevent the formation and growth of vortices.
- Sediment, which could be foul, must not accumulate within the sump. Stagnant regions, or regions of such low velocity where sedimentation might occur, must be avoided. A sloping floor and fillets or benching often help to prevent sedimentation. For large variations in flow, part of the sump can be dedicated to low inflows with a lower floor level and a small pump. Consult Xylem for an optimum sump design.
- Surface scum, floating sludge, and small debris can accumulate in any relatively calm region of the water surface, and this material must be pumped away. The water level should be lowered as much as possible at intervals to increase both velocity and turbulence, however, air should not be drawn into the pump. Please consult with an Xylem engineer in order to achieve optimum pumping performance. The occasional increases in flow velocity will also assist in preventing the accumulation of sediment on the floor.
- Station inflow often approaches the wet well at a relatively high elevation. In such cases, the liquid may fall a significant distance as it enters the sump. Such a drop can also occur whenever the pumps have lowered the liquid level in the sump to the point at which all pumps are about to be switched off. Therefore, the path between the sump entrance and the pump inlets must be sufficiently long for the air to rise to the surface and escape before reaching the pumps. The energy of the falling water should be dissipated sufficiently so that excessively high and irregular velocities do not occur within the sump. This can be accomplished with properly designed and correctly positioned baffle walls.
- The sump should be as small and as simple as feasible to minimize construction costs, however, a minimum sump volume may be specified for other reasons, such as to provide for a minimum retention time, or to ensure that only a certain number of pump starts per hour occur.

Principles to be adopted in the design of any sump are given in a number of design guides or "codes of practice" – for example, both the American Hydraulic Institute and the British Hydromechanics Research Association have published such guides. Nevertheless, whenever a new design departs significantly from established configurations, model tests of the sump and its approaches should be considered.

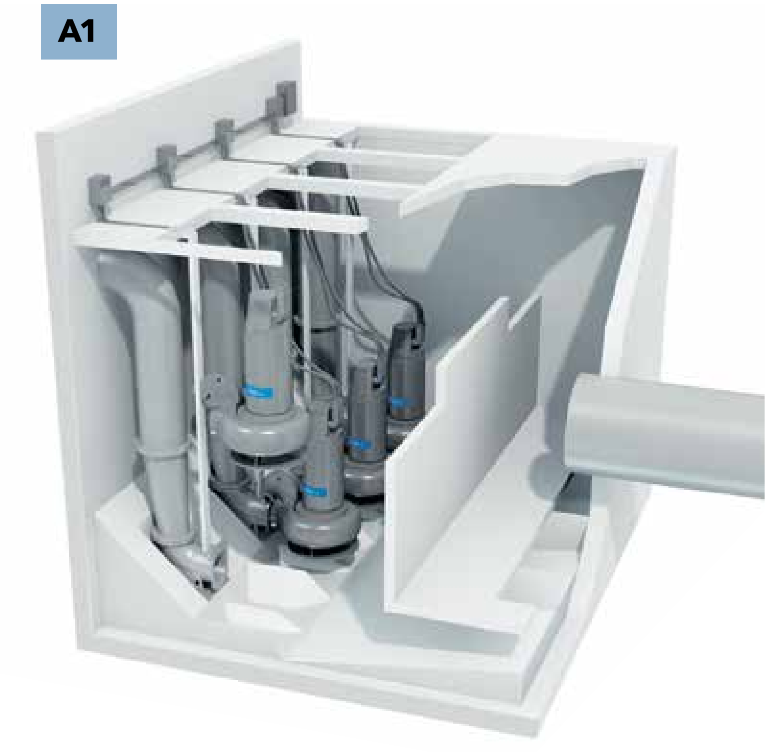
Xylem standard sump

A sump designed in accordance with this brochure is smaller than a conventional sump. Consequently, there may be less buffer volume to accommodate transient variations of the flow rate. Nor is there extra retention volume to store the inflow in excess of the total pump capacity (the pipe volumes are usually much larger than any pump station volume). A proper design of a complete pump station should therefore consider all critical aspects of operation. Of course, the pump capacity must match the extreme inflows to minimize the risk of flooding. Often flow characteristics of the feeding sewer system should also be analyzed.

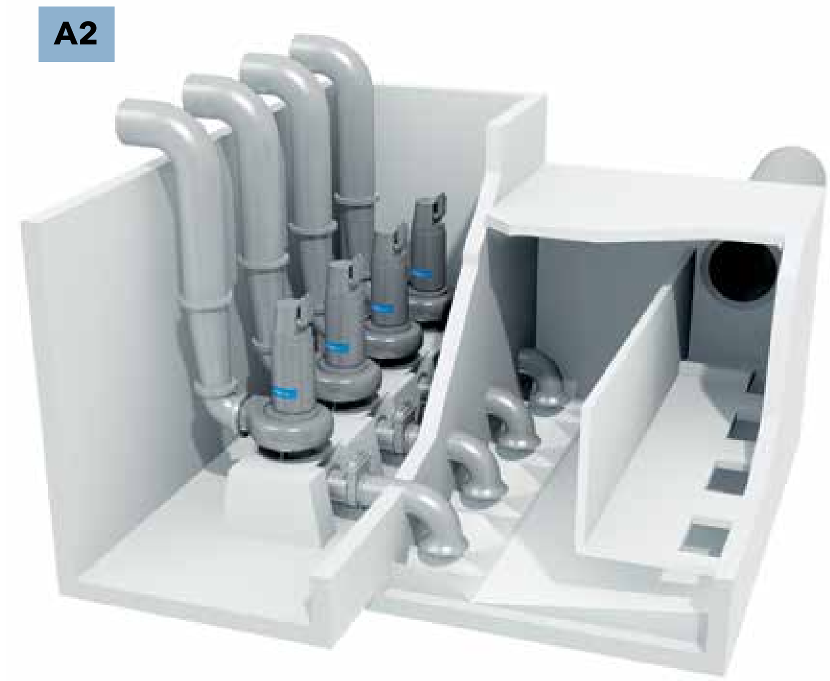
The control system for the pumps must also provide protection in the event of a power failure. Precise level sensors are crucial if the sump volume is minimized in accordance with the recommendations in the preceding section.

The discharge pipe work should be designed to prevent flooding by the return flow when the pumps are stopped, and also in emergency situations. The effects of possible pressure surges should be minimized by appropriate design of the control devices.

A1



A2



To avoid pre-swirl into the pump chamber, the inlet pipe must have a straight length of five pipe diameters upstream from the sump. The exact sump design varies with the number of pumps and pump size.

The central front high-level entry sump design is referred to as type A1. In this configuration, the flow does not have to make a horizontal turn, which might induce mass rotation in the sump.

A specially designed baffle wall minimizes air entrainment due to falling water. The flow from the inlet pipe strikes the partition wall then flows down into the inlet chamber through the slot in the floor of the baffle. The slot distributes the flow evenly toward all the pump inlets. The partition wall is high enough to ensure that the flow does not surge over it. Although the flow in the inlet chamber is highly turbulent, various materials can collect there. In such cases, side overflow weirs or side gaps may be used to carry away debris and thus prevent its accumulation. (The top of the partition wall, or parts of it should be below the highest start-level of any of the pumps to allow transport of the floating material into the pump chamber).

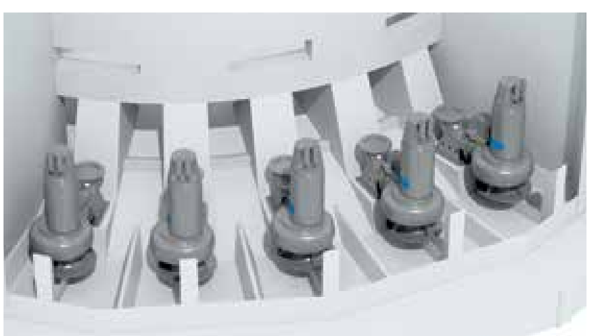
If the piping system and the sump location do not allow for a front entry inlet – a side entry inlet with a baffle wall modified with ports can be used. This configuration is referred to as type A2. In this design, the baffle wall redirects the incoming flow and distributes the flow evenly toward the pumps through the ports. At high inlet, it is recommended to have a baffle on the inlet chamber floor. This baffle breaks flow jets when the water level in the station is low.

Equipping the sump with fillets, baffles, and/or benching is often beneficial depending on the number of pumps and their size. Therefore, please consult with Xylem for an optimum sump design.

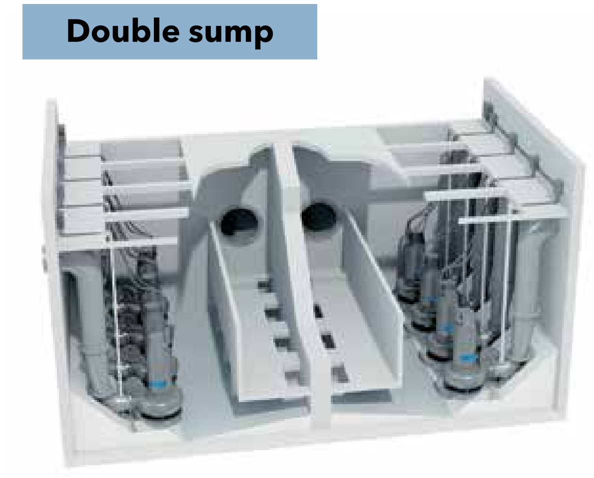
Circular sump

B2

Reverse oriented pumps



Double sump



Construction alternatives

Distributing the flow evenly to all pumps over the width of the sump can present problems if the number of pumps is more than four. In such cases, a double sump may be more suitable.

For deep sumps, using a circular outer structure can be advantageous from a construction viewpoint. Inside such a structure, individual pump sump modules similar to those used for the compact sump can be accommodated.

Please contact Xylem for advice of compact sump designs with a central front low-level entry.

In type B2, with a straight baffle wall, the sewer is below the normal water level in the sump, or an open channel supplies the sump. In the absence of falling flow in the entrance, no intense entrainment of air takes place. Consequently, the inlet chamber can be greatly simplified because its only task is to distribute the flow evenly to the pumps. In dry pumps application, it is recommended to have vertical baffles between suction pipes, to protect mass rotation in the wet well.

Sometimes there is a need to locate the riser pipe in the center of the stations or locate the outlet in another direction where reversed pump orientation can be a solution.

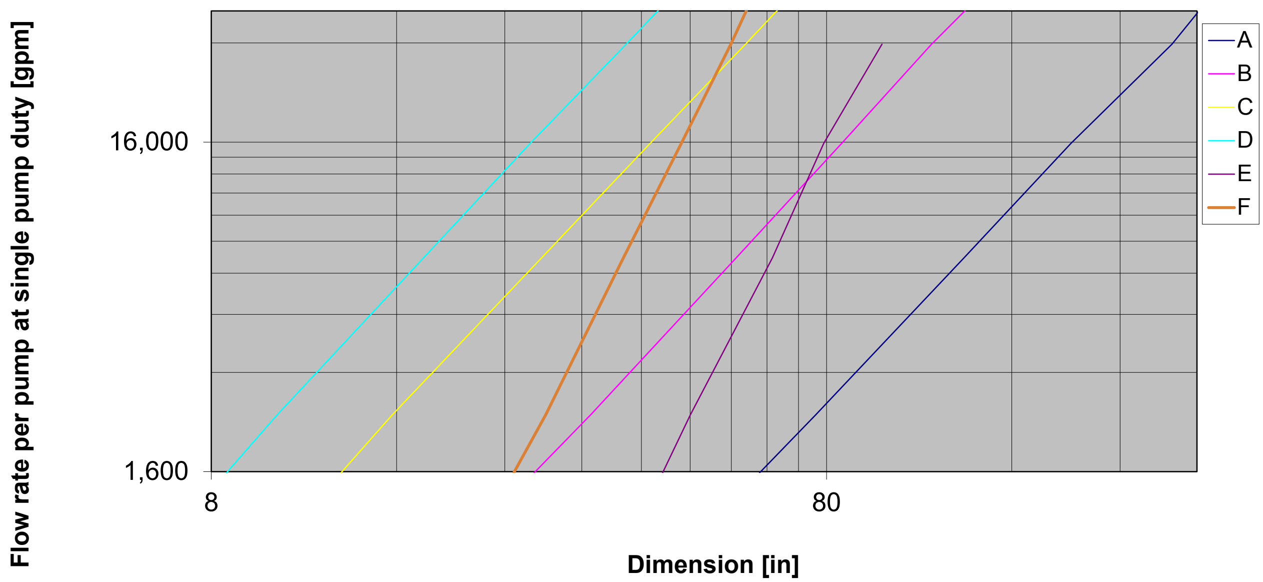
This picture shows an extract of a reverse orientation wastewater pumping station design.

When operated in combination with recommended pump control philosophies, optimal pumping conditions are achieved while also providing sump floor cleaning for transportation of solids.

Sump dimensions

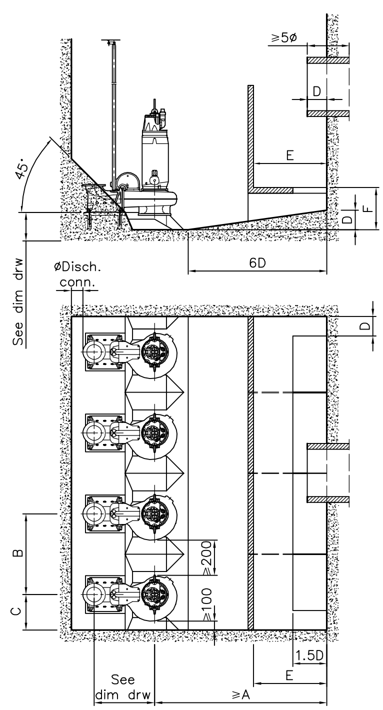
The sizing diagram is valid for pumping stations up to four pumps, all of which may be duty pumps. Tolerances of ±10 % on the sump dimensions shown in the table below are acceptable provided that the combined effect of the departures does not lead to velocities significantly higher than those for the standard sump. Flow per pump refers to one pump duty point for maximum total flow (in a common pressure pipe).

Pump sump dimensioning diagram

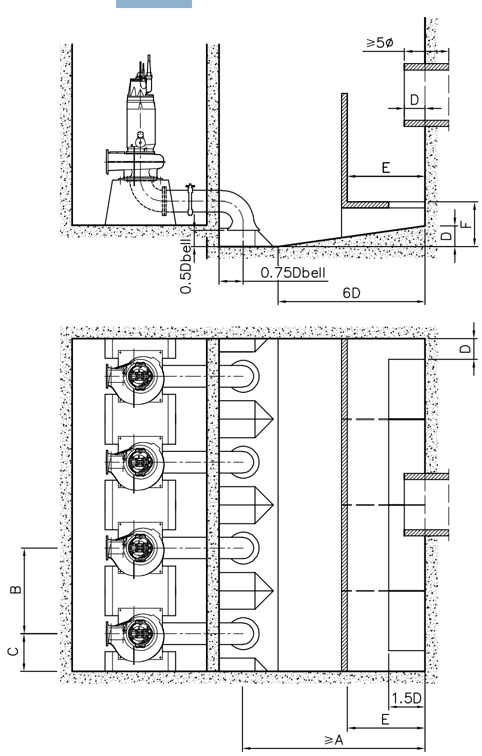


Please note that in this flow region is also sump design recommendations for the mid-range product line are applicable.

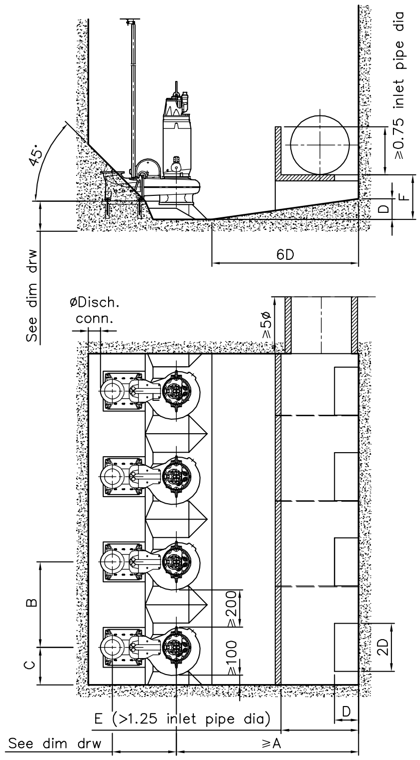
A1 **Submerged**



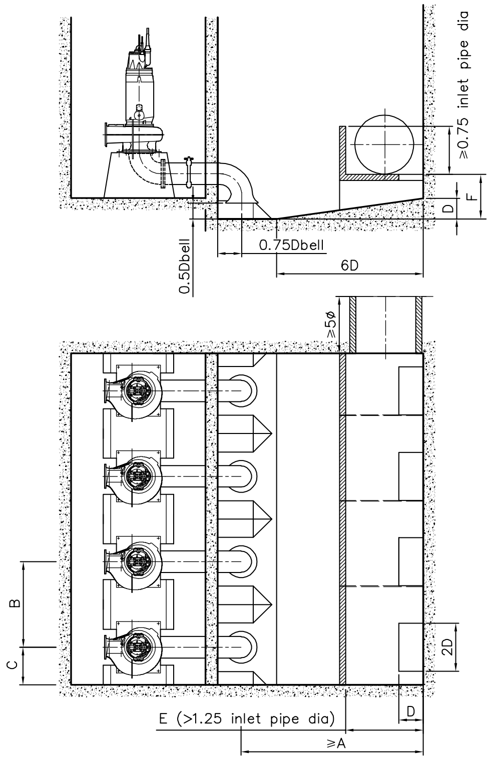
A1 **Dry**



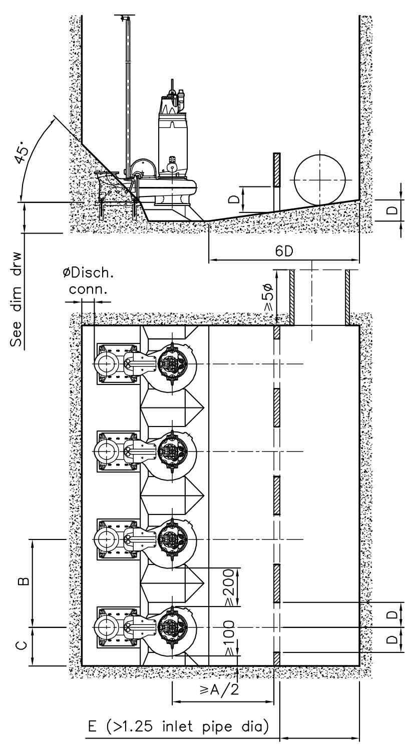
A2 Submerged



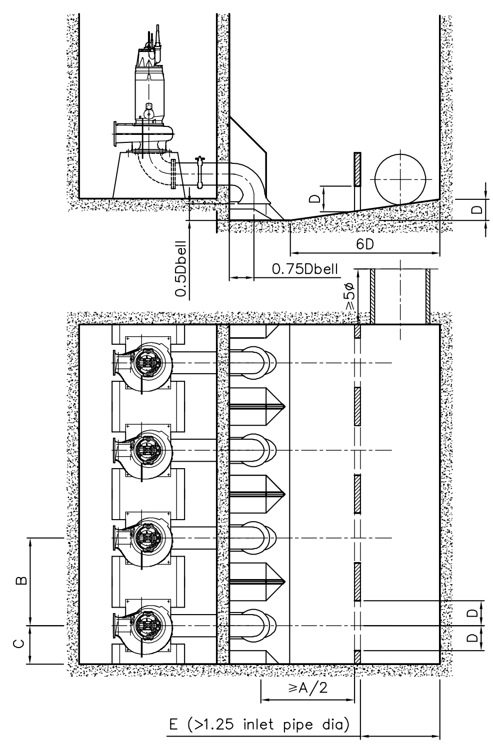
A2 Dry



B2 Submerged



B2 Dry



Required sump volume

The required live volume of the sump, V, i.e. the volume between the start level and the stop level of the pump, depends upon such factors as the cycle time for the pump, T; the pump capacity, Q; and the rate of the inflow, q.
For one pump and for variable inflow rate, the shortest cycle time occurs if q = Q/2 which gives the minimum required volume of the sump:

$$V_{req} = \frac{T_{minimum} Q}{4}$$

The minimum cycle time, (Tminimum) is determined by the number of pump starts with regard to the mechanical stress from the temperature rise in the motor.

T = 3600 / starts per hour

For a pumping station with identical pumps, the required volume is smallest if the pumps start in sequence as the water level rises due to increasing inflow, and stop in sequence as the water level drops due to decreasing inflow. To minimize the required sump volume, the last pump to start should be the last pump to stop, i.e. cyclic alternation.

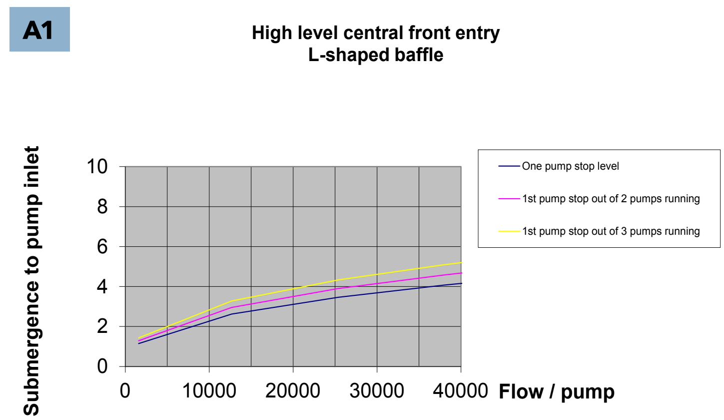
Minimum stop levels

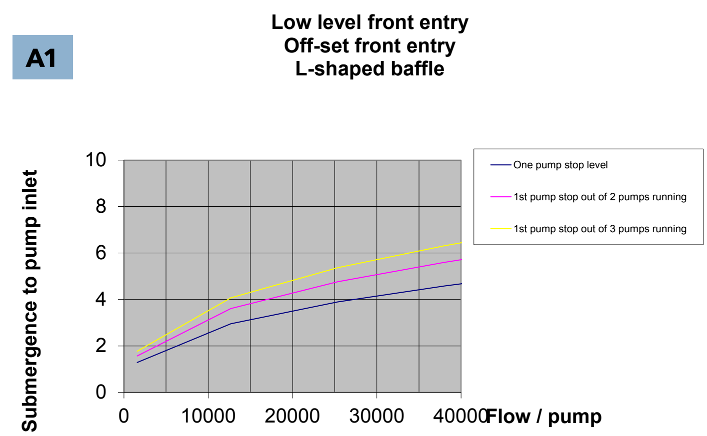
The pumps can be stopped at the same water level, but a time delay between the stops is important to avoid high immediate flow changes and pressure transients in the discharge pipes. The following minimum stop level recommendations prevent vortices and air penetration through to the pump intakes. For a short period of time the level could be less, e.g. during the sump cleaning cycle.

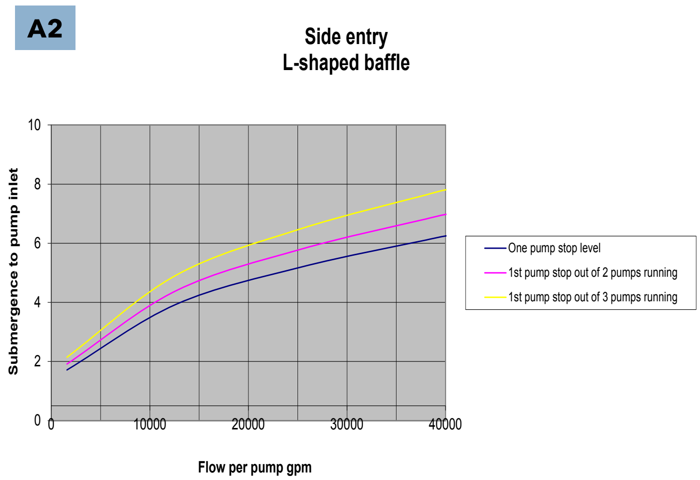
Sump design type A1, A2, B2

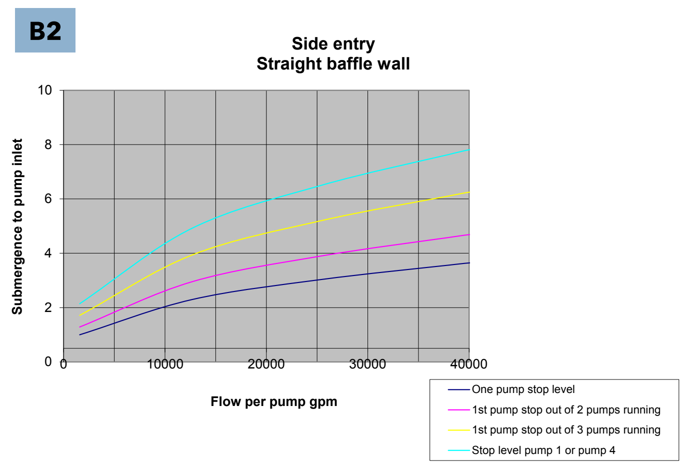
These recommendations are valid for the Flygt pump sump design for two, three, or four pumps, installed either in a semi-permanent (P) or permanent wet well (T). It is valid for all four positions of the pumps at all combinations of pumps in duty, though exceptions in the recommendations are made for the straight baffle wall. It is assumed that at least one pump is assigned as a standby pump, and only in extreme cases will all four pumps run simultaneously.

When the location of the inlet pipe is unsymmetrical, at low level, or the last part is less than five straight pipe diameters, higher stop levels to suppress vortices should be applied according to the recommendations for non-optimal inflow (see graph: Low level front entry).









Note that NPSHreq has to be fulfilled according to the paragraph below.

Net Positive Suction Head – NPSHav

The positive head required on the suction side of the pump to secure safe operation in terms of cavitation is determined by the NPSH (net positive suction head) curve. The basic condition to be fulfilled in all applications where rotodynamic pumps are used is:

NPSHav > NPSHreq

where:

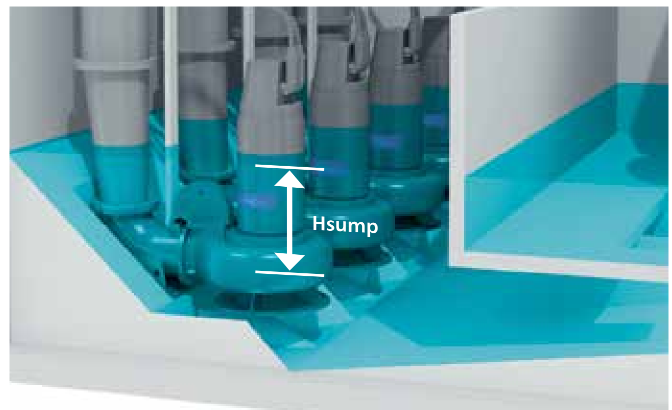
NPSHav – Available suction pressure due to atmospheric pressure, temperature, water level in the sump, and inlet losses.

NPSHreq – The pressure required to obtain a trouble-free operation in terms of cavitation, the value is determined by the NPSH curve for the pump.

The available suction head has to be greater than the suction head required by the pump.

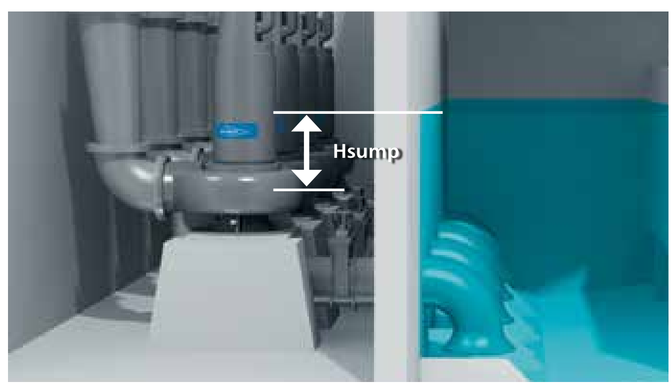
The available suction head in a wet-installed pump application is:

NPSHav = Hatm + Hsump - Hev



For a dry installed application, the dynamic head losses in the inlet pipe have to be taken into account. Consequently the relation for the available suction head becomes:

NPSHav = Hatm + Hsump - Hloss - Hev



where:

Hatm – Atmospheric pressure

Hsump – Difference in level between centerline of the impeller and liquid surface in the sump

Hev – Evaporation pressure of the liquid

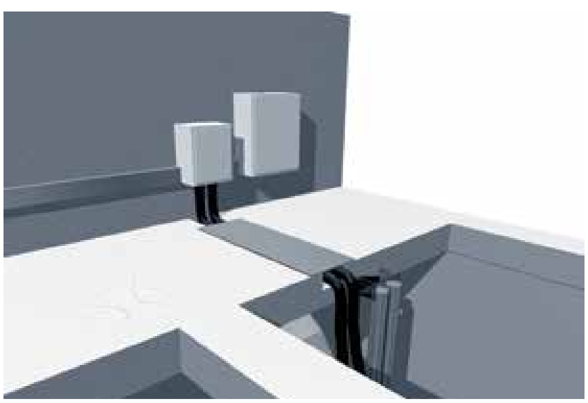
Hloss – Dynamic head loss in inlet pipe system

Installation tips

Submerged pumps

The following are some general installation guidelines for submersible pumps:

- The check valve should be located at least 8 meters (27 feet) above the pump discharge to avoid cavitation.
- A trough in the wetwell floor is recommended for station cable runs (refer to electrical codes). This will protect the cable make the station easier to maintain.
- The cable support bracket/strain relief sheathing should be mounted for easy access, i.e. within reach under the hatch.
- When a pipe or a hose is used to protect the cable, it should not cover the cable all the way into the control panel, as evaporating explosive gases from the wastewater entering the cabinet could be dangerous inside the control panel (refer to local codes).
- Wastewater gas can cause relay oxidation. It is therefore beneficial to locate the control panel in a ventilated environment.
- A stillwell located with its opening below the lowest water level may be used to avoid any problems with floating debris interfering with the operation of level regulators.
- The pocket in the benching with the discharge connections can collect sediment. A steel plate or concrete infill benching covering the pocket may be used to prevent sedimentation.



Dry installed submersible pumps

Suction pipe design

The position of the suction pipe relative to the dry installed pump follows the same hydraulic guidelines as for a submerged pump. However, with dry installed pumps, additional consideration must be given to the submergence of the inlet. This is because air can be drawn into the inlet pipe in a dry installed pump easier than the suction of a wet installed pump since the volute of a submerged pump acts as a vortex suppressor.

Accumulated air in the inlet pipe can impair pump operation and can cause the system to become “air bound” – preventing pumping altogether.

For flows over 500 l/s (8000 gpm), the inlet pipe should be equipped with an inlet bell to minimize losses and disturbed flow into the pump.

To achieve a uniform flow to the inlet of the pump, the suction pipe design should fulfill the following:

1. Provide sufficient NPSHav
2. Minimize friction losses
3. Minimize number of elbows
4. Eliminate vapor from suction pipe
5. Ensure correct pipe alignment
6. Provide automatic air venting downstream of the pump before the check valve

Valve location at the suction pipe

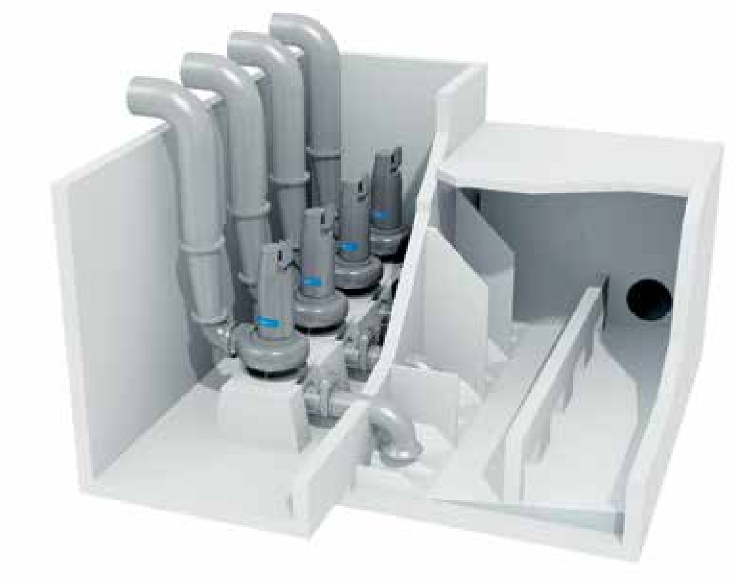
To minimize the risk of cavitation, noise, and vibration, the valve and the valve seat should be smooth to avoid flow disturbance (gate valves are preferred), and if possible, be located more than five pipe diameters away from the pump.

Effects of elbows

Elbows in the piping generate dynamic losses and swirling flow and should be avoided whenever possible. To minimize the effects of the elbows, the pre-swirl (which could increase the power requirements for the pump) should be located in one plane – as shown in the 360° and 180° pipe configurations.

The inlet bellmouth

To accelerate the flow smoothly into the inlet pipe and reduce inlet losses, the inlet should be provided with a bellmouth.



The optimal velocity at the entrance of the bellmouth is 1.7 m/s, (5.6 ft/s) and should be within the following limits.

Flow	Velocity
< 1200 l/s, <19,000 gpm	0.9–2.4 m/s, 3–8 ft/s
> 1200 l/s, >19,000 gpm	1.2–2.1 m/s, 4–7 ft/s

Installation guidelines for the pump and its piping

Avoiding vibration and noise

A rotary machine will always be a source of energy for acoustic/vibrational disturbance. The pump and/or motor unit can propagate disturbances to the environment that may excite vibration and cause noise in other parts of the system, pipes, etc. With wet-well installed pumps, the medium helps reduce vibration and noise. The design for dry installed pumps must be more carefully analyzed in order to reduce these types of problems.

The first rule to follow is that the pump is best operated in the duty area it is designed for – normally between 50 % and 125 % of best efficiency point (BEP). In this area, disturbances such as impeller and volute forces, cavitation, etc., are kept to a minimum.

The standard pump accessories are designed for use with a fixed, stiff installation where the main disturbance frequency will be below the lowest natural frequency and result in low vibration levels.

In some cases, a totally fixed design is not enough, and the system or parts of it have to be isolated with rubber machine feet, a rubber carpet, flexible pipe joints, etc.

When evaluating the system, an analysis of the source of any disturbance can include:

- Imbalance in the rotating parts. These have a dominating magnitude at the rotation frequency of the pump.
- Hydraulic forces that are caused by the pressure differences in the volute
- The passage of the impeller blade past the volute cut water which creates both forces on the impeller and pressure pulses in the pipe system at a frequency that is the product of the rotating impeller frequency and the blade number.

With this information, it is possible to analyze the system in order to minimize the risk for vibration, i.e. the critical pipe length and the minimum distance for the pipe support to prevent harmonics.

Other factors that might create noise are the electric motor, the internal flow (turbulence and swirl can cause pipes and valves to radiate noise), and cavitation within the pump or in the pipes/valves.

For more information regarding vibration and noise prevention for dry installed pumps, please see Xylem's engineering paper "Noise and vibrations from pumping installations".

Pump anchoring and piping support guidelines

The following guidelines can prevent unwanted vibration:

1) All parts of the system should be anchored so the primary disturbances have frequencies below the lowest natural frequency of the system, including pump, valves, supports, and pipes.

2) If the pump and foundation are to be insulated from the pumping station, the following procedure is recommended:

   a) The weight of the foundations should be at least two times the weight of the rotating parts.

   b) Use flexible supports, e.g. machine feet or a rubber carpet, between the base and the floor or ground.

   c) Use flexible joints for the pipes.

   d) Anchor the pipes to the floor or to another solid structure.

3) Horizontal and vertical supports should be provided, with extra supports at heavy components such as valves.

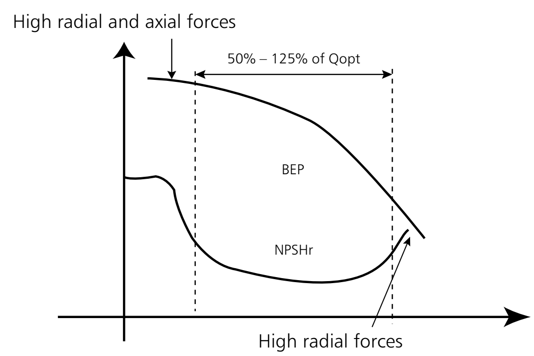
4) For pipe systems with bellows to minimize vibration, the pipe should be supported at the bellows to avoid transference of pressure fluctuations.

5) Vertical pipe velocities must be kept at a level that prevents the settling of solids. The recommended range is 1.5–2.5 m/sec.

Importance of duty point

In order to achieve the best possible pump operation and maximize equipment life, it is very important to select the correct pump for the duty point in question. The preferred operating region (POR) for most large centrifugal pumps is between 70 % and 120 % of the Best Efficiency Point (BEP), as outlined in the Hydraulic Institute Standards. The Allowable Operating Region (AOR) from BEP for optimal operation of centrifugal pumps in wastewater applications is between 50 % and 125 % of BEP (unless the curve does not have an operational limit and sufficient NPSH is available). By running the pump outside the AOR the following problems can occur:

- Unstable operation.
- Incipient cavitation resulting in impeller erosion, noise or vibration.



Consult Xylem Engineering if operation outside of the AOR is required.

Systems Engineering

Xylem offers in-depth expertise in the design and execution of comprehensive solutions for water and wastewater transport and treatment.

Our know-how and experience are combined with a broad range of suitable products for delivering customized solutions that ensure trouble-free operations for customers. To do this our engineers utilize our own specially developed computer programs, as well as commercially available programs, for design and development projects.

Scope of assistance includes a thorough analysis of the situation and proposed solutions, together with selection of products and accessories.

We also provide hydraulic guidance and assistance for flow-related or rheological issues. Customers turn to us, as well, for analysis of complex systems for network pumping, including calculations for hydraulic transients, pump starts, and flow variations.

Additional services:

- Optimization of pump sump design for our products and specific sites
- Assistance with mixing and aeration specifications and design of appropriate systems
- System simulation utilizing computational fluid dynamics (CFD)
- Guidance for model testing
- Guidance for achieving the lowest costs in operations, service, and installation
- Specially developed engineering software for system design

The range of services is comprehensive, but our philosophy is very simple: There is no substitute for excellence.

Xylem |'zīləm|

1) The tissue in plants that brings water upward from the roots;
2) a leading global water technology company.

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Let's Solve Water

Xylem, Inc.
14125 South Bridge Circle
Charlotte, NC 28273
Tel 704.409.9700
Fax 704.295.9080
855-XYL-H2O1 (855-995-4261)
www.xyleminc.com