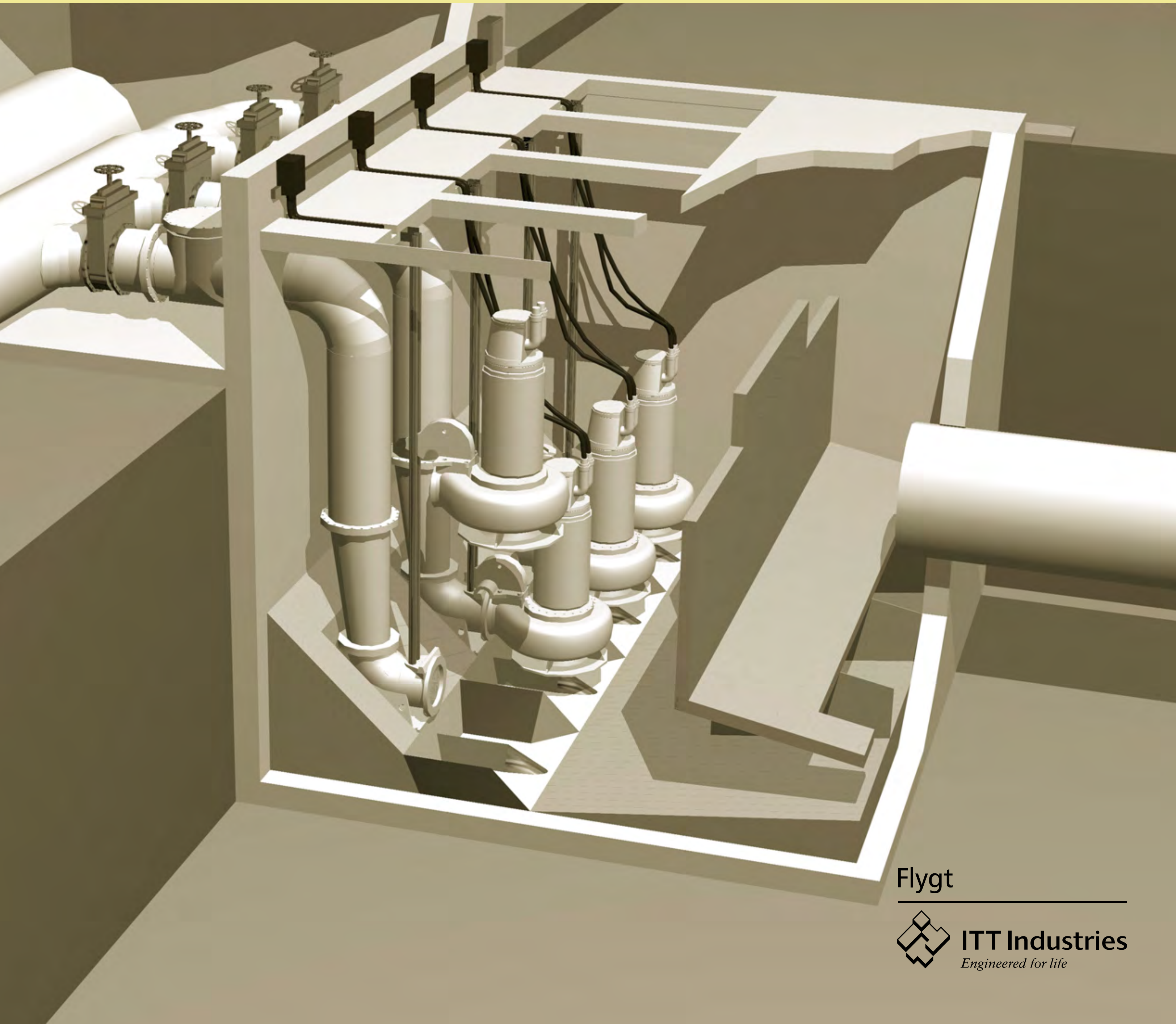
Design recommendations

for pump stations with large centrifugal wastewater pumps



Flygt

ITT Industries
Engineered for life

This brochure is intended to assist application engineers, designers, planners and users of sewage and stormwater systems incorporating submerged and dry installed Flygt submersible pumps.
A proper design of the pump sump in such installations is crucial. Two important design objectives are; preventing 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.
Pump and sump are parts of an overall system that also includes a variety of structures and other elements such as ventilation systems and other handling equipment.

Operating costs can be reduced with the help of effective planning and suitable operation schedules. ITT Flygt 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 ITT Flygt can offer advice on these topics.
Please consult with an ITT Flygt engineer to achieve optimum pumping performance, maximum pump life, and a guarantee that product warranties are met. The design recommendations are only valid for Flygt equipment. ITT Flygt assumes no liability for non-Flygt equipment.

General considerations for sump design

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 impeller to operate away from the optimum design condition, and therefore at a lower hydraulic 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 for proper approach flow to the pumps, it should also prevent the accumulation of sediment 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.
- 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 also must 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 ITT Flygt 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 ITT Flygt 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 placed baffle walls.
- The sump should be as small and as simple as feasible to minimize construction costs. However, required 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.

Design capacity

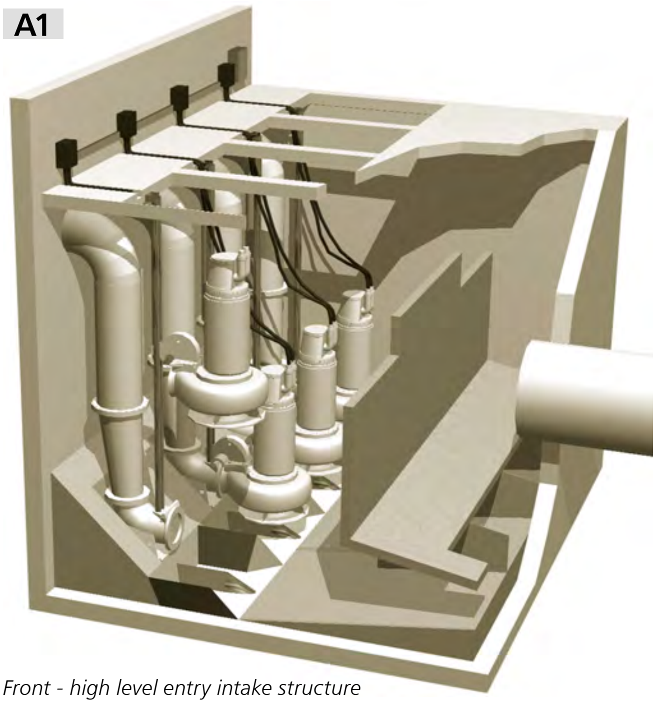
A sump designed in accordance with this brochure is smaller than a conventional sump. Consequently, there may be less buffer volume to accommodate transient variations of the flow rate. Nor is there extra retention volume to store the inflow in excess of the total pump capacity (the pipe volumes are usually much larger than any pump station volume). A proper design of a complete pump station should therefore consider all critical aspects of operation.

The installed 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. If possible, a weir can be installed in the main sewer just upstream of the pump station in order to minimize the short-term variation of the flow.

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.

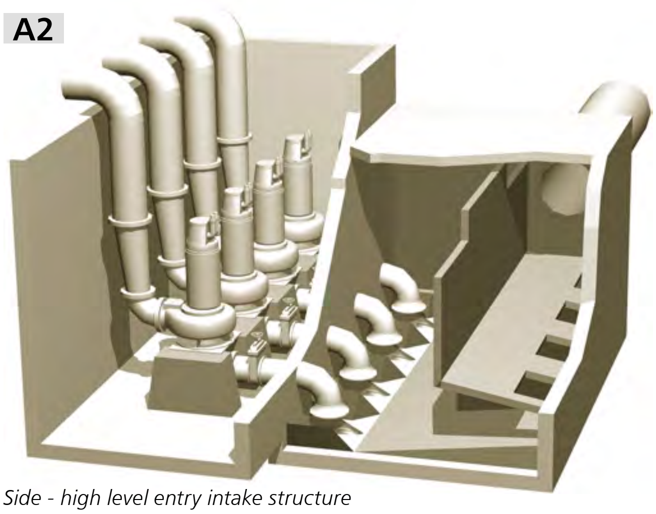
The discharge pipe work should be designed to prevent flooding by the return flow when the pumps are stopped - also in emergency situations. The effects of possible pressure surges should be minimized by appropriate design of the control devices.

A1

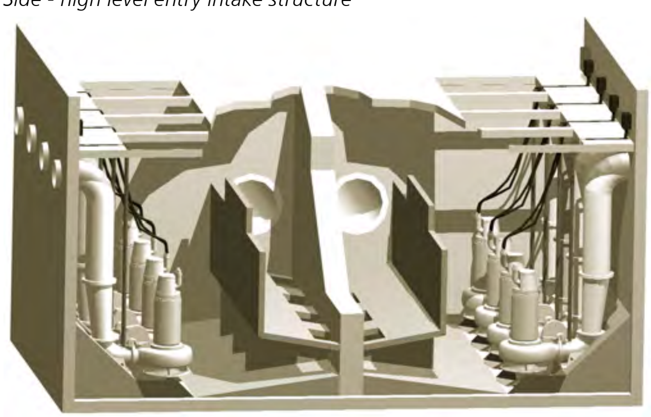


Front - high level entry intake structure

A2



Side - high level entry intake structure



Side - double sump, high level entry intake structure

ITT Flygt standard 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).

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 ITT Flygt for an optimum sump design.

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 central front high-level entry is the 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. The exact sump design varies with the number of pumps and pump size.

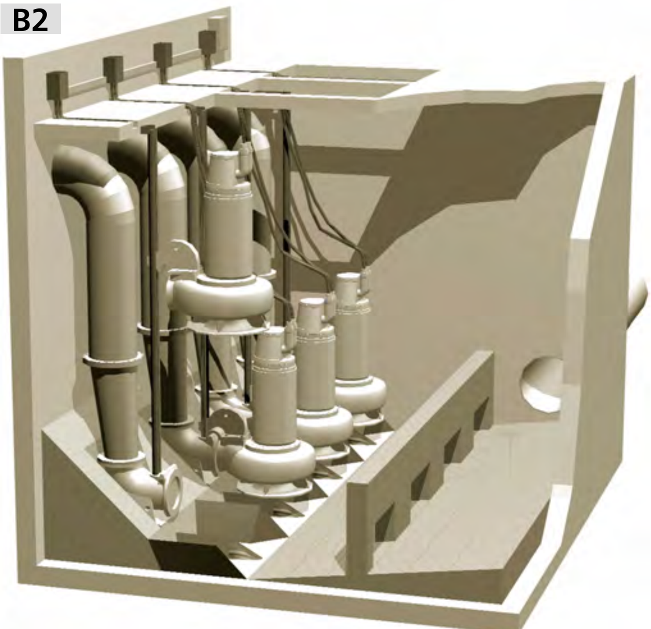
If the piping system and the sump location do not allow for a front entry inlet - a side entry inlet with a baffle wall modified with ports can be used. This configuration is referred to as Type A2. In this design, the baffle wall redirects the incoming flow and distributes the flow evenly toward the pumps through the ports.

Construction alternatives

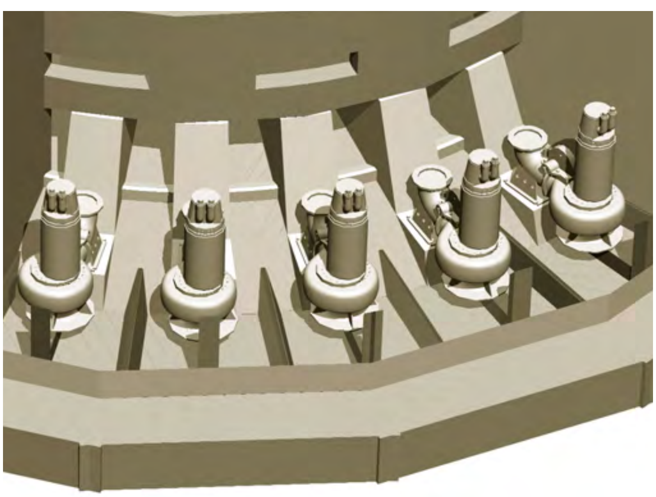
Distributing the flow evenly to all pumps over the width of the sump can present problems if the number of pumps is more than four. In such cases, a double sump may be more suitable.

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.

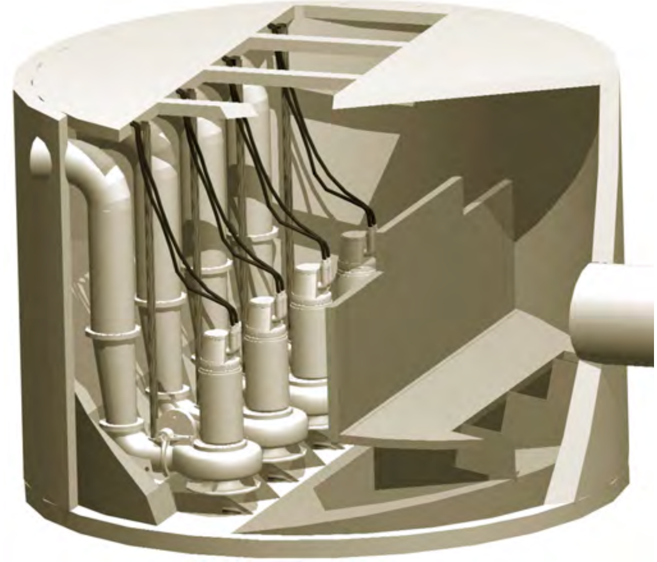
B2



Side - low level entry intake structure



Pumps in a reversed orientation.



Front - high level entry in a circular outer structure.

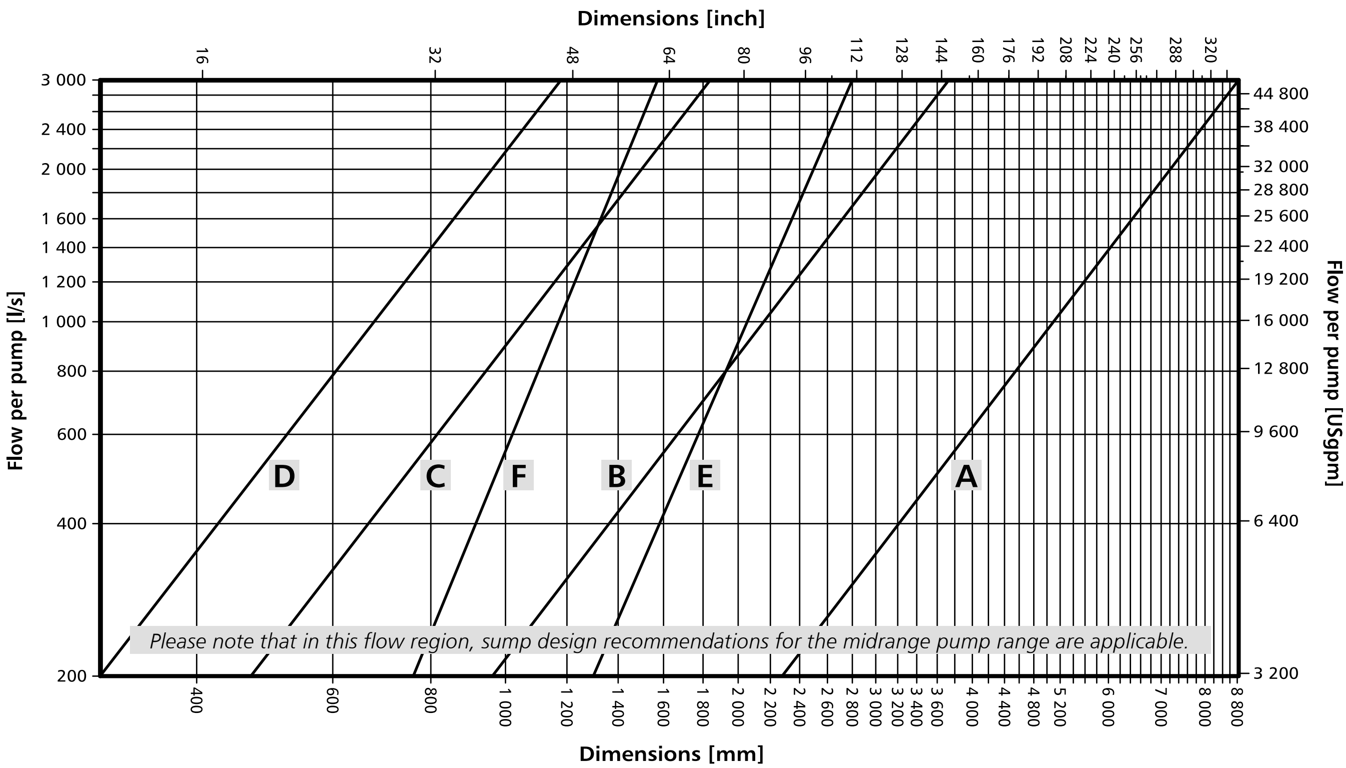
In this arrangement, Type B2, with a straight baffle wall, either the sump or the sewer is below the normal water level in the sump, or an open channel supplies the sump. In the absence of falling flow in the entrance, no intense entrainment of air takes place. Consequently, the inlet chamber can be greatly simplified because its only task is to distribute the flow evenly to the pumps.

Sometimes there is a need to locate the riser pipe in the center of the stations or locate the outlet in other directions where reversed pump orientation can be a solution.
The picture shows an extract of a reverse orientation wastewater pump station design.

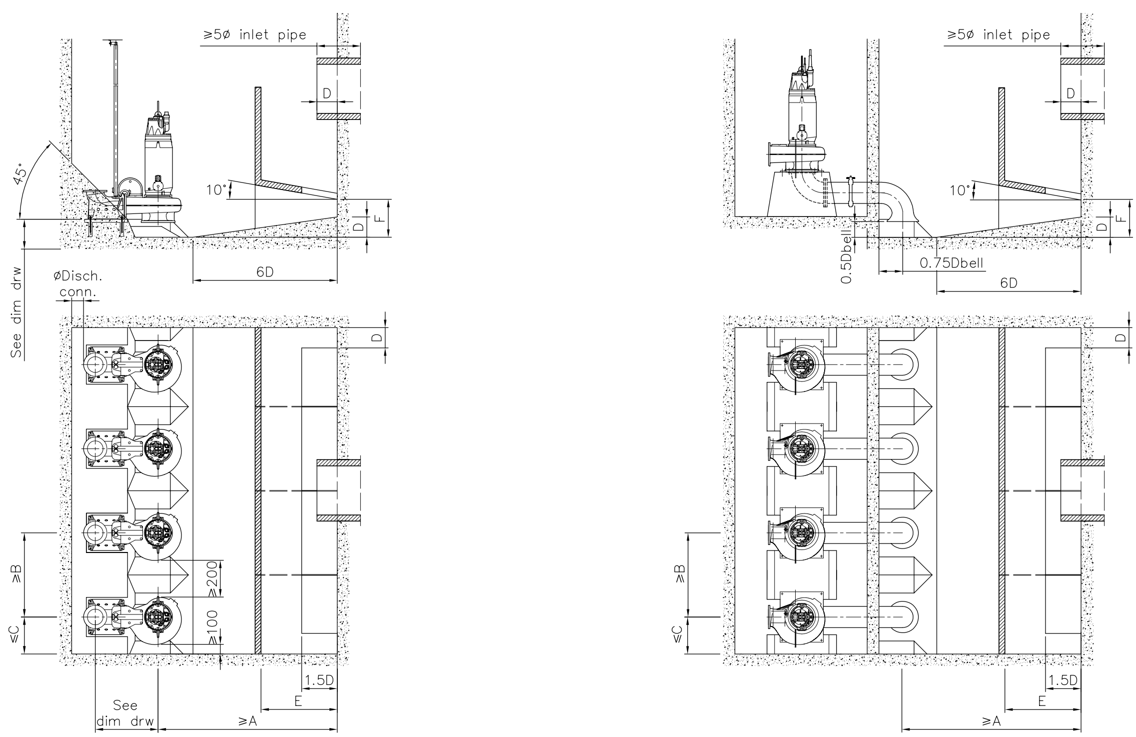
When operated in combination with recommended pump control philosophies optimum pumping conditions are achieved - providing sump floor cleaning and transportation of solids.

Sump dimensions

The sizing diagram below is valid for pump stations up to four pumps, all of which may be duty pumps. Tolerances of ±10% on the sump dimensions 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 the pump duty point when one pump is running alone (in a common pressure pipe).



A1



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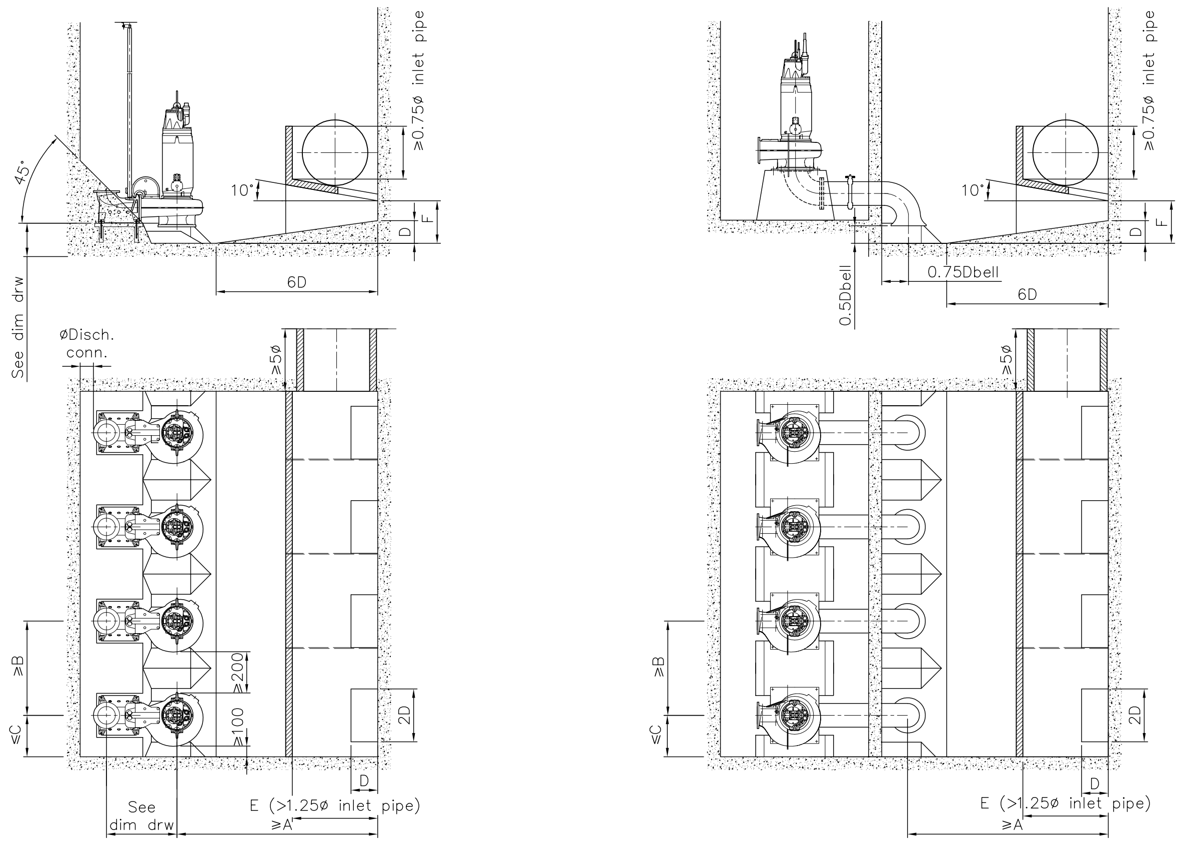
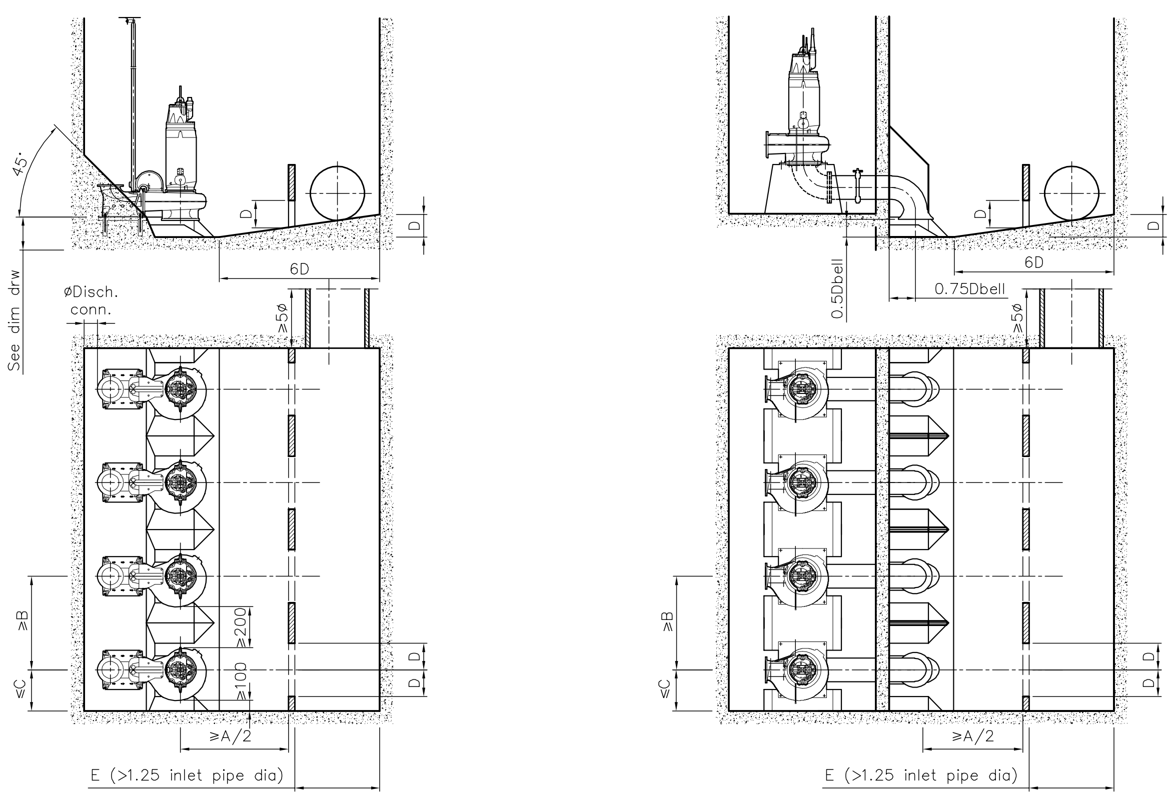

45°
10°
≥0.75ø inlet pipe
D
F
6D
See dim drw
øDisch. conn.
≥5ø
≥B
≤C
≥200
≥100
2D
See dim drw
E (>1.25ø inlet pipe)
≥A
0.5Dbell
0.75Dbell

B2


45°
D
6D
See dim drw
øDisch. conn.
≥5ø
≥B
≤C
≥200
≥100
≥A/2
E (>1.25 inlet pipe dia)
0.5Dbell
0.75Dbell

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:

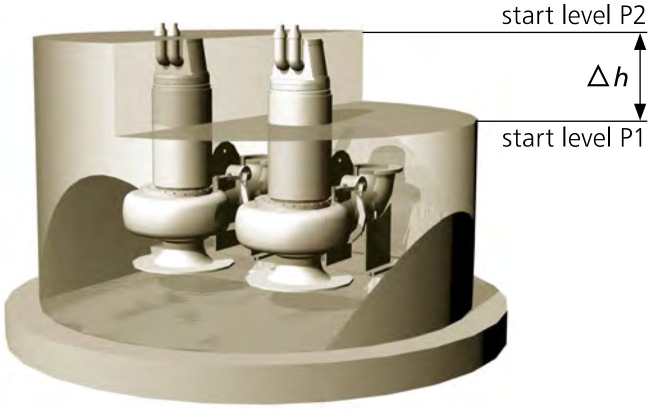
$$V_{req} = \frac{T_{minimum}\, Q}{4}$$

The minimum cycle time, $T_{minimum}$, is determined by the number of pump starts with regard to the mechanical stress from the temperature rise in the motor.
For a pump 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. The total sump volume can then be determined as

$$V_{total} = \frac{V_{req}}{n} + (n\text{-}1)\,\Delta h\, S$$

Where S is the plan area of the sump, V_{req} is the total volume required for a single pump and n is the number of pumps in the alternating cycle.

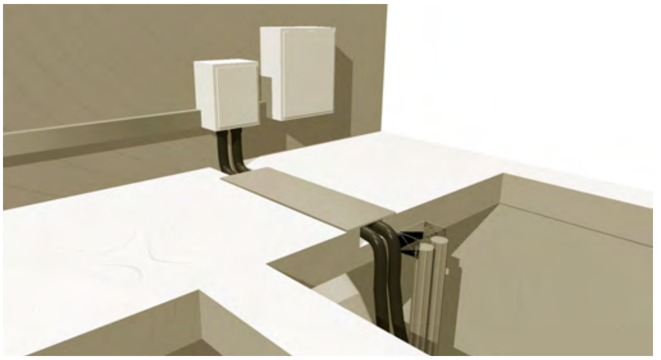
The start and stop levels of all pumps differ by a constant value Δh that is determined by the characteristic of the control system. Δh should be large enough to eliminate accidental pump starts that could be caused by surface waves or imprecise level sensors.



If a pump station consists of several pumps of different capacities, the required volume for each pump or group of pumps must be determined separately. The combined required sump volume will depend on operating requirements for the pump station and must be analysed in each case.

Installation tips for submerged pumps

The following are some general installation guidelines for submersible pumps:



- To avoid check valve cavitation, the valve should not be located at an elevation greater than approximately 27 feet (8 meters), above the pump discharge.
- To facilitate maintenance and protect the cable, a trough in the floor is recommended for station cable runs (refer to local electrical codes).
- 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 explosive gases from the wastewater entering the cabinet could be harmful (refer to local codes).
- Wastewater gas can cause relay oxidation. It is therefore beneficial to locate the control panel in a ventilated environment.
- To avoid problems with the operation of the level regulators from floating debris, etc. - a stillwell may be used, with its opening below the lowest water level.
- The pocket in the benching where the discharge connections are can collect sediment. A steel plate covering the pocket will prevent this from occuring.

Installation tips for dry installed submersible pumps

Suction pipe design

The position of the suction pipe to the dry installed pump follows the same hydraulic guidelines as for a submerged pump. The submergence of the inlet must be given more attention though, as air can be drawn into the pipe more easily than a submerged pump, which has a volute acting as a vortex suppressor. Accumulated air in the inlet pipe can impair pump operation, and can

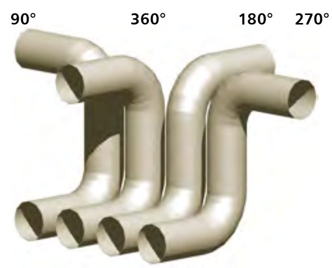
cause the system to become "air bound" – preventing pumping altogether.
For flows over 8,000 gpm (approximately 500 l/sec), the inlet pipe should be equipped with an inlet bell to minimize losses and disturbed flow into the pump.
To achieve a uniform flow to the inlet of the pump, the suction pipe design should fulfil the following:

1. Provide sufficient $NPSH_{av}$
2. Minimize friction losses
3. Minimize number of elbows
4. Eliminate vapor from suction pipe
5. Ensure correct pipe alignment

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, should be located more than five pipe diameters away from the pump.

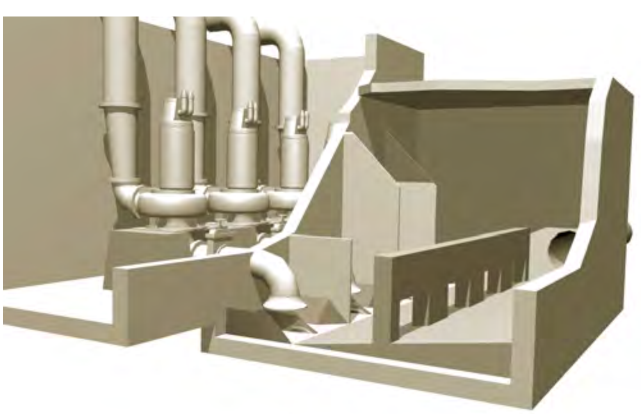
Effects of elbows



Elbows in the piping generate dynamic losses and swirling flow and should be avoided whenever possible. To minimize the effects of pre-swirl (which could increase the power requirements for the pump) the elbows 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 optimum velocity at the entrance of the bellmouth is 5.6ft/sec, (1.7m/sec), and should be within the following limits.

Flow	Velocity
<19000 USgpm <1200 l/sec	3-8 ft/s 0.9-2.4 m/s
>19000 USgpm >1200 l/sec	4-7 ft/s 1.2-2.1 m/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/vibration disturbance. The pump and/or motor unit can radiate disturbance 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 should be operated in the duty area it is designed for - normally between 50% and 125% of best efficiency point (BEP) at operational speed. 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 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 itself (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 ITT Flygt's "Installation Recommendations for Dry Installed Pumps"

Pump anchoring and piping support guidelines

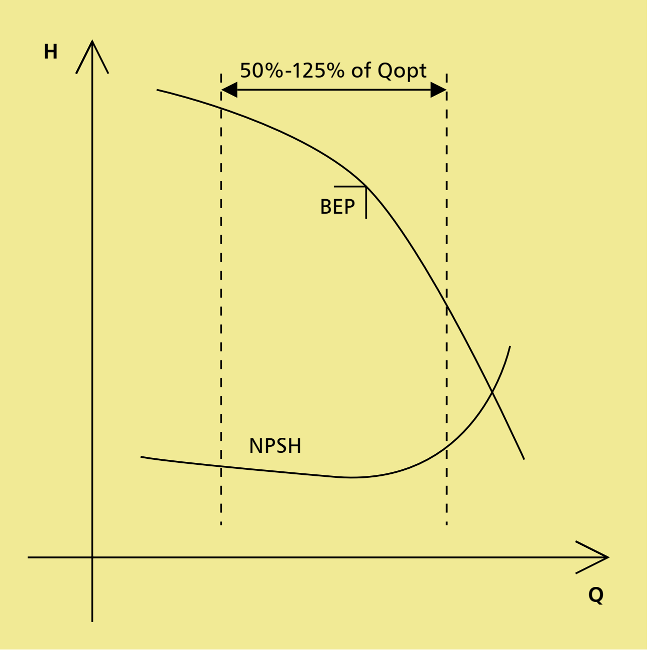
The following guidelines can prevent unwanted vibration:

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 pump station, the following procedure is recommended:
   a) The weight foundations should be at least two times the weight of the rotating parts.
   b) Use flexible support, 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. Extra supports must be provided at heavy components such as valves.
4) The maximum distance between the pipe support should be 1/3 critical pipe length. See appendix in ITT Flygt's "Installation Recommendations for Dry Installed Pumps".
5) For pipe systems with bellows to minimize vibration, the pipe should be supported at the bellows to avoid transference of pressure fluctuations.
6) Vertical pipe velocities must be kept at a level which prevents the settling of solids. The recommended range is 5-8 ft/sec (1.5-2.5 m/sec).

Importance of duty point and problems with off-duty pumps

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) flow, as outlined in the Hydraulic Institute Standards. The Allowable Operating Region, (AOR) from BEP for optimum operation of centrifugal pumps in wastewater applications is typically between 50% and 125% of BEP flow at operational speed (unless the curve does not have an operational limit). By running the pump outside the AOR the following problems may occur:

- Unstable operation.
- Insufficient NPSH margin resulting in noise, vibration and impeller erosion.



- Recirculation - resulting in noise, vibration and impeller erosion.

Consult an ITT Flygt engineer if operation outside of 50% - 125% of BEP flow at operational speed is required.

ITT Flygt Systems Engineering

ITT Flygt provides design assistance on a project basis to owners of pump stations and their consultants. We have broad experience in design and operation of pump stations, and we use a wide range of system optimization tools and computer programs developed by ITT Flygt. The scope of our assistance includes:

1. Selection of pumps with consideration of the variations in the flow capacity and costs involved.
2. Optimization of sump design for given pumps and sites.
3. Analysis of complex systems for pump stations including calculations of hydraulic transients and pump starts.
4. Advice on the need for model tests and arrangements for such tests.
5. Advice on achieving the lowest possible life cycle costs, i.e., lowest operation, service and installation costs.

ITT Flygt Systems Engineering is always ready to assist you in finding the most suitable solution to your pumping requirements.

ITT Flygt is the world's leading manufacturer of submersible pumping and mixing solutions. Over 2,000,000 ITT Flygt submersible pumps and mixers are operating in wastewater treatment plants, stormwater and sanitary pumping stations, and in diverse applications throughout the Municipal and Industrial marketplace.

ITT Flygt is at total solution provider, and our experience is utilized by engineers, planners and consultants throughout the world to ensure reliable and cost-effective solutions. ITT Flygt has service and sales facilities in more than 130 countries.

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