

xylem



PSS Handbook

Practical recommendations
for pressure sewage systems

PSS Handbook

This PSS handbook is published by Xylem Inc,
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Foreword

Flygt pumps have been installed in wastewater applications for more than 50 years.

Following the worldwide boom in demand for reliable pressure sewage systems (PSS) with long life, we realized the need for guidelines to design such systems.

This handbook is intended to give practical recommendations to wastewater consultants in their PSS design work. It also aims to provide a basic understanding of the PSS application for users and operators as well as tips to contractors who work on such installations.

A PSS consists of a branched network including liquid pressure generating equipment (pumps).

The target scope is mainly directed to the Australian, European and American markets. That is why some parts of the handbook might be outside the most common praxis in some markets. But that uncommon praxis might also provide you with some new ideas.

Complementary documentation can be installation and operation manuals, pump handbooks covering more advanced duty point estimation, guidelines for electrical machine installation and pipe foundation recommendation handbooks.

The first chapters are devoted to introducing readers to PSS. The latter ones explain our design guidelines and look at deeper issues, such as the formation of hydrogen sulphide.

This handbook was produced with assistance from people within our organization from around the world with many years of PSS experience.

Flygt is present worldwide to provide our customers with personal support. Don't hesitate to contact us if you need any additional information.

Acknowledgements

This handbook would not have been accomplished without the global team spirit in our company. We would especially like to thank the following people for valuable input and contribution: John Bauer, Ad Damme, Klas Dans, Doug Darville, Alain Derville, Per Hedmark, Björn Lundqvist, Dana Mullen, Therese Myske, Erik Quijano, Johan Seijmer, Anders Ström, Roland Svensson and Peter Söderlund.

Introduction

The purpose of this handbook is to provide consultants, designers, contractors, city planners and sewage system operators with information and guidelines for sizing and designing pressure sewage systems (PSS). Advice is also offered for the selection of proper PSS packages, including pumps, basins, monitoring and control equipment and accessories such as valves and siphon breakers. Pipe and pump selection are also covered in the brochure, and descriptions of Flygt software tools are also provided. We are present in the PSS markets in Australia, Europe and North America, so this book may therefore include discussions that are not applicable to every market; however, the contents include useful design tips.

1.1 Why PSS?

Initially developed in the United States in the 1960s, pressurized sewage systems (PSS) became popular in the early 1970s in rural areas where high water tables and rocky ground made the use of conventional sewer systems difficult and costly. The worldwide breakthrough for pressure systems occurred around 1980 with the development of submersible centrifugal pumps with grinders. These pumps were inexpensive, reliable and easy to use. They could also pump raw sewage at high pressures through systems using small-diameter pipes. Due to the high costs of gravity sewage systems, pressure sewers have become one of the most popular and practical forms of alternative collection systems today, especially in less densely populated areas.

There are several options for handling wastewater, including transportation by gravity sewers, local wastewater treatment plants, septic tanks and PSS systems.

PSS has advantages over other systems, including:

- Cost-efficient installation, particularly in hilly and rocky areas and when dealing with high water tables, very flat land and stream crossings
- Reliability with no need for time-consuming and/or costly operation or maintenance

Flygt has supplied pumps for pressure sewage markets around the world since the 1980s. Those sales include more than 400,000 grinder pumps and 40,000 prefabricated stations operating in more than 10,000 pressure sewage systems.

In the late 1990s, Flygt participated in and drove development of European PSS standard EN 1671, which has now been superseded by EN 16932-2. (Standards used in the U.S. are UL, CSI and/or NSF.)

In addition to the most reliable high-quality PSS pumps, we also offer:

- System design services that use the most modern and sophisticated software tools
- An extensive range of pumps and monitoring and control equipment
- Local installation and after-sale service
- A worldwide network of staff and production facilities

The Flygt line includes centrifugal grinder pumps that reach heads up to 67 m (220 ft) and 6 l/s (95 USGPM).

New legislation that raises treatment standards and requirements to protect local recipients has increased the need for new installations of wastewater equipment.

Pressure sewage systems are frequently used in less densely populated areas such as suburbs and rural areas. This handbook presents the Flygt perspective on designing such systems. It explains system requirements and shows how to determine the required performance of components, such as pump duty points. As pressure sewage systems typically use long pipes, preventing hydrogen sulfide odor and corrosion is important (see chapter 7). Hydraulic considerations such as minimum water velocity, retention time, and valve locations are also discussed.

For recommendations on operation, installation and maintenance, see the Installation, Operation and Maintenance Manual for pumps. The purpose of wastewater treatment is to separate sludge from water and make it possible for water to be returned

to the recipient for reuse. For households this can be done using either a micro-wastewater treatment plant (household size) on the property or by transporting wastewater to a treatment plant; these functions are described in chapter 3. Local wastewater treatment plants can be efficient solutions in remote and less densely populated areas.

Wastewater can be transported to a larger wastewater treatment plant with a gravity pipe system or a pressurized sewage system. The gravity system, most commonly used in cities and suburbs, relies on a minimum inclination of the sewer pipe to the pump station. Septic tank systems are frequently used in more rural, remote locations. Their functionalities are also described in chapter 3.

Pressure sewage systems

A pressure sewage system (PSS) consists of a branched, small-diameter pipe system. The system is based on small pump stations located near homes from which wastewater is received. A small system may involve only a few households, while a large system can include as many as several hundred pump stations. Sometimes several households connect to a single pump station.

The usual pump basin volume is 400-500 litres (100-130 US gallons), which often equals a receiving capacity of 24 hours. Pumps are usually grinder types that reduce solids in the wastewater to small particles that help prevent clogging of the pump and pipe system. A typical pump size is in the range of 1-3 kW (1.4-4 HP) and a flow of 1-3 l/s (16-48 USGPM).

Wastewater from a PSS system is released into the main sewer or into a larger receiving pump station for subsequent transportation to a wastewater treatment plant. A typical household produces 400-800 litres (100-200 gallons) of wastewater per day.

Wastewater transport can be divided into residential, commercial and municipal applications.

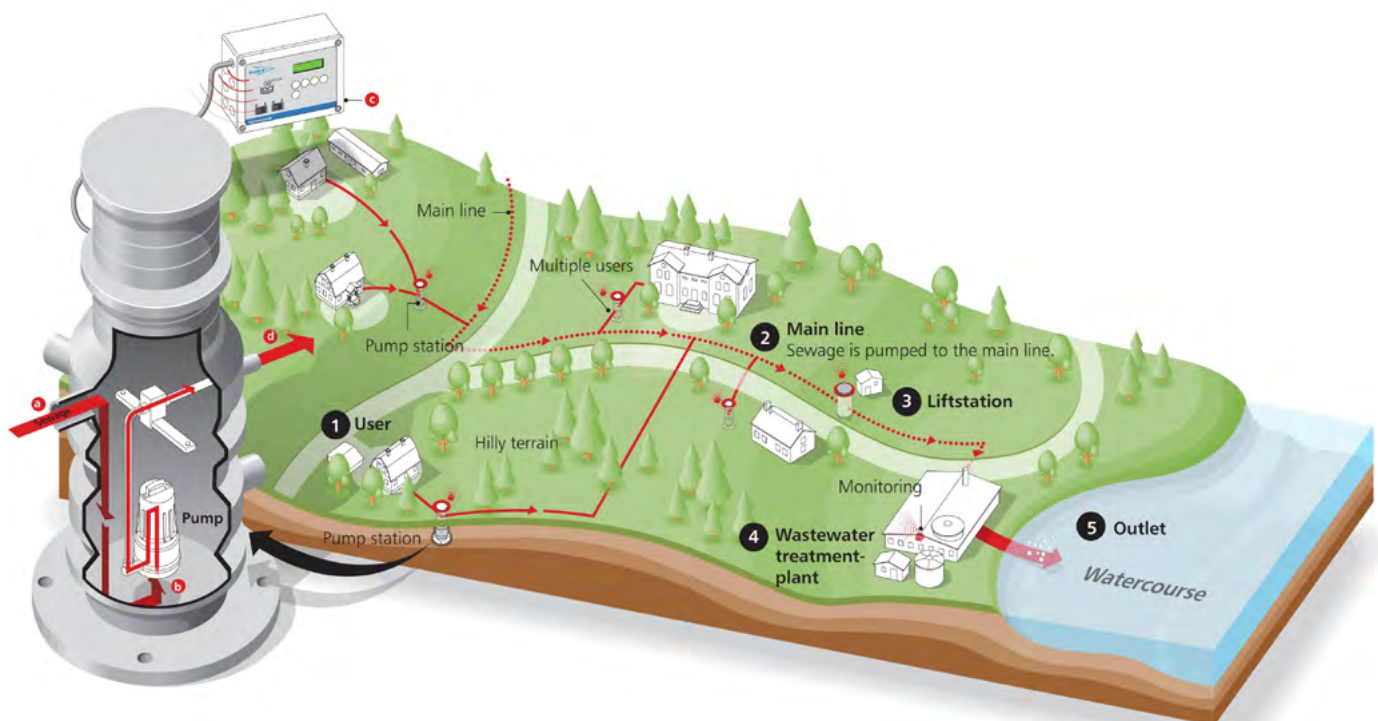


Figure 2.1: Landscape showing PSS basins and pressure piping.

2.1 Residential housing, commercial and municipal applications

Though the purpose and method of wastewater handling is the same, there are differences in the application of residential, commercial and municipal PSS systems. For the purpose of clarification, those differences are listed below. Please note that this handbook only focuses on systems with residential applications. If needed, Flygt can also provide guidelines and recommendations for commercial wastewater transport applications.

Residential applications often have:

- Small pumps that typically weigh less than 50 kg (100 lbs), have a maximum power rating of 5 kW (7 HP) and have a flow capacity of 2 l/s (30 USGPM) (please see appendix 8.1 for more information on power rating)
- Higher focus on maintenance-free equipment
- Less focus on energy efficiency
- Limited power supply

Commercial applications usually have:

- The pump station located inside the building or on the lot of the facility
- Higher flows
- Larger pumps
- Longer running hours
- Higher demands on redundancy, as consequences of a system failure are more serious
- Wastewater with sometimes higher solids content, including paper towels, grease, etc.
- Sometimes high fluctuations in flow
- Professional maintenance by “generalist” operators who monitor, control and operate using industrial equipment (i.e., remote supervision)

Municipal applications:

- Have lift stations on the wastewater distribution network
- Can have large pumps
- Can be telemetric monitored (from the wastewater treatment plant downstream)
- Are operated by professional operators trained for wastewater pump applications

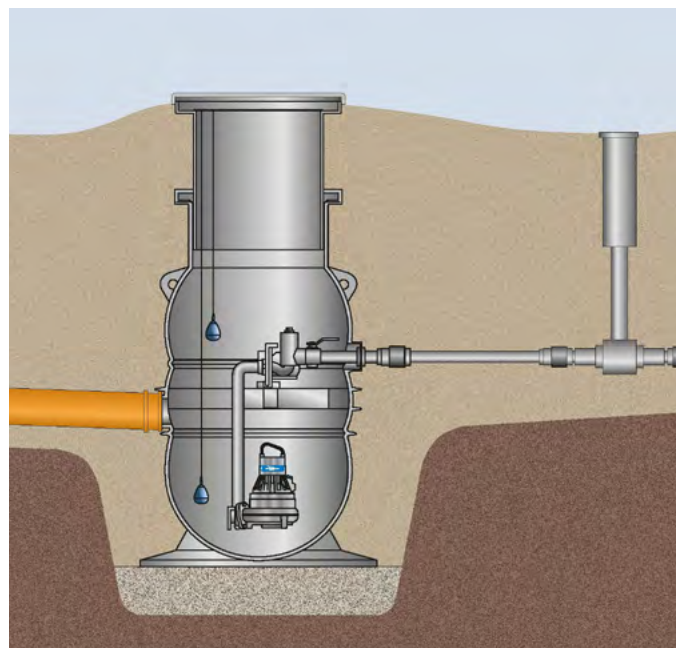


Figure 2.2: Elevation view of a PSS tank with a centrifugal grinder pump and typical included components. Different pump station configurations are used for different markets. For instance, in Scandinavia it is common to use two level switches, while in the U.S. it is more common to use three.

Other wastewater transport system descriptions

In wastewater transport, water is used to transport human waste for treatment. The purpose of wastewater treatment is to separate water and sludge so that clean water can be released to a recipient. Several methods can be used such as treating wastewater locally and occasionally transporting sludge away by truck. Another method is to pump wastewater into a large-scale wastewater treatment plant. The following is a general description of those systems, including septic tanks, small wastewater treatment plants, wastewater gravity systems and vacuum sewer systems.

3.1 Septic tanks

A septic tank is a sealed underground tank into which sewage from a household enters. The heavier solids in wastewater settle in the septic tank. Self-forming bacteria in the tank help the system to 'digest' these solids or sludge. At certain intervals the remaining solids are emptied and transported away by a septic tank pump hauler.

Instead of pumping the separated liquid away from the property, an infiltration system can also be used to follow the septic tank. This requires a well functioning system to avoid local discharge of untreated wastewater. Baffles built into the tank hold back the floating scum and prevent it from moving past the outlet of the tank.

3.2 Septic Tank Effluent Pump (STEP) pressure sewers

A STEP system pumps effluent in a branched system the same way that pressure sewage systems with grinder pumps do. The main difference is that in the STEP system an interceptor tank for removing solids and grease is included, reducing the amount of solids in the effluent that need to be pumped to the wastewater treatment plant. The STEP system also features a pumping chamber with a pump that is equipped with a recessed or ½" solid handling throughlet (a Flygt pump impeller type M, D, N or C), check valves, shut-off valves, and a monitoring and control system. The sewage separated in the interceptor tank must be emptied on a regular basis and transported to the treatment plant.

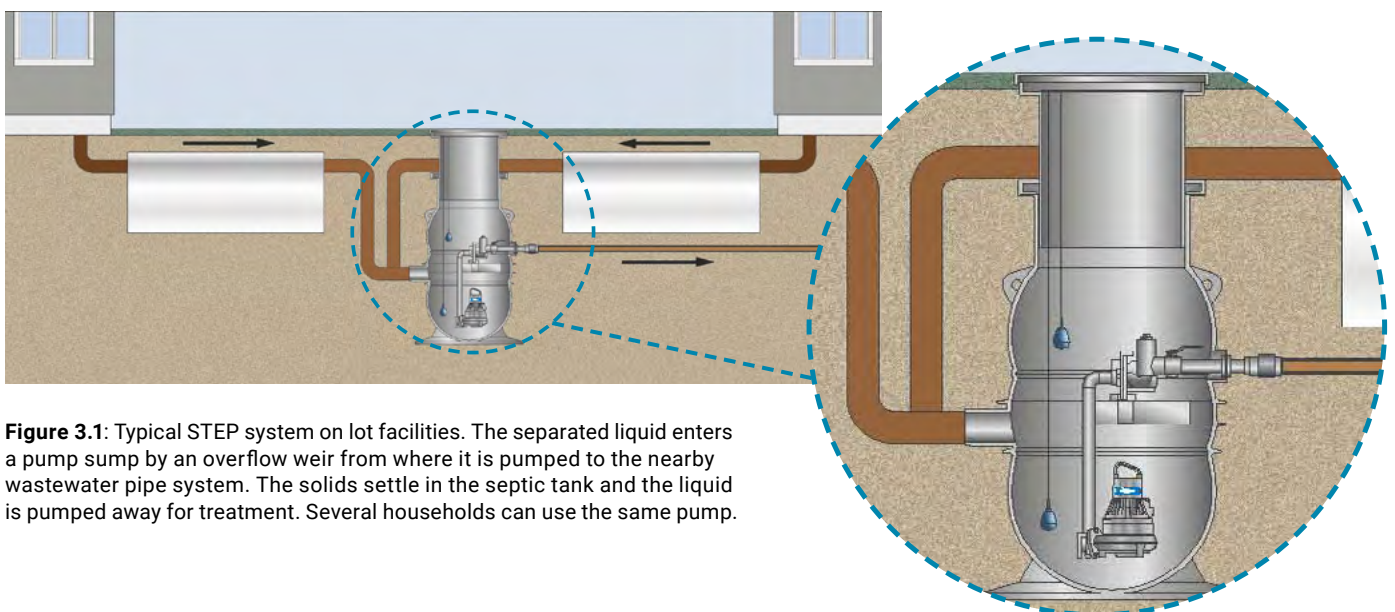


Figure 3.1: Typical STEP system on lot facilities. The separated liquid enters a pump sump by an overflow weir from where it is pumped to the nearby wastewater pipe system. The solids settle in the septic tank and the liquid is pumped away for treatment. Several households can use the same pump.

3.3 Small wastewater treatment plants

The treatment process in small wastewater plants is basically the same as in large ones (but without pre-treatment, grit chamber, etc.), in that it has both a biological step in which nitrogen is removed and a chemical step in which solids assemble and settle, allowing for the separation of settled sludge and water. The treated water is then released for infiltration to the ground or to a local recipient such as a lake. The treatment can also include disinfection before the water is discharged. The sludge is then emptied and stored in local compost facilities or emptied and transported

away by truck once or twice a year. The number of households connected to the system is usually between one and five. Power consumption needed for treatment is also low.

Other costs for treatment of the wastewater include chemicals and sludge transportation.

Treatment is measured by the reduction of biological oxygen demand (BOD) and chemical oxygen demand (COD). The degree of treatment obtained can typically be: BOD₅-reduction >90%, COD-reduction >90%, P total reduction >90%.

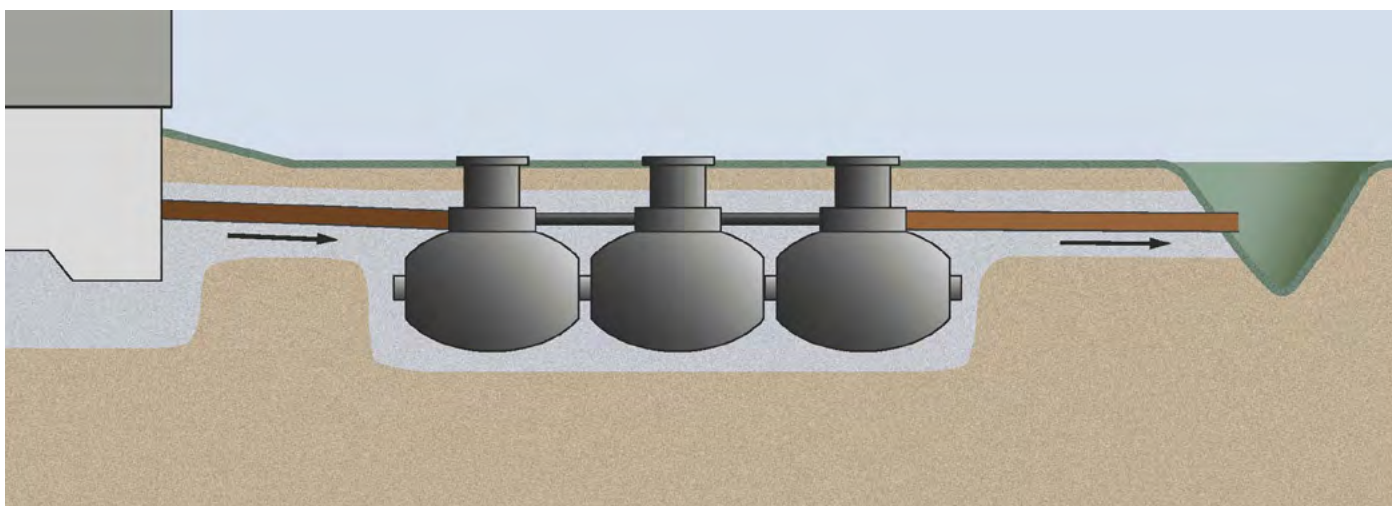


Figure 3.2: Wastewater treatment plant for typically 1-5 population equivalent (PE).

3.4 Gravity sewer

Gravity sewers are sloping pipes that convey wastewater from individual households or multiple household buildings to pumping stations and wastewater treatment plants. Sewer branches connect to the main branch. Since the pipe must have a slope to make the water flow with sufficient speed to avoid sedimentation of the solids in the pipe, lift pump stations have to be used when the pipe reaches a certain depth. A self-cleansing velocity of the sewage in the pipe generally requires a minimum flow rate of 0.7 m/s (2 ft/s). Sewers are laid beneath roads at certain depths to avoid damage from overhead traffic loads. Typical slopes are approximately 1%. Gravity sewers can carry both sewage and rainwater (combined sewers) or have separate pipes for sewage and stormwater.

Gravity sewers are economically beneficial in densely populated areas where large flows must be transported.

Because they require less mechanization, gravity sewer wastewater systems also result in maintenance savings.

This technology also provides a high level of hygiene and comfort for households and requires no maintenance by homeowners (since the municipality maintains the equipment).

3.5 Vacuum sewer system

In a vacuum sewer system, vacuum is created using a pump that sucks sewage from a buffer tank in a household, households or lot into a larger central tank where the pump is located. To have a cost efficient system only a few meters under pressure (vacuum) is possible and the size of such systems is limited, especially in hilly areas.

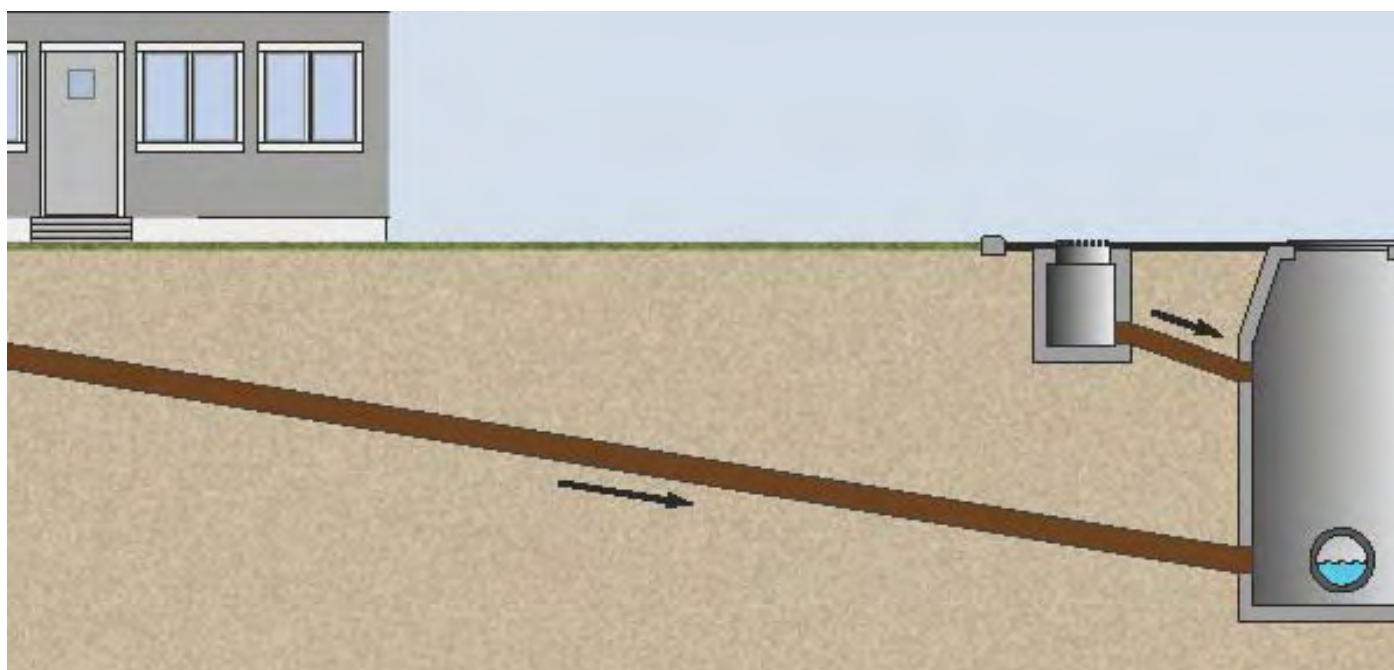


Figure 3.3: In a gravity sewer, the sewage from households is discharged to the sewer main which has a slope making the liquid flow to the receiving pump station.

The vacuum system consists of:

- Buffer tank with level control and a motor-controlled valve
- Vacuum sewer
- Pump station with vacuum pump and sewage pump

The wastewater from the household enters the buffer tank through a gravity pipe. When the liquid reaches a certain level, the valve opens and sewage is sucked into the sewer. Before the valve opens, it ensures that no other unit is in its emptying phase. The sewer has a declining angle of approximately 0.3%. After a certain distance the

sewer has a steep inclination of a few meters, a transport pocket, then declines again until it reaches the pump station (i.e., the sewer is laid in a saw-tooth profile with 50-70 meters between the lifts). The liquid accumulates in the pockets and is lifted in intervals when the vacuum valve opens. The liquid then flows to the next low-level point of the pipe and lifts when the vacuum valve opens the next time.

The reliability of the system is very dependent on the maintenance efforts.

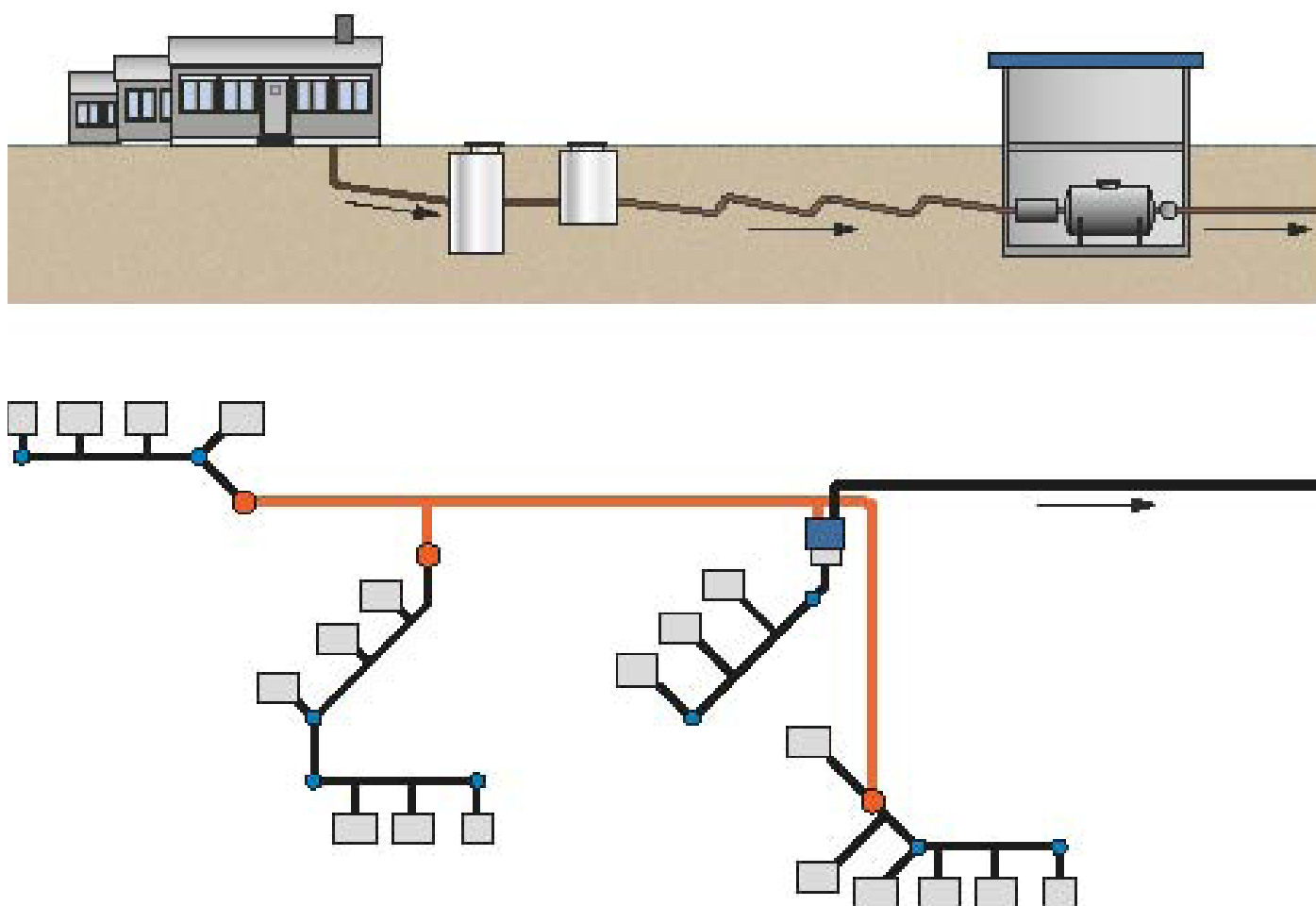


Figure 3.4: As soon as the vacuum sewer system buffer tank is filled, a valve opens and the buffer tank is emptied by the low pressure.

System sizing

In the design process of a pressure sewage system, pumps and pipes are selected to ensure that the system will work without failures or unwanted stops. This chapter is divided according to the components included in a PSS package: the pump, the tank / basin / sump including valves and piping, and the monitoring and control equipment. As pipe selection is closely connected to pump size selection, it is discussed here as well.

The primary customer requirement is a PSS system that operates without the need for manual work (such as for sedimentation in the pipes, blocked pumps, etc.). The energy consumption is usually of less importance. (Energy-efficient pumping can be defined by using specific energy; please see the appendix for definitions.)

A PSS system can contain a great number of pumps, so minimizing the number of pump types can be advantageous for maintenance purposes, particularly in large systems.

4.1 Pump selection

This chapter describes pumping duties in a PSS with centrifugal grinder pumps.

The system curve defines, together with the QH curve, the duty point for the pump. Because of the long pipes in a PSS, the system curve is often steep; i.e., the major portion of the total head loss is from pipe friction.

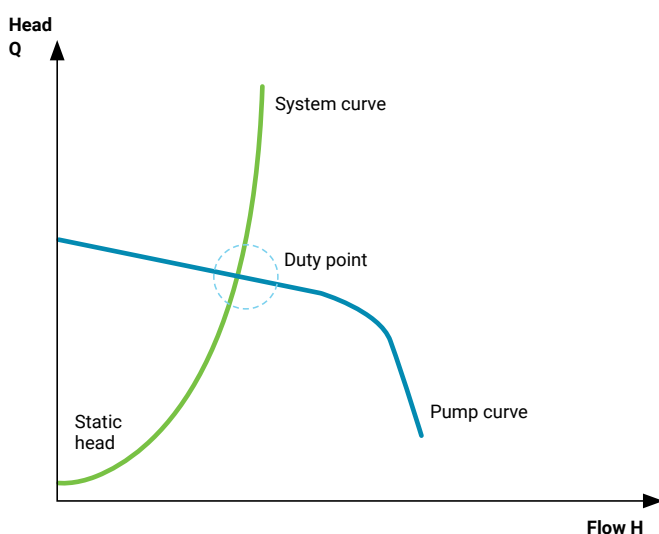


Figure 4.1.1: System curve with a small static head and high dynamic head from the friction losses in a long pipe,

$$h_{tot} = h_{geo} + h_{dynamic}$$

Static head

The static head is usually defined as the elevation difference between the water surface above the pump and the water surface at the outlet, or the elevation of the outlet if it is above the surface. For a pipe design as pictured, the second part of the pipe will empty itself after the pump has stopped. Air will entrain from the outlet and the right water column and be separated from the left water column at the pipe's peak.

When the static head and duty point for the pump are estimated, the peak of the pipe must be considered.



Figure 4.1.2: The outlet of the liquid is above the surface. As a result, the right part of the pipe will be emptied after the pump stops.

Friction head loss

The dynamic head loss is estimated according to:

$$h_{dynamic} \propto f \frac{l}{d} \frac{v^2}{2g}$$

Where $h_{dynamic}$ is the head loss in m or ft, f friction factor, l pipe length, d pipe diameter, v water velocity in the corresponding pipe section.

To define the pumps' duty points, liquid velocities and junction node results, hydraulic modeling software such as RioGI and KYPipe are used to size pipes and run various hydraulic simulations for both residential and commercial applications.

When designing a system, the following parameters are needed as input in the design process:

- Vacation homes or permanent residences
- Number of households {equivalent dwelling units (EDUs)}
- Number of pumps running in simultaneous operation based on Rational method or Probability method design criteria
- Volume of wastewater as defined by design flow
- Future extension/expansion of the PSS system
- Topology {static elevation}
- Area development sequence and build-out schedule
- Need for extra-high reliability (duplex pump stations)
- Monitoring, control and maintenance strategies
- Pipe type
- Power available

The result from the estimation will be the pumps' running conditions (i.e., duty points at different numbers of pumps running simultaneously, water velocities and head pressure in the different pipes' retention time).

The designer fine-tunes and checks different combinations of pipe dimensions, number of different pumps running, etc., until the optimal system is found.

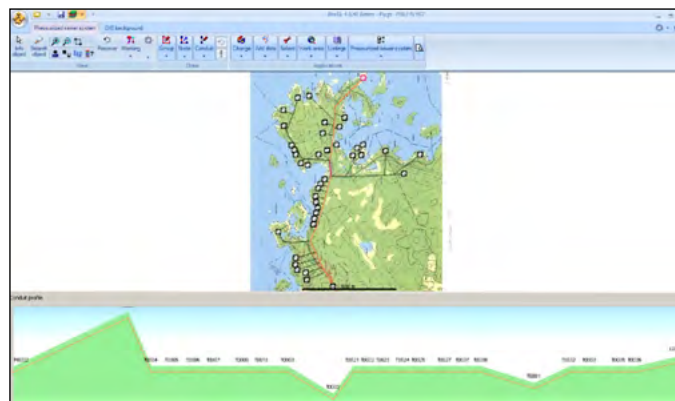


Figure 4.1.3: Screenshot from a design software showing a PSS map for a system of households in which the white dots represent each PSS tank / basin / sump. The straight lines are the piping. The outlet of the system is shown at left.

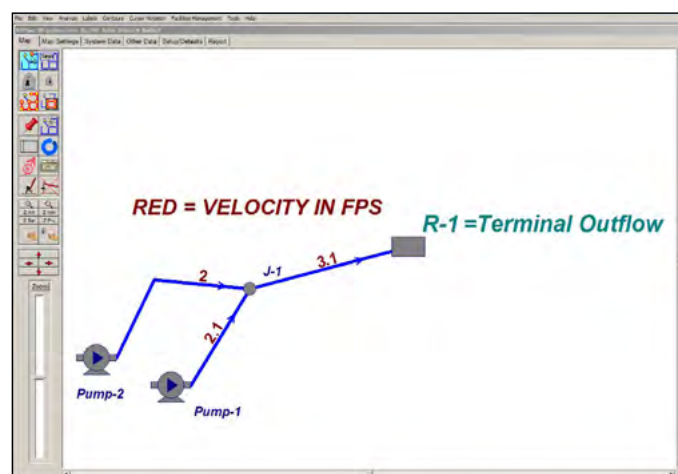


Figure 4.1.4: PSS design example with KY Pipe 2000.

Results for each pump

Pump name	Pump type	Capacity (l/s)	Head losses (m)				Running time (min/day)	Liquid level pump operation	
			Total	Friction	Static	StaGen		Start (m)	Stop (m)
P02/p1	DXG_25_11	1.9	8.52	6.47	1.55	0.50	6	31.40	31.30
P03/p1	DXG_25_11	1.9	7.89	5.74	1.65	0.50	6	31.30	31.20
P04/p1	DXG_25_11	1.9	7.77	5.62	1.65	0.50	5	31.30	31.20
P05/p1	DXG_25_11	2.0	6.98	4.83	1.65	0.50	5	31.30	31.20
P07/p1	DXG_25_11	1.9	8.11	5.86	1.75	0.50	6	31.20	31.10
P08/p1	DXG_25_11	1.9	8.02	5.77	1.75	0.50	6	31.20	31.10
P09/p1	DXG_25_11	2.0	7.26	5.01	1.75	0.50	5	31.20	31.10
P01/p1	DXG_25_11	1.8	10.08	8.57	1.01	0.50	6	31.94	31.84
P06/p1	DXG_25_11	1.9	8.86	6.61	1.75	0.50	6	31.20	31.10

Figure 4.1.5: Output result from software RioGI. The table includes estimations of the different pumps' duty points (i.e., the intersection between the pump curve and the system curve).

Results for each pipe

Start	End	Length (m)	Diam. internal (mm)	Material	Friction-coefficient	Friction head losses (m)		Max. velocity (m/s)	Max. flow (l/s)
						Pipes	Nodes		
P02	T0001	3.30	40.9	PE SDR 11	0.20	0.28	0.00	1.44	1.90
T0001	T0002	12.19	40.9	PE SDR 11	0.20	1.02	0.00	1.44	1.90
P03	T0002	3.99	40.9	PE SDR 11	0.20	0.35	0.00	1.47	1.94
T0002	T0003	1.81	40.9	PE SDR 11	0.20	0.16	0.00	1.47	1.94
P04	T0003	3.88	40.9	PE SDR 11	0.20	0.34	0.00	1.48	1.94
T0003	T0004	11.26	40.9	PE SDR 11	0.20	0.99	0.00	1.48	1.94
P05	T0004	3.51	40.9	PE SDR 11	0.20	0.32	0.00	1.52	1.99
T0005	FHM 1.4	3.48	40.9	PE SDR 11	0.20	0.32	0.00	1.52	1.99
P07	T0006	3.33	40.9	PE SDR 11	0.20	0.29	0.00	1.46	1.92
T0006	T0007	1.07	40.9	PE SDR 11	0.20	0.09	0.00	1.46	1.92
P08	T0007	2.91	40.9	PE SDR 11	0.20	0.25	0.00	1.47	1.93
T0007	T0008	11.92	40.9	PE SDR 11	0.20	1.03	0.00	1.47	1.93
P09	T0008	3.31	40.9	PE SDR 11	0.20	0.30	0.00	1.50	1.98
P01	k0001	37.53	40.9	PE SDR 11	0.20	2.79	0.00	1.36	1.78
k0001	T0001	3.69	40.9	PE SDR 11	0.20	0.27	0.00	1.36	1.78
T0008	k0002	10.64	40.9	PE SDR 11	0.20	0.96	0.00	1.50	1.98
k0002	T0005	37.92	40.9	PE SDR 11	0.20	3.43	0.00	1.50	1.98
T0004	k0003	6.97	40.9	PE SDR 11	0.20	0.64	0.00	1.52	1.99
k0003	T0005	38.42	40.9	PE SDR 11	0.20	3.54	0.00	1.52	1.99
P06	k0004	4.14	40.9	PE SDR 11	0.20	0.34	0.00	1.42	1.87
k0004	T0006	11.92	40.9	PE SDR 11	0.20	0.97	0.00	1.42	1.87

Figure 4.1.6: Pipe data and estimated water velocities in the different pipes.

4.1.1 Hydraulic characteristics for centrifugal grinder pumps when utilized in PSS applications

Centrifugal grinder pumps are wear-resistant and widely used for pumping small and large volumes of sewage. They consist of an electrical motor, double mechanical seals that separate the motor from the wet end, a cutting device that grinds solids in the liquid, and an impeller.

Depending on system head conditions, centrifugal grinder pumps will produce flows of 1-3 l/s (16-48 USGPM). Typical shut off heads are 33 m (110 ft) up to 60 m (200 ft). Larger pumps (and larger motors) are needed at very high static heads.

The high pumped flow scours the pipes and empties the tank fast. Due to the short running time, fewer pumps will need to run simultaneously in large systems, and the risk of pipe clogs is reduced.



Figure 4.1.7: Flygt 3069 centrifugal pump.

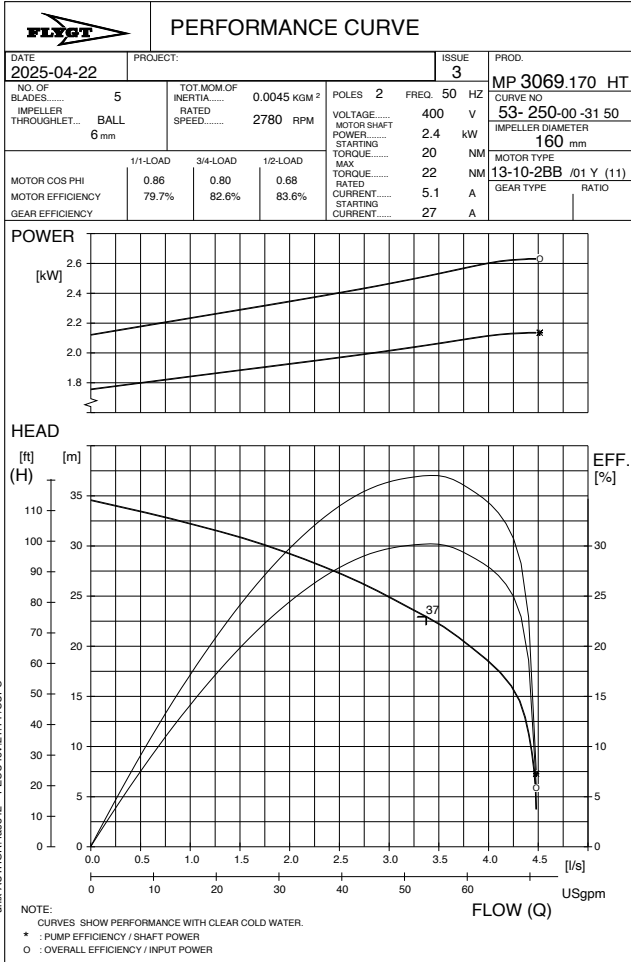
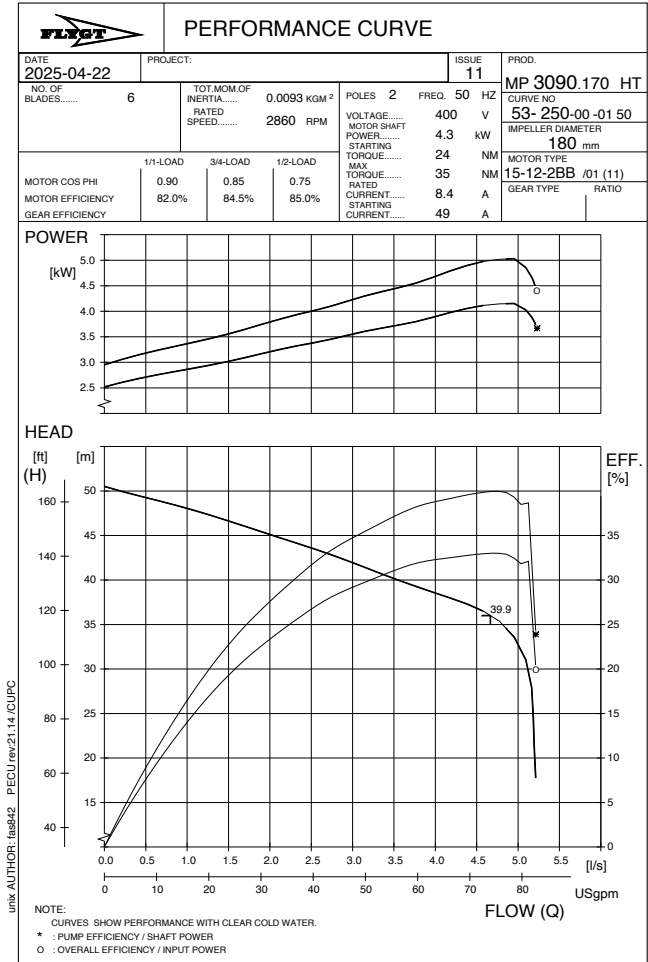


Figure 4.1.8: Power uptake and pump curves for centrifugal grinder pumps (50 Hz).

Typical rated power is 1.4-2.3 kW (2-3 HP) to achieve 33 m (100 ft) total dynamic head (TDH). The power rating increases, however, for TDH exceeding 44 m (145 ft). It is important to note that when sizing grinder pumps, run amps represent the critical factor for energy consumption comparison.

As TDH increases, power consumption decreases. This means the pump can run at shut-off head for an extended period of time, such as following a power break in the area when all pumps start to empty basins simultaneously.

For large pipe diameters a detailed calculation is required to ensure, among other things, that sufficient scouring velocities in the pipe are obtained (see chart below). The maximum pressure is not a concern when centrifugal grinders are used.

In unusual situations, such as an overall power outage, all pumps in the system can start simultaneously when the power is turned on again. Together, the pumps add pressure in the pipe until each pump reaches the pumps' shut-off head pressure. The pump closest to the end of the system (i.e., the pump with the lowest total head to overcome) will not run at shut-off head and will first start to empty its tank and then stop pumping when the pump has reached the stop liquid level in the tank. The next

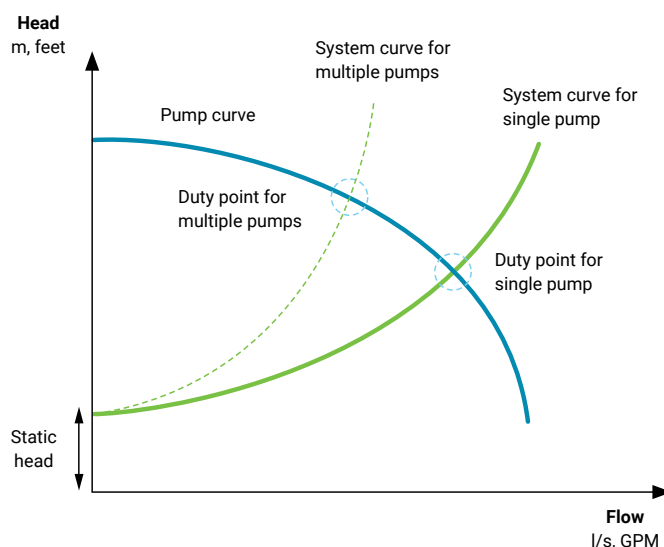


Figure 4.1.9: Performance and system curves and the duty point change following a second pump in the system starting. The shut off head has a maximum pressure.

pump close to the end of the system will then have a lower head to overcome and slowly start to empty its tank. Then the third pump starts, etc. Hence, centrifugal pump systems adjust themselves after power failures.

We can offer design assistance for large systems to determine the duty points at different running conditions, such as when a number of pumps are running simultaneously.

Nominal Pipe Diameter		Flow required for scouring		Total # Centrifugal pumps
mm	inch	l/s	USGPM	
32	1 ¼	0,7	12	1
40	1 ½	1,0	15	1
50	2	1,5	24	2
63	2 ½	2,2	35	2
75	3	3,6	58	3
100	4	5,3	84	4-5
150	6	11	180	8-10
200	8	20	310	16
250	10	30	480	24
300	12	43	680	34

Actual Pipe ID		Flow required for scouring		Total # Centrifugal pumps
mm	inch	l/s	USGPM	
35	1,38	0,6	9	1
41	1,61	0,8	13	1
53	2,07	1,3	21	2
63	2,49	1,9	30	2
78	3,07	2,9	46	3
102	4,03	5,0	80	4-5
154	6,08	11	180	8-10
203	8	20	310	16
254	10	31	490	24
302	11,9	44	700	34

Figure 4.1.10: Different pipe sizes will require different flows as will a number of centrifugal pumps running simultaneously to ensure transport of wastewater solids. Assumed pumped flow is 1.3 l/s (20 USGPM). Please note that the actual inner pipe diameter differs from different pipe standards and the table should only be used as an example of the variation in needed pumped flow to prevent sedimentation.

4.1.2 Hydraulic design system requirements

The following hydraulic requirements should be met to ensure a pressure sewage system operates reliably:

- Sufficient liquid velocity (in the pipe) to ensure pipe scouring to prevent sedimentation and build-up of bio-film on the inside of the pipe
- Retention time to prevent an excessive amount of hydrogen sulfide (H₂S) gas
- Sufficient liquid velocity to ensure removal of air pockets in the pipes

Ensuring that these criteria are fulfilled is one of the main aspects of the design process. In addition to the hydraulic requirements, local product demands must also be met.

Liquid velocity

A minimum water velocity of 0.6 m/s (2 ft/s) is frequently used in the United States. ($U = Q_p / A$ where U is the average water velocity, Q_p is the pumped flow and A is the inner cross-section of the pipe).

PSS standards, such as European standard EN 16932-2, state that a minimum velocity of 0.7 m/s (2.3 ft/s) should occur at least once every 24 hours. Please note that grinder pumps are most often used in PSS. When other types of hydraulic ends are used, slightly higher velocities may be required.

Minimum velocity can be achieved (in the main pipe) with one or several pumps running simultaneously.

Retention time

Both long wastewater retention time and low scouring velocity will result in the formation of hydrogen sulfide gas (H₂S). The formation of this gas in the pipes begins soon after anoxic conditions become present. The first symptoms can be detected at the outlet of the system (i.e., at the connection to the main sewer or pump station). In small quantities, the colorless H₂S gas smells bad – but in large quantities, it is deadly. The formation of H₂S is described in more detail in chapter 7.

The average liquid retention time (t) is

$$t = \frac{V}{Q_i}$$

in which V is the pipe volumes and Q_i is the inflow to these pipes.

The European standard EN 16932-2 (and in the U.S. the UL, CSI and/or NSF standards) states that measurements to prevent problems from H₂S gas should be considered at retention times of more than eight hours.

Air or gas pocket transportation (removal)

Air can enter the pipe system when, for example, a siphon breaker opens (when under pressure from a siphon from a lower-level outlet). As liquid in a PSS does not move when water consumption is low (i.e., during overnight hours), air will accumulate in displacements in the pipe peaks. These air displacements increase the system head loss to be overcome by the pumps.

A limited air pocket will normally have limited influence.

There are different theories available to estimate the needed minimum velocity for the transportation of gas in a downward-inclined pipe. The original Kent equation states that

$$V > 1.58 \sqrt{\phi_{pipe} g \sin \alpha}$$

An update of the equation is

$$V > \sqrt{\phi_{pipe} g} (0.55 + 0.5 \sqrt{\sin \alpha})$$

According to Bown, the minimum velocity for

- 10° slope (inclination 1:6) is 0.7 m/s in a ϕ_{pipe} 60 mm
- 5° slope (inclination 1:12) is 0.9 m/s in a ϕ_{pipe} 100 mm

The pumps in a PSS usually have short running times (e.g., 10 minutes a day). Even if the minimum velocity required to transport the gas further down the pipe is met, it is important that the running time is long enough to transport the air pocket beyond the lowest point of the pipe. Otherwise, the air pocket will move back to its starting point (at the peak of the pipe) after the pump has stopped. If this cannot be obtained, an air-release valve is required.

4.1.3 Designing pressure sewage systems with multiple grinder pumps running simultaneously

This chapter explains the background to the design criteria for several pumps running simultaneously – a situation that occurs in larger pressure sewage systems.

Centrifugal grinders are the most common hydraulic end types in PSS, though centrifugal channel impellers are also sometimes used.

As centrifugal grinder pumps empty tanks in a short amount of time thanks to their high flow capacity, the most common hydraulic situations involve one pump running by itself (i.e., liquid velocities in the pipes need to be sufficient with one pump running). But, as mentioned above, in large systems, multiple pumps can sometimes run simultaneously.

To determine how many and how often multiple pumps will run simultaneously, four different methods are used: the Statistical method for the European and Australia markets, the Peak Flow method for Germany and both the Rational and Probability methods in the United States and Canada.

Design flows are maximum flow rates expected to occur once or twice per day. They are used to determine the size of pressure sewer mains. Flow rates in excess of design flows can occur under certain situations, so design flows should not be considered the maximum flow rate that could occur. Design flows, however, are established for a baseline analysis for sizing pipe.

Two design approaches have been used successfully in the U.S. for the past 40 years: the Rational method and the Probability method. The Probability method, however, is not described in this handbook.

Determining water consumption

The water consumption to be used when designing PSS comes mostly from local standards. Below is an example:

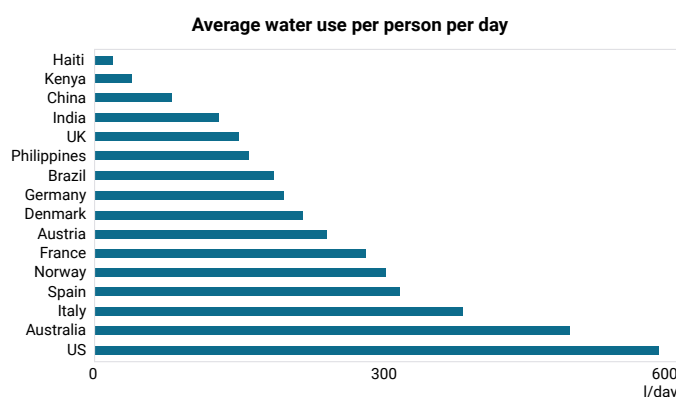


Figure 4.1.11: Example of water consumption in different countries.

4.1.4 Statistical method

A pressure sewage system consists of several pumps in a branched system.

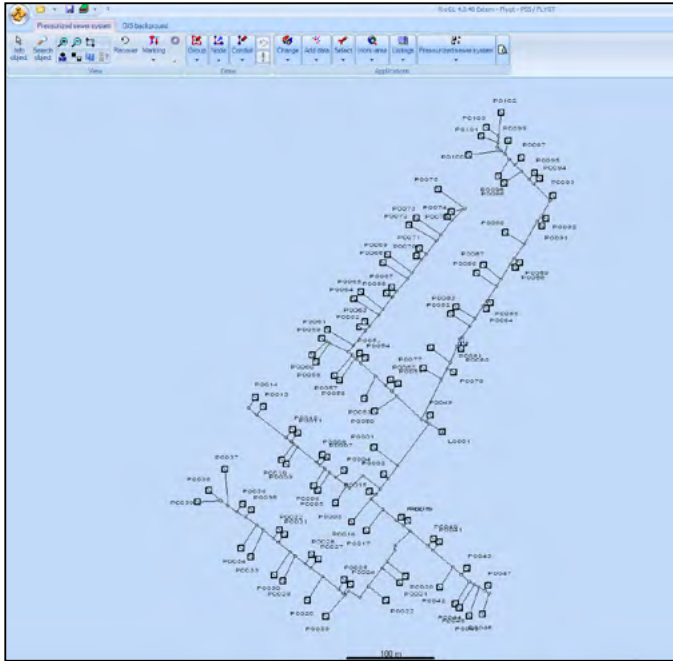


Figure 4.1.12: Overview of a small PSS. Squares represent pump stations and the lines represent the piping.

Depending on the water consumption from each household, pumps will run with more or less frequency in order to transport wastewater away from the tank. For pressure sewage systems with a large number of pumps, there will be times when several pumps in different households run simultaneously throughout the day (two pumps running, three pumps running, four pumps, etc.). The frequency with which those running conditions can occur can be described using a Gauss curve.

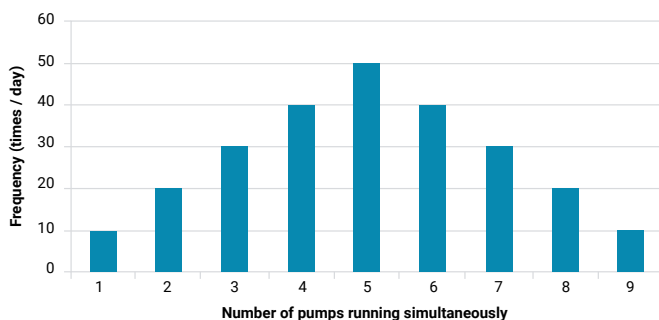


Figure 4.1.13: Example of how often different combinations of pumps run simultaneously.

Poisson distribution expresses the probability of a number of events occurring independently, such as the odds and analysis of randomly occurring events:

- The number of telephone calls entering a switchboard
- The chance of getting a 6 when rolling a dice is 1-in-6, while getting an even number is 3-in-6

The Poisson distribution equation can be used to estimate the probability for a certain number of pumps running simultaneously.

$$P = \frac{N!}{R!(N-R)!} \left(1 - \frac{q_{in}}{q_p}\right)^{N-R} \left(\frac{q_{in}}{q_p}\right)^R$$

P is the probability that a certain number of pumps are running simultaneously. (Probability is defined below.)

R is the number of pumps for which P is estimated.

N is the total number of pumps.

q_{in} is the inflow to the pump station. The water consumption is estimated to be consumed during 10 hours / 24 hours.

q_p is the pump flow.

Results from the equation can be exemplified in a Gauss diagram below.

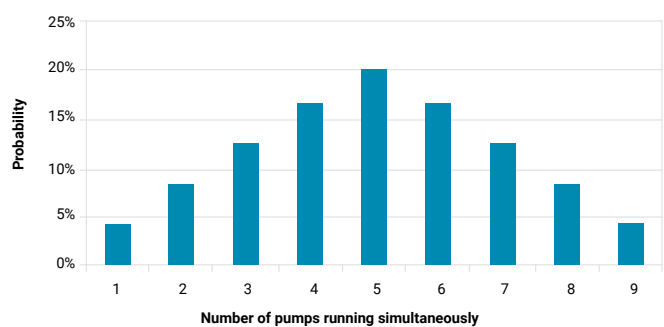


Figure 4.1.14: Example of probability for different combinations of pumps run simultaneously.

Probability, P, is the measure of how likely an event is.

$$P = \frac{\text{The number of ways Event A can occur}}{\text{The total number of possible outcomes}}$$

For the PSS case the probability can be defined as:

$$P = \frac{\text{The number of different number of pumps running simultaneously}}{\text{The total number of pumps}}$$

The statistical method derives from the report “Design and performance of pressure sewerage systems”, which states that pressure sewerage systems shall be designed for the running conditions of 10% probability for the pumps running simultaneously. The number of pumps should be defined from the 10% probability value in the right part of the Gauss curve.

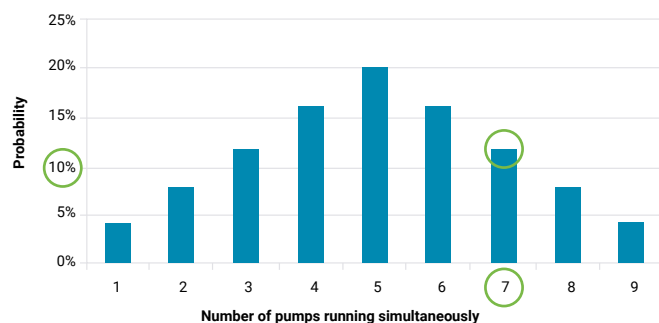


Figure 4.1.15: Example of a large PSS where the probability of approximately 10% indicates that the design should include seven pumps running simultaneously.

The report also states that for small systems the running probability case of zero pumps running should be excluded from the estimation. If the probability of one pump running is higher than 80%, the design case is one pump (otherwise it is the design case corresponding to approximately 10% probability).

The system should be designed for a worst-case scenario, which is usually the design number of pumps located in the most remote points of the same branch running at high pressures all the way from the remote points to the outlet. Please note that it is conservative design criteria; the probability of these specific pumps running simultaneously is lower than 10%.

Software used by Flygt engineers estimates how frequently pumps run simultaneously. Duty situations with one pump, two pumps, three or more that occur daily must be designed for; design situations occurring only once a week can be overlooked.

4.1.5 Rational method for establishing design flows in PSS

The Rational method is described in detail in the US handbook EPA Manual 625/1-91/024. For the Rational method the simplified equation below is easy to use and easy to modify to suit project needs.

$$Q = AN + B$$

- Q is design flow (gpm)
- A is a coefficient selected by the engineer, typically 0.5 which includes the probability for number of pumps running simultaneously
- N is number of EDUs
- B is a factor selected by the engineer, typically 20 but can be anywhere from 12 to 25 for centrifugal pumps

The equation is normally expressed as $Q=0.5N+20$. However that may vary to account for an increase in water consumption and correspondingly high wastewater flows.

4.1.6 Peak Flow method

The Peak Flow method is described in "Design and performance of pressure sewerage systems" by Peter Söderlund, Lennart Jönsson, Peter Nilsson.

The Peak Flow method of calculating the design flow in the pipes has been used in Germany for many years. It uses the peak flow per inhabitant, multiplied by the number of inhabitants connected to the system.

$$q = VW / 10 / 3600 * 1.5 * NI [l/s] \quad (4)$$

Where q is the average produced peak waste flow.

VW is the produced wastewater per inhabitant per day (usually about 100-250 l).

The number 10 is used to distribute this flow within 10 hours, which usually is the average number of wastewater producing hours (this value can vary from about eight to about 12 hours).

The 3600 figure represents one per second (instead of one per hour).

NI is the number of connected inhabitants.

The design flow (q_d) for each pipe uses the above calculated flow, adjusted to the closest number of pump design flows.

4.1.7 Probability theory

Probability method is the branch of mathematics concerned with analysis of random phenomena. The central objects of probability theory are random variables, stochastic processes and events: mathematical abstractions of non-deterministic events or measured quantities that may either be single occurrences or evolve over time in an apparently random fashion. Although an individual coin toss or the roll of a die is a random event, if repeated many times the sequence of random events will exhibit certain statistical patterns, which can be studied and predicted. Two representative mathematical results describing such patterns are the law of large numbers and the central limit theorem.

Reference:

Design and performance of PRESSURE SEWERAGE SYSTEMS, Peter Söderlund, Lennart Jönsson, Peter Nilsson. Department of Water Resources Engineering Lund Institute of Technology, Lund University Sweden, Report No 7180.

4.2 Distribution network installation tips

This chapter includes advice on the installation of pressure sewage system piping. Detailed information on pipe installation requirements can be supplied by pipe suppliers. Air pocket transportation in descending pipe inclination is explained in chapter 4.1.2.

To ensure a long and reliable system life, pipe suppliers meet certain conditions, such as a requirement to pack sand around pipes for in-ground pipe installation. This chapter also includes tips on related hydraulic issues.

4.2.1 Profile recommendations

Inlet pipe to the tank

The liquid is transported from the house to the tank by a gravity pipe. Local regulations typically define the pipe diameter as 100 mm (4 inches). To ensure transportation of solids, this pipe should descend at least 1:100 (1 cm slope for every m of pipe) and avoid sharp bends where solids can become stuck.

Elevation requirements

For installations in cold climates, pipes must be installed deep enough to prevent the liquid from freezing. Alternatively, an electrical heating cable can be installed along the pipe and be controlled according to the outside temperature. An insulation box should also be used to minimize heating demands and energy consumption.

As in all pumping systems with peaks, vacuums can occur under certain conditions. If the peak is higher than 10 m above the outlet, special consideration should be given in the network design.

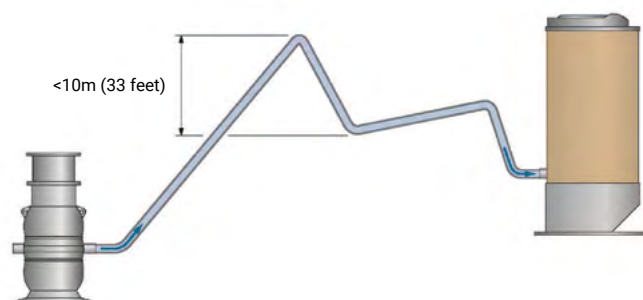


Figure 4.2.1: Vacuum bubbles can occur in pipe systems with high peaks.

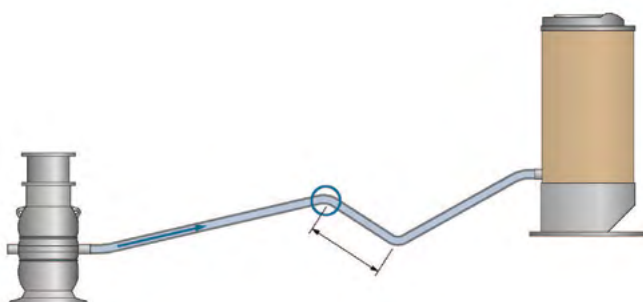


Figure 4.2.2: Liquid flow direction from left to right. The marked area shows the minimum distance the wastewater should be transported for one pump cycle to avoid a gas bubble returning to the peak of the pipe after the pump has stopped.

For pipe systems in which the outlet is below the pump station, a siphon breaker in the pump station is needed. This is described in chapter 4.5.

Entrained air or gas should be pumped out of the pipe system. As pumps in PSS applications only operate for short periods, it is necessary to ensure that the liquid is transported long enough to pass the next elevation low point in the pipe. Otherwise, it will return to the peak when the liquid stops its movement. If a minimum distance is not possible, installation of an air release valve in the peak should be considered.

4.2.2 Pipe installation tips

A carefully performed pipe installation will prolong the life of a pipe system. Pipe suppliers can provide recommendations or advice on required local standards, such as trench evenness and trench width, minimum pipe bending radius, packing and filling methods, rock crack sealing, installation depth (to avoid freezing at low temperatures), and sand or gravel quality for packing around the pipe.

Pipe installation should also ensure smooth flow deflections, for example in pipe connections.

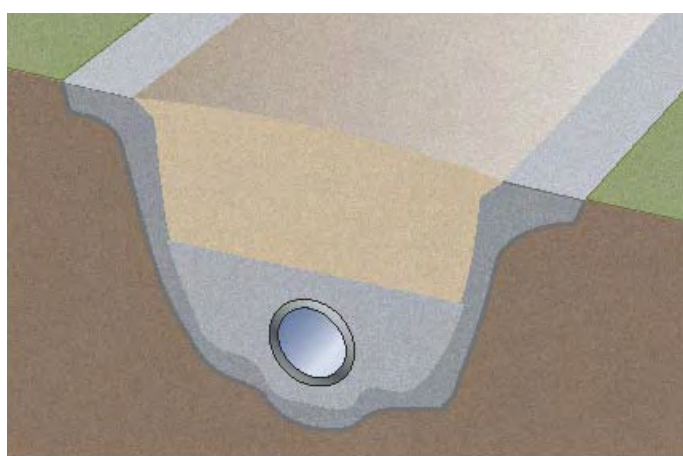


Figure 4.2.3: Example of sewage pipe installation.

When bending the pipe, stresses will be built into the material. To ensure that pipe life is not reduced, it should have a minimum radius defined by the pipe manufacturer. Below is an example of those recommendations.

Temperature	Minimum radius
-20°C to + 10°C	$25 \times \phi_{\text{pipe}}$
above 11°C	$22 \times \phi_{\text{pipe}}$

Figure 4.2.4: Example of minimum pipe bending radius.
Reference: *Uponor teknisk Handbok*, Tryckrörssystem, 2008.

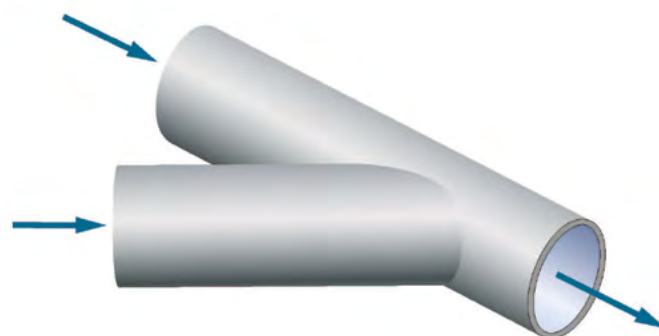


Figure 4.2.5: Pipe connection from the household to the main pipe. Make sure the connections are connected according to the direction of the flow; it can be difficult to see the pump direction of the water.

4.2.3 Pipe dimensions and pressure class definition

The following are pipe standard explanations:

Standard dimension ratio (SDR) defines the ratio nominal diameter (outer pipe diameter) and pipe wall thickness.

The pressure class, PN, defines the maximum pressure (bar) at 20 °C average temperature.

Below is an example of the dimensions of a PSS discharge pipe.

Nominal diameter		Wall thickness	
mm	inch	mm	inch
32	1.3	3	0.12
40	1.6	3.7	0.15
50	2	4.6	0.18
63	2.5	5.8	0.23
75	3	6.8	0.27
90	3.5	8.2	0.32
110	4.3	10	0.39

Figure 4.2.6: Uponor pressure pipe PE80, PN 10, SDR 11.

4.3 Control and supervision strategies

This chapter addresses monitoring and control solutions for different user needs. Typical features and benefits needed for the design of a reliable PSS system are listed and grouped in solutions to meet different customer needs.

On average, a pump in a pressure sewage system is started and stopped a few times each day for a total running time of approximately 10-20 minutes.

A pump must be controlled in order for it to fulfill its required duty. This is usually achieved in wastewater pumping (with low flows) through the use of on-off water level regulation. In a PSS application the wastewater enters a pump sump and the pump is started and stopped from the controls at different liquid levels. The controls measure the pressure at the different liquid levels either constantly, analogically, or by starting or stopping the pump after a signal from a start- or stop-level switch when the liquid reaches certain levels. The control strategy can be more sophisticated, increasing the intelligence, access and control of the pump system to cover power failure, increased pipe pressure, etc.

The pump is also monitored to protect it from damage or to protect the pump station from flooding, a situation that can prove detrimental to the environment. There may also be a need to document the pumping history (running hours, number of starts, etc.) since the pump station may be located in environmentally sensitive areas. Whether for summer residences or permanent households, there are different technical solutions available to fulfill the requirements cost efficiently.

Functionalities and features for a reliable monitoring and control solution can be summarized as follows:

- Controller, alarming and monitoring function integrated in one unit
- Easy access and overview of station alarms, status, logging and type
- All parameters can easily be changed (without need for extra display or external resources) allowing for individual settings for optimal pump operation
- Secure reliability and long lifetime
 - Maintenance run after long periods of system rest
 - Power-on Delay after power failure
 - Maximum Run Time for a Pump for unnecessary pumping
- Early warning system, to prevent emergency call-outs
- Different ways of communication
 - GSM, GPRS, PSTN, Radio, LON, SCADA system
 - Built-in monitoring
 - Remote Service management

4.3.1 PSS monitoring & control solutions

The following are three examples of solutions to fulfill different functional requirements such as different types of alarms, telemetric surveillance and pressure monitoring.

Solution 1, Simple and robust

The pump is started and stopped by a level regulator. If unwanted solids enter the tank and both block and stop the pump, the liquid level will rise until the high level alarm is activated (light and sound). This is a typical simple installation for a seasonal house or a permanent household without any need for remote surveillance or pumping data logging.

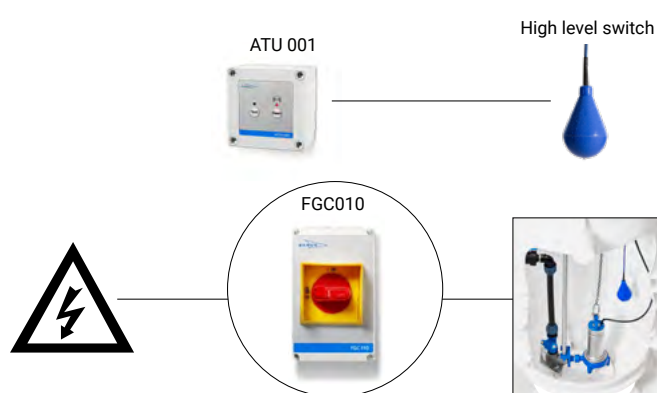


Figure 4.3.1: This package consists of a 1.1 kW (1.5 HP) centrifugal grinder pump with an on-off level regulator included, a manual starter (Flygt FGC 010), a high liquid level switch and an alarm buzzer box (Flygt ATU 001). The high level switch together with ATU 001 provides a flooding warning by alarming the household.

Solution 2, Smart and dedicated

The pump is controlled and monitored by the control unit (such as a Flygt FGC 200). The liquid level is measured constantly and determines when the pump starts and stops. Start and stop levels can be adjusted in the pump controller. Running information such as liquid level, alarm log, pump current, running hours and number of starts is also stored. When an alarm sounds, a light and sound signal is activated in the control unit and ATU 001.

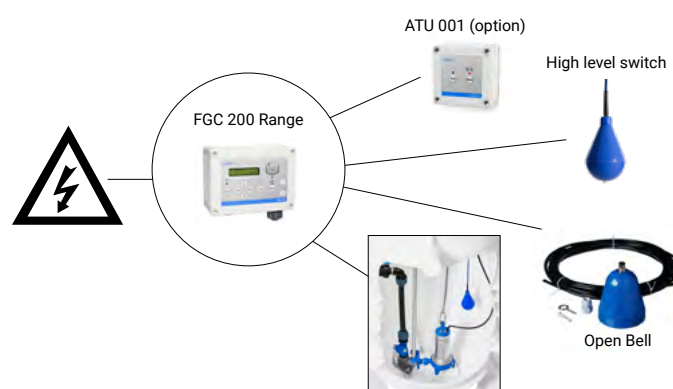


Figure 4.3.2: The control unit (Flygt FGC 200) monitors and controls pump and high liquid level. The FGC 200 and ATU 001 unit sounds for alarms such as power failure, high liquid level, or overly long pump running cycles.

Solution 3, Intelligent with communication

This solution has the same functionalities as solution 2 but with different types of communication possibilities such as GSM. It is also designed for a maximum of two pumps, as in demanding applications with several houses connected to one pump station. This solution can be used in instances where high reliability, control, logging and communication is required.

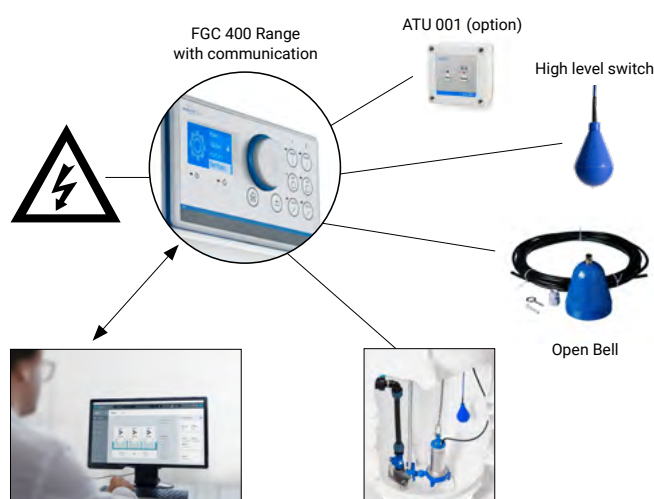


Figure 4.3.3: The control unit (Flygt FGC 400) monitors, controls and also remotely communicates with a SCADA system. The intelligent and flexible controller has built-in contactors and can be equipped with main breakers and a modem to send an alarm to a mobile phone.

Depending on the level of complexity and user needs, functionalities and features for the three monitoring and control packaged solutions are explained more thoroughly below:

Solution 1: Simple and robust

Feature	Functionality
Stationary hand-operated 3-phase starter for D-O-L start of pumps	Manual starter for 1 pump up to 7.0 kW (i.e., Flygt FGC 010).
Simple alarm distribution	Audible alarm unit is a compact battery operated unit that will give summary alarm, i.e., Flygt ATU 001. It can be equipped with DC supply to save batteries.

Solution 2: Smart and dedicated

Feature	Functionality
All features in Solution 1	
Compact controller with alarming and monitoring, all in one unit	Fits in any application or location.
Automatic reset of the pump after an over current failure (overload)	After release of the circuit breaker to protect the pump, the unit makes a second attempt to start the pump in order to eliminate unnecessary call-out.
Maximum Run Time for a Pump	Maximum time a pump can run continuously to eliminate pump damage by unnecessary pumping. When the pre-set time has elapsed, the pump is stopped and an alarm is generated and indicates specifically what is wrong.
High level Backup Pump Control	Guarantee no overflow if level sensor fails. If start switches or the level sensor malfunctions, the pump is started when the high level switch is activated and will continue to run an additional specified time, after it drops below the high level.
Maintenance run	Reconditioning of the pump to ensure reliable operation. If a pump has not been started within the pre-set interval, it will automatically perform a maintenance run.
Power failure alarm	Alarm is activated to prevent overflows when a power or one or more of the phases failure should occur.
Check of pump impeller rotation	The pump will be stopped and blocked from restarting if incoming phases are connected in the wrong sequence.
Power-on delay	Minimize risk of new power failure and cost by using lower fuse class. The delay prevents pumps in different sumps from restarting simultaneously after a power failure by being randomly delayed between 0–120 seconds.
Pre-configuration of parameters	Less commissioning time as no setting is needed before start-up the station (e.g., Flygt FGC). Easy start-up by factory pre-configuration of all parameters.

Solution 3: Intelligent with communication

Feature	Functionality
All features in Solutions 1 & 2	
Alarms sent to a SCADA system or SMS receiver	Intelligent and complete overview of your systems status and alarms with help of a communication module (telephone modem, GSM modem, radio modem or signal cable). An alternative is to use LON communication.

4.4 Tank design

This chapter describes the functionality of the tank and the tank components.

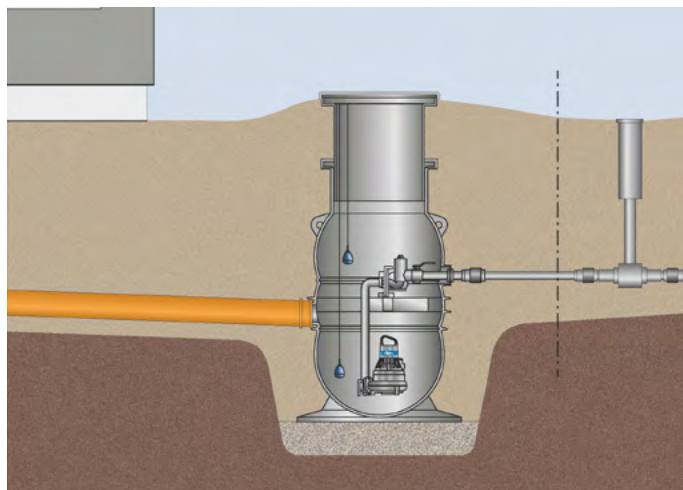


Figure 4.4.1: Elevation view of a PSS package installed outside a household.

The tank collects a household's sewage from a gravity pipe. Typical water consumption levels are listed in chapter 4.1.3. When the liquid reaches a certain level, the pump starts and lowers the level until the liquid reaches a set stop level. This is a very reliable way of controlling wastewater transport from the household to the pressure sewage system.

To ensure reliable pumping, the tank equipment should meet the following requirements:

- According to the European standards, the tank should have an emergency storage volume of at least 25% of the daily water consumption in the household (to be continued above the normal start level). This is to prevent flooding, for example, during power supply outages.

- The design must prevent freezing in the piping.
- The tank must remain fixed in the ground even in the presence of high water tables. Ground water will put pressure on the tank, which can rise if not properly anchored in the ground.
- The tank equipment must be easy to install, inspect and service.
- It must have a long-lasting design and be built with corrosion-resistant materials.
- It must have a smooth, rounded interior shape to prevent the collection of sediment and debris.
- It must be lightweight and have a flexible design for easy installation at different depths.
- The design must respect local regulations or preferences that may require the tank to have a ventilation pipe.

When several households (typically more than five) are connected to the same tank, dual pumps are often used for extra safety.

The pump is started and stopped by a signal from either on/off level regulators or from a pressure transducer. A high-level alarm regulator can also be used to avoid the risk of flooding in instances in which the pump could fail due to the introduction of unexpected objects into the system.

The pump can be installed hanging inside the pressure pipe, either double-bar guided or standing on the bottom with a hose connection to the pressure pipe. The installation preference varies between countries.

Accessories in the tank include a check valve, a shut-off valve and, in some cases, a siphon breaker and a high-pressure water flush connection.

The check valve prevents backflow from the pressure sewage system into the tank. Reliable check valves are of utmost importance to ensure the system works properly. Double-check valves can also be used: one in the tank and one at the boundary of the building plot.

When water consumption is low, wastewater can remain in the pipe system for long periods of time. Occasional fresh water flushing of the pressure pipes may be necessary to prevent the wastewater from becoming septic.

The shut-off valve in the tank is used when maintenance of the equipment in the tank takes place (to isolate the tank from the pressure sewage system). A shut-off valve installed at the boundary of the building plot is also used when installing the tank.

The use of siphon breakers differs according to markets. When the outlet is below any pressure sewage system pump station, however, a siphon breaker should always be used in that pump station. Siphon breakers are discussed in the chapter 4.5, together with the air-release valve.

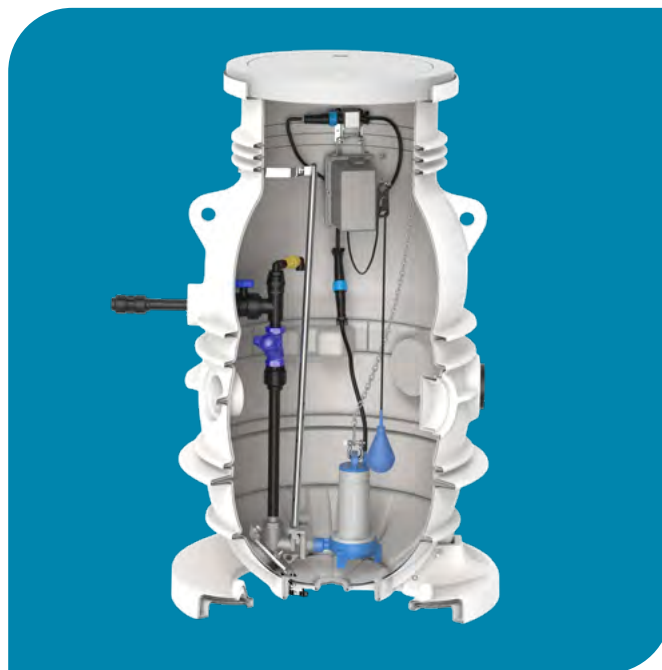


Figure 4.4.2: Flygt centrifugal grinder pump DXG Plus installed on a double-guide bar system.



Figure 4.4.3: Flygt centrifugal grinder pump M3069 installed hanging inside the tank.

4.5 Air-release valves, siphon breakers

Air-release valves

Air can enter into the pipe system and/or gas can develop inside the pipe from biological activity. For pipes in topographies with significant peaks, entrained or developed gas bubbles can accumulate in the peaks if the liquid velocity in the descending pipes is insufficient for transportation to the outlet. The accumulated gas can increase the pump system head loss, thus causing problems in the pressure sewage system. To release the gas, air-release valves can be installed at the peaks of the pipes. These automatically open when gas is present and close as soon as the gas is expelled.

To ensure reliable and trouble-free operation of the PSS, air release valves that are specifically designed for wastewater should be used. Please see suppliers' recommendations.

Sufficient velocity to transport air in descending pipes is recommended in pressure sewage systems. This is described in more detail in chapter 4.1.2.

Siphon breaker

When the system outlet is located at a lower elevation than the liquid level in some pump stations, those stations and their corresponding pipes can be emptied by siphon action – under sub pressure – until air entrains, breaking the siphon. The entrained air could cause air-lock in the pump, creating a need for manual priming before the pump can be restarted. A siphon breaker is an air inlet valve that opens under pressure in the pipe and stops the liquid flow. As air is released into the pipe, the water velocity must be high enough when the pump is running to transport the air pockets to the outlet at the declining pipe slopes.

The siphon breaker can be placed either upstream or downstream of the check valve.



Figure 4.5.1: Siphon breaker located downstream of the check valve.



Figure 4.5.2: Siphon breaker located upstream of the check valve. Image from PSS package, Flygt USA.

Design tools

Several engineering tools are available from Xylem. Below are short descriptions of PSS software possibilities; more information can be found on our website.

RioGI software can be used to select optimal pump and pipe sizes. SECAD, which includes dimensional drawings of the Flygt 3000 pump assortment, can be used to design large pump stations and includes other Flygt products that are not used in PSS applications. Xylem's selection tool includes data and information about pumps, pumping stations and monitoring and control equipment.

When using RioGI, a map or aerial photo is imported in jpg format. After the placement of pump stations and elevations are entered, RioGI proposes solutions with regard to pump types and pipe diameters. Those solutions are contained in a report that also includes wastewater retention times, liquid velocities and pump duty points.

Other design tools with similar functionality are also available.

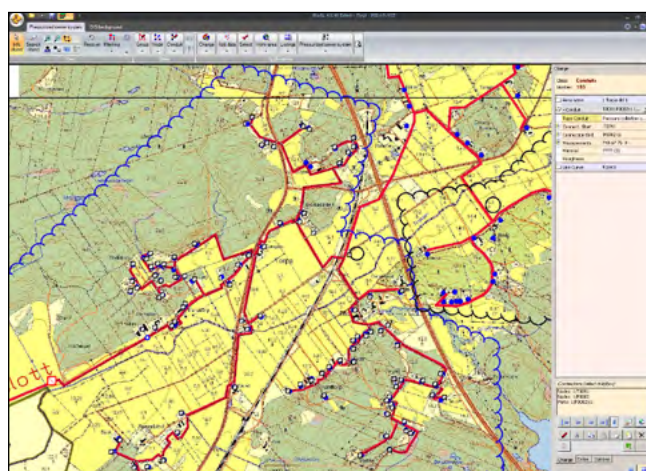


Figure 5.1: Pressure sewage system design input in RioGI. The software reports liquid velocities in each pipe when one or several pumps are running simultaneously.

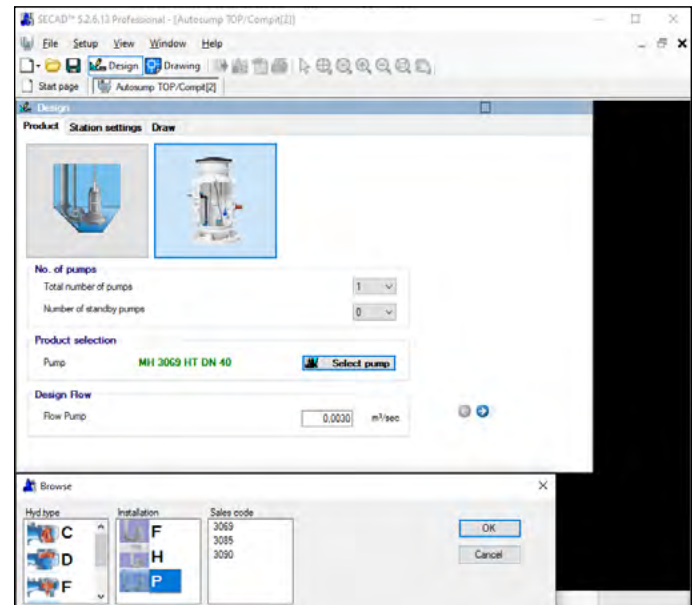


Figure 5.2: SECAD input interface. The tank type and pump type is defined.

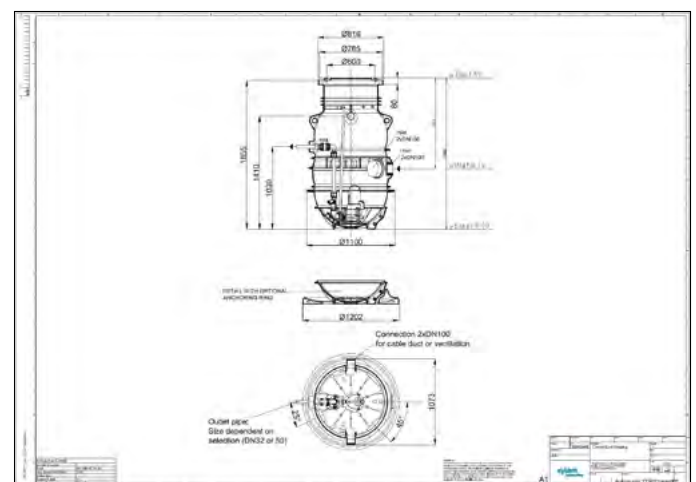


Figure 5.3: SECAD produces a dimensional drawing.

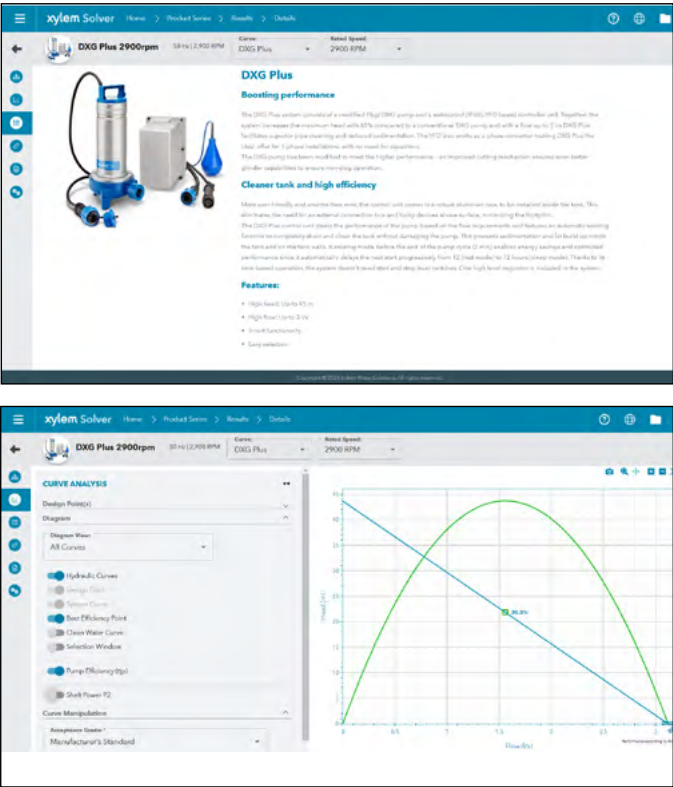


Figure 5.4: Xylem’s selection tool includes product data for pumps, tanks, and monitor and control equipment used in PSS installations.

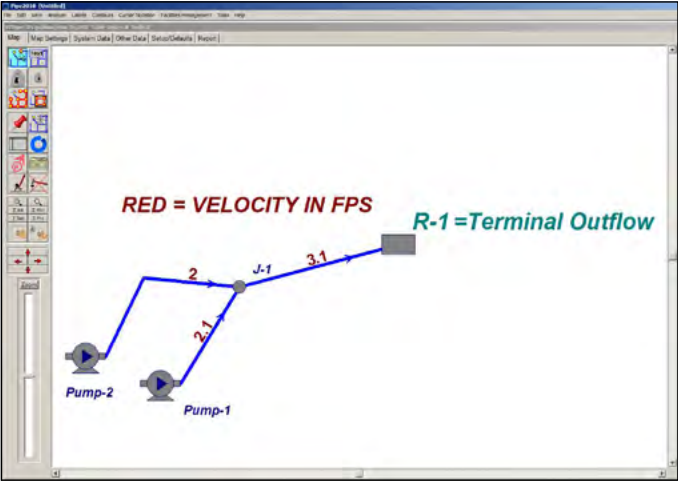


Figure 5.5: KY PIPE 2010 is used to estimate pipe flow velocity.

Description of hydraulic end types

Described below are the different centrifugal grinder pump impeller types used in PSS applications: multi-vane impellers (Flygt type M) and vortex / recessed impellers (preferred in the U.S.). In particular, the hydraulic ends are evaluated from the perspective of the primary customer who requires a system that operates without manual labor.

Grinder pumps have a mechanical cutting device outside the pump inlet which is independently designed from the hydraulic end type. The cutting device is normally made of an abrasive-resistant material. In the context that follows, the hydraulic end will be referred to as impeller, excluding the cutting device.

Note: Flygt N-impellers are the preferred choice in lift pump stations for receiving wastewater from the PSS system. Since this handbook is limited to the PSS application where a grinding of the liquid usually is required, N-impellers are not described.

6.1 Multi-vane impeller

The impeller unit of the grinder pump, with Flygt denomination M, is specifically designed to handle the rigors of pressurized sewage systems. The pump inlet is equipped with a cutting device that grinds particles into a low viscous liquid that can be pumped through the system's narrow pipes, which measure 32-50 mm or 1.25-2 inch in diameter.

For normal PSS operation, Flygt grinder pumps can be operated at all duty points along their performance curves, including the vertical portions. Centrifugal grinder pump performance curves often have horizontal and vertical portions

The power uptake data adheres to the dictum, "What you see is what you get". The performance curve shows the power uptake at different duties. Since the maximum power is lower than the rated power for all duties on the performance curve, there is no need to consider overloads when selecting the pump. Please also see chapter 8.1.

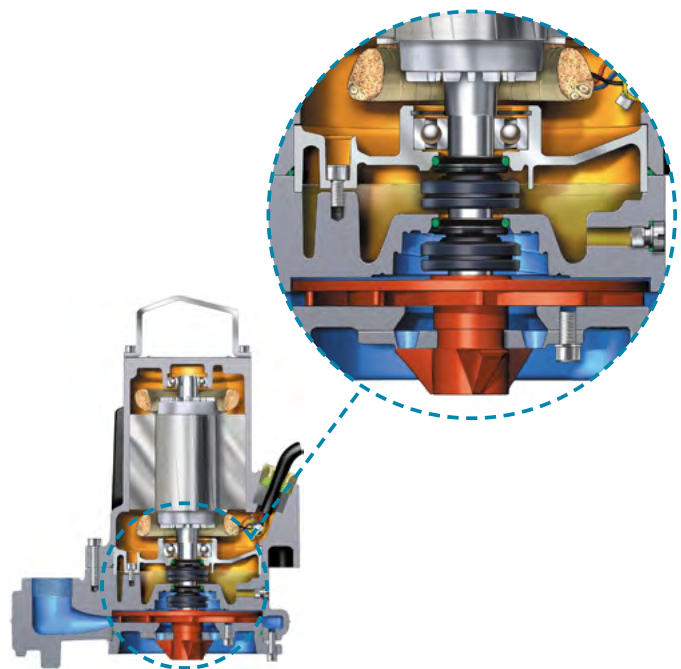


Figure 6.1: The first choice for houses which employ slender plastic pipes, the grinder impeller is supplied with a cutting device that grinds the solids in the wastewater. As the solids are ground, no wear occurs on the impeller.

6.2 Recessed / vortex impeller

With a vortex pump, flow through the unit is produced not by the actual impeller but by the rapidly rotating vortex that is created by the impeller.

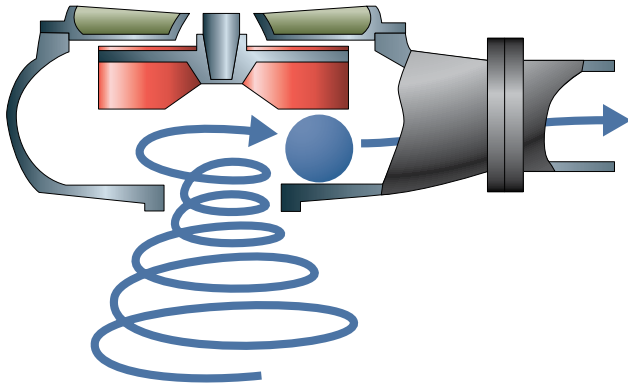


Figure 6.2: The D-impeller is a vortex-type impeller and single volute pump casing with large throughlets for sludge containing solids and fibers. A cutting device is not included in the picture.

6.3 Comparison of multi-vane and recessed / vortex impellers

Pumping operation times in PSS applications are short (e.g., 10 minutes a day), thus energy costs are negligible making motor size less important. However, the restricting factor for a PSS is maximum amperage consumption because the electrical installation must be sized for the rated (maximum) amperage. Costs, relative to pump, can increase substantially due to electrical installation if the amperage exceeds a certain amount. The dependency between efficiency and amperage is described below (power consumption is proportional to amperage consumption). The required shaft power for a certain duty point is:

$$P_2 = (H Q \rho g) \frac{1}{\eta_{Hydraulic}}$$

In which P_2 is shaft power, H is head, Q is pumped flow, ρ is liquid density, g is constant of gravity, and $\eta_{Hydraulic}$ is hydraulic efficiency.

As a result, lower hydraulic efficiency requires a larger motor and higher amperage consumption to achieve a certain performance curve.

The hydraulic efficiency (excluding the grinder mechanism) for multi-vane impellers is slightly higher than for vortex impellers. The hydraulic efficiency of the Flygt grinder pump series M3000 includes the power consumption for the grinder device.

Conclusion

A vortex pump is a good choice for sewage pumping where low energy consumption demand can be neglected. However, the multi-vane grinder pump, due to its slightly higher efficiency, has lower amperage consumption than the vortex. To reduce the installation cost, minimizing the amperage consumption is especially important with single-phase power supply.

The multi-vane impeller has proven highly reliable and long-lasting, with more than 400,000 Flygt M-type grinder pumps running in more than 10,000 PSS applications worldwide.

Hydrogen sulfide in PSS

This chapter describes the problems caused by hydrogen sulfide (H_2S), its properties, origins and possible corrective measures.

The formation of hydrogen sulfide in sewage systems has long been known as a source of odor and corrosion problems.

The main problems associated with H_2S are:

- At low concentrations it has an unpleasant odor, not unlike that of rotten eggs, from both the pipes and pump stations. At higher concentrations the gas is poisonous.
- It causes corrosion of metal parts in the sewage system, including pipes, installation equipment, sensors, etc.
- It also causes corrosion of concrete in the sewage system, including pipes, pump stations, sump, etc.
- There is a risk of explosion if the concentration of gas is above 4 percent.

H_2S is formed by anaerobic processes (absence of oxygen) during the degradation of organic material in the sewage system. It occurs mainly in sewage pipes when the retention time is overly long. The formation of H_2S starts when the amount of oxygen in the wastewater is low (approximately below 1 mg/l) and nitrates in the wastewater are consumed.

The main parameters that affect the formation of H_2S are: pH, temperature, available oxygen (free or chemically bonded) and retention time in the system (bio-film).

Corrective actions to minimize these problems involve optimization of the system design and/or the addition of oxygen / air or chemicals into the process.

Different types of systems may have different optimal solutions to eliminate H_2S problems. Minimizing the problem requires careful consideration.

Properties of H_2S

H_2S is a colorless gas that is heavier than air and soluble in water. The gas gives a bad odor at low concentrations, and it is poisonous at higher concentrations, capable of causing severe health problems and even death.

Health hazards of H_2S

Content of H_2S (ppm) in air	Human reactions
0.002-0.2	Smell threshold
1	Faint but noticeable smell
3-5	Distinct smell
10	Acceptable sanitary level for 1-day exposure
10-50	Irritation to eye
30	Unpleasant odor
50-100	Eye and respiratory difficulties after 1-hour exposure
100-200	Coughing and eye irritation (The odor disappears after 1–15 minutes. Dizziness occurs after 10–20 minutes.)
150-300	Paralysis of the sense of smell
500-1000	Paralysis of the breathing system and unconsciousness
>1000	Death

Table 7.1: H_2S level over 100 ppm (harsh conditions) can occur in pump stations.

When organic compounds degrade, organic sulfuric compounds are converted into H_2S , sulfide (S^{2-}) and hydrogen sulfide ions (HS^-).

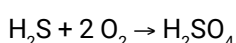
The volatility of the H_2S enables the gas to easily evaporate from liquid to air. The amount of gas that evaporates into the air depends on the temperature, the concentration of sulfide and the turbulence of the water.

Corrosion

H₂S can cause corrosion on concrete and metal parts in the sewage system according to the following reactions.

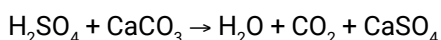
When water comes in contact with the surface of the pipes, the gas can either diffuse into air-filled pores in the pipes or dissolve into the water around solid particles and also diffuse into the pipes. If oxygen is present, the H₂S is oxidized by bacteria into sulfuric acid which in turn attacks the material according to the reactions below.

Corrosion of concrete



(Hydrogen sulfide + oxygen → sulfuric acid)

The sulfuric acid reacts with the alkaline cement in the concrete according to:



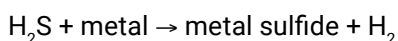
(sulfuric acid + cement → water + carbon dioxide + calcium sulfate (gypsum))

The action of sulfuric acid on concrete converts it to a pastry mass consisting largely of calcium sulfate and the residual sand and gravel used to make the pipe.

These reactions occur mainly above the water surface, where there is oxygen available to enable these chemical reactions.

Corrosion of metals

H₂S reacts with metals according to the reaction:



This reaction will/can affect the pipes and the installation equipment in the pump station as well as electronic components (sensors, etc.) in the stations.

Problematic H₂S formation occurs mainly in stationary water systems with low flow where the water contains organic compounds with sulfate and the water is relatively warm, such as in long, pressurized sewage systems or poorly ventilated gravity sewers.

Origins of sulfides

The formation of H₂S in sewage systems is a result of the reduction of sulfates and the degradation of organic compounds by sulfate-reducing bacteria in anaerobic (oxygen-free) environments. The degradation occurs mainly in the anaerobic zone in the “slime layers” (bio-film) in the sewage pipes. (See figure below.)

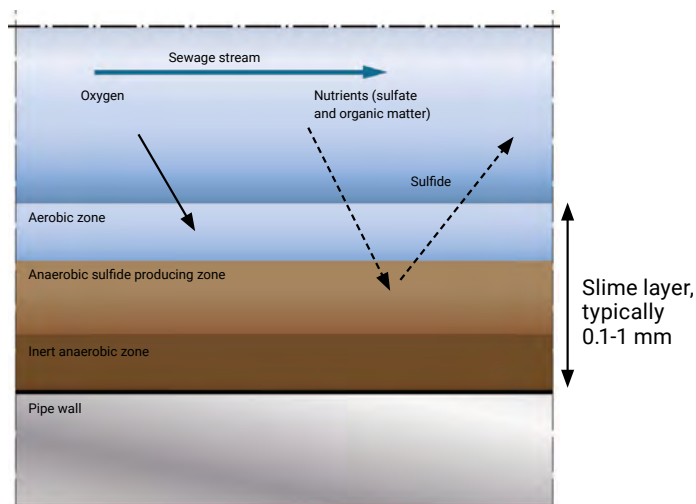


Figure 7.2: Illustration of the “slime-layer” zones inside a sewage pipe.

The bacteria that promote the formation of H₂S are mainly located in the slime layer on the inside of pipes used for wastewater. The thickness of slime layers range from 0.1-1 mm. It is in that anaerobic (oxygen-free) zone that H₂S is formed.

1. As long as there is free oxygen in the sewage, the bacteria in the oxygenated aerobic zone of the slime layer dominate the degradation of organic material, limiting the H₂S formation to minor amounts.
2. When all dissolved oxygen is consumed, the bacteria will dominate and use nitrates as an oxygen source in the degradation process.
3. When all the oxygen in the nitrates is consumed, bacteria in the anaerobic zone will take over the degradation process, resulting in the formation of H₂S.

Sulfide exists in wastewater in the state of insoluble sulfides such as ferric sulfide (FeS) and zinc sulfide (ZnS) and as dissolved sulfide ions (S²⁻), hydrogen sulfide ions (HS⁻) and in the form of hydrogen sulfide (H₂S).

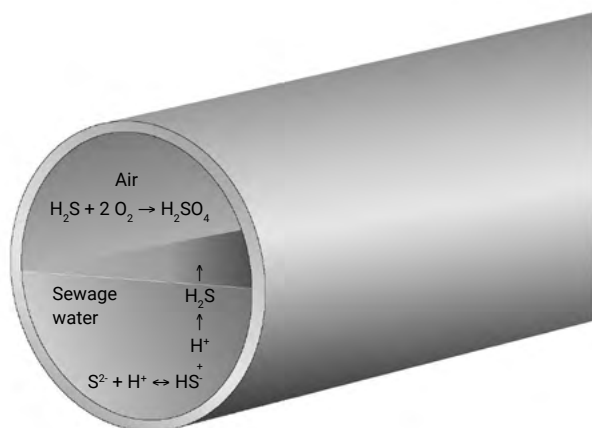


Figure 7.3: Schematic illustration of sulfuric components in water and air inside a sewage pipe.

Factors that favor the formation of H_2S :

- Low concentration of dissolved oxygen. If the content of oxygen is higher than approx 1.0 mg/l, H_2S will not form.
- Low water velocity. The minimum water velocity in pipes is recommended to be >0.7 m/s at least once every 24 hours to prevent sediment build-up and formation of H_2S .
- Long retention time in the system.
- High content of organic sulfur compounds in the sewage.
- High water temperature. As a rule of thumb, the rate of sulfide production increases by approximately 7 percent per degree Celsius up to 30°C, and it is negligible if the temperature is below 7°C.
- Low pH-value promotes the formation of H_2S instead of the ions HS^- and S^{2-} , as shown in the figure below. At a pH below 5, the fraction of H_2S is about 100 percent and at pH above 9 the fraction of H_2S in the water is approximately 0 percent. Adding chemicals such as sodium hydroxide will increase pH and thereby minimize the amount of H_2S .

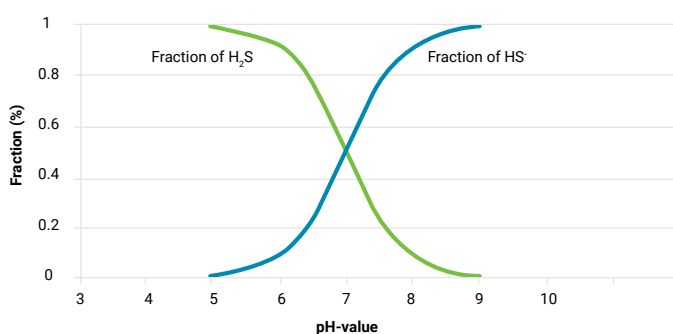


Figure 7.4: The pH-dependence of the fractions of H_2S and HS^- in sewage.

Guidelines to avoid or minimize the formation and effects of H_2S in sewage systems:

- Keep the retention time in pressurized sewers as short as possible.
- Place the exits of the pressurized sewage for gravity sewers in places where complaints of odors will be least expected.
- Avoid biochemical reduction of sulfur by making air available in both the sewer and the pump sump.
- Select corrosion-resistant materials in the pump station and in sewers.
- Add chemicals (see below) or active bacteria.
- Inject air / oxygen into the effluent on the delivery side of the pump during operation.
- Ventilate the pump station.
- Design for an “anti-splash” barrier at inlets to avoid or minimize the formation of aerosols which can emit H_2S .
- Prepare the sewage system for cleaning / removal of the slime layer on the inside of the pipe walls.
- Reduce the consequences (corrosion) of H_2S by encouraging its release at the outlet of the network in a sealed “pre-manhole” made of polyethylene or polyester / glass fiber separated from the sewage sump. On the walls of the “pre-manhole,” the released H_2S oxidizes to form H_2SO_4 by condensation, and then dissolves and dilutes in the effluent. A good precaution is to protect the gravity feed pipe from the “pre-manhole” to the pump sump over a distance of at least 20 meters with PVC-sleeving or other materials to eliminate corrosion.

Addition of chemicals:

- Nitrates (source of oxygen). Calcium nitrate (i.e., Nutriox®)
- Chlorine (sodium chlorite or sodium hypochlorite)
- Hydrogen peroxide (produces dissolved oxygen)
- Sodium hydroxide (raises pH to 12 for approximately 30 minutes, must be repeated at intervals)
- Iron salts (react with H_2S to form ferric sulfide)

Appendices

8.1 Electrical parameters

M3090 is a more powerful grinder pump used primarily for PSS applications. It qualifies as a 2 HP class (U.S.) grinder pump and is capable of pressures up to 48 m (157 ft) at 50Hz and 58 m (190 ft) at 60Hz. It is the same size as other PSS 2 HP pumps, though its rated shaft power is 4 kW.

M3090 has the same size, weight, input power uptake and current as other 2 HP centrifugal grinder brands. Its rated power, 4 or 6 kW, follows the usual rating praxis used for all Flygt pumps to categorize the size of the pump.

Parameters are needed to specify the required performance – and expected results – for all mechanical equipment. That is also true with regard to pumps. The most common parameter in pumping is the amount of time it takes to transport certain volumes away from the pump to an outlet of the pipe system – or the ‘required pump flow.’ In commercial applications, flows are often quite large, and energy consumption needs to be minimized in order to get a cost-effective solution. In residential applications, such as in pressure sewage systems, the water volumes to be transported are much smaller and require less energy. However the maximum amperage is important because it defines the size and cost of the electrical installation.

The electrical parameters used in pump system design are described in this chapter.

8.1.1 Background

Electrical parameters are used to select the best pump and the proper size of electrical installation equipment. This chapter also includes background information on shaft power usage for defining the size of the pump.

Power consumption or input power or power uptake is proportional to supplied voltage and consumed amperage.

$$P_i \propto U I \text{ [kW or HP]}$$

$U \text{ [V]}$ is the voltage supplied by the electric net.

$I \text{ [A]}$ is the consumed amperage.

The power the pump consumes multiplied by the number of running hours determines the total cost of the electricity bill.

I and P_i vary with duty point (head and flow). For centrifugal pumps, including grinder pumps, amperage and power consumption increase with increasing flow.

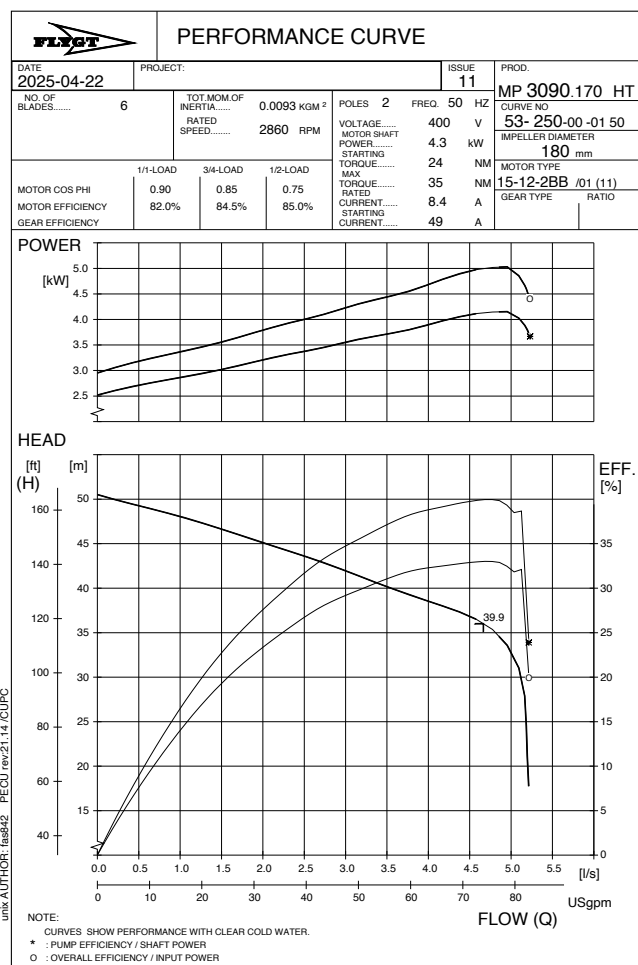


Figure 8.1.1: Power uptake increases with increasing flow.

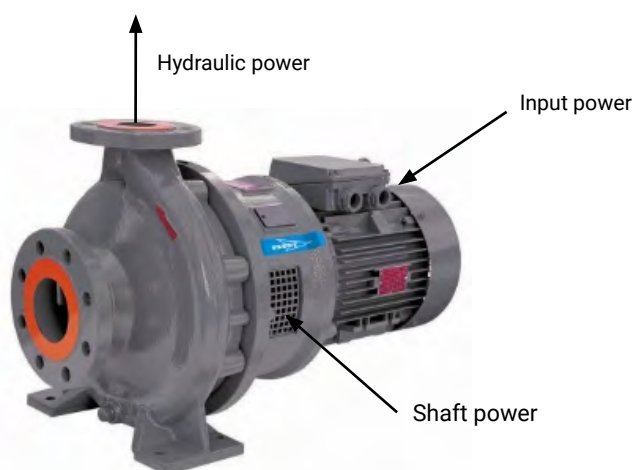
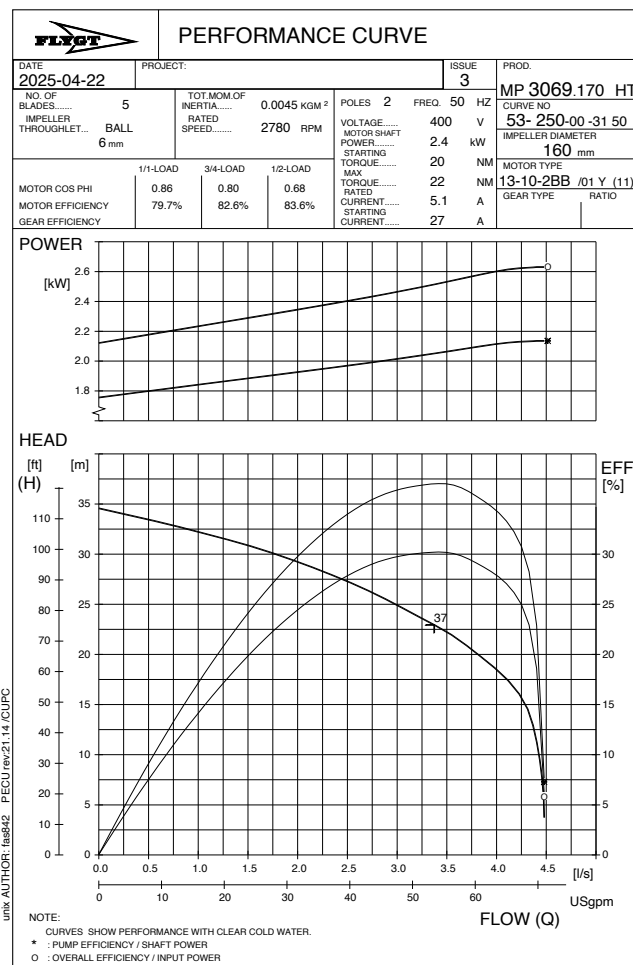


Figure 8.1.2: Shaft power P_2 is the power transmitted from the motor to the wet end.

Historically most pumps and motors have been separated. The required pump flow and head defined the hydraulic power and, in combination with the hydraulic efficiency, the needed shaft power.

The shaft power (P_2) is the power to be transmitted from the motor to the wet end, the interface between the wet end (from one supplier) and the motor (from another supplier), sometimes via a clutch between the wet end (pump) and the motor.

Shaft power [kW, HP]

$$P_2 = \eta_{motor} P_1$$

η_{motor} defines the efficiency of the motor. It varies with the loading of the motor. The motor efficiency is the difference between the total efficiency and the hydraulic efficiency (see the curve above).

Hydraulic power is proportional to pumped flow [l/s, USGPM] and produced pressure, head [m, feet]

$$P_{hydraulic} \propto QH [\text{kW, HP}]$$

The efficiency of the wet end is defined as:

$$\eta_{\text{hydraulic}} = \frac{P_{\text{hydraulic}}}{P_2}$$

The maximum hydraulic efficiency a particular pump can achieve is denoted as best efficiency point (BEP). (See performance curve above.)

The total efficiency for the pump is defined as:

$$\eta_{\text{total}} = \frac{P_{\text{Hydraulic}}}{P_1} \quad \text{or} \quad \eta_{\text{total}} = \eta_{\text{hydraulic}} \eta_{\text{motor}}$$

Detailed data for a specific pump can be supplied by Flygt.

For submersible pumps, in which the wet end and the motor are integrated, the nameplate power indicates the maximum shaft power that the motor can handle in continuous operation. However, the input power should also be considered for pump selection. When defining the shaft power to be included in the product data, the shaft power has to be calculated or measured with the pump taken apart.



Figure 8.1.3: Centrifugal grinder M3090, typically 1 l/s @ 43 m and 13 Amp (16 USPGM @ 140 feet, 22 Amp).

P_2 at maximum input power allowed determines the rated power. The rated amperage corresponds to the maximum power input and defines the needed circuit breaker size and wiring sizes

An electric motor has a limit on how much electric power it can transfer to shaft power without being damaged by high temperature. In intermittent duty electric motors can handle higher loads; thus, intermittent-duty equipment can be rated higher.

8.1.2 Power ratings at different duty conditions

Different ratings are used to define possible overload during shorter periods. In the U.S. the service factor (SF) is used to define how much additional power a motor can be loaded with. For example, a SF of 1.25 at a 2 HP motor can be overloaded up to 2.5 HP during shorter periods. An alternative definition is the IEC duty cycle. S1 applies to continuous duty (i.e., the motor works at a constant load for enough time to reach temperature equilibrium). S3 is the rated power for intermittent periodic duty. Temperature equilibrium is never reached; starting current has little effect on temperature rise. S3 can be used for normal PSS installations.

8.1.3 The essential parameters

The requirements on a pump for pressure sewage systems are:

- Sufficient flow to ensure enough scour in the pipe;
- Sufficient head to overcome the geodetic head and the dynamic head generated in the system;
- Low amperage consumption to ensure smaller components in the control panel, minimizing installation cost. M3090 is available with a 15-amperage rating as well as 22 amperage in single phase (60 Hz).

8.1.4 Conclusions

The name plating of the unit follows the typical Flygt convention. Competitor units may show a lower 2 HP – thus higher input power and amperage. The Flygt MP3090 has comparable power consumption and requires equivalent components for the electrical panel as other centrifugal grinder pumps.

8.2 Flygt PSS assortment

For more information regarding PSS packages, please contact your local Flygt representative or visit the Xylem website.

8.3 Pump and pipe design guideline

Many decisions must be made when designing a pressure sewage system, e.g., pump selection, inclusion of telemetric monitoring, sophistication level of the alarm for possible emergency conditions. Future extension / expansion of the PSS also needs to be considered, as this can affect pipe sizes, etc.

This chapter includes guidelines for both pump size and pipe size selection. Each step refers to additional information in corresponding chapters.

The checklist in chapter 8.4 complements the following methodology for supporting the design work. The methodology defines the needed pump capacity and pipe dimensions according to the hydraulic conditions that will occur.

Guidelines to choose the optimal monitoring and control solution based on user preferences can be found in chapter 4.3. Requirements to be considered when defining the tank, such as buffer volume for emergency conditions, are described in chapter 4.4.

There can also be additional local requirements such as a need for heating cables, emergency discharge, pump snoring, etc.

Step by step guidelines to define pump duties and optimal pipe dimension

1. Define or identify the number of pumps in the current / future system based on criteria such as one household per pump station or several households per pump station, permanent / seasonal usage, average water consumption per household, pipe lengths, and pipe elevations.
2. Make a first assumption on the pipe diameters and pump size to fulfill the hydraulic requirements such as liquid velocities to prevent sediments. See chapter 4.1.2.
3. Estimate the duty points for the pumps in single run operation and following liquid velocities in the pipes using, for example, RioGl. See chapter 4.1.
 - a. If the velocities (for recommended liquid velocity see chapter 4.1.2) and pressures are as required go to 4.
 - b. If the liquid velocities are low, smaller pipes and / or larger pumped flow might be needed. Repeat until velocities are as required, and then go to 4.
 - c. If pressures are high consider larger pipe diameters. Repeat until pressures are as required, and then go to 4.
4. Estimate the maximum number of pumps that will operate simultaneously. See chapter 4.1.3.
5. Make an estimation of the hydraulic conditions with multiple pumps running simultaneously. The scenario where largest pressures and lowest flow are usually with the remote pumps running simultaneously. Review that the hydraulic requirements are fulfilled (i.e., 0.7 m/s [2.3 ft/s] are obtained at least every 24 hours). If not go to 2.
6. Adapt the PSS system to additional local requirements such as need for heating cables, emergency discharge, pump snoring, etc.
7. Design done!

8.4 Checklist for a PSS design

System data	Select/ Value
Number of households to be connected	
Household season usage:	Summer / Winter ☐ All year household ☐
Average number of persons in the household Normally 3-4 persons	
Average water consumption per person in the household, e.g., 100 – 400 l/day (100 USGPD)	
Are there commercial users (schools, restaurants, etc.) connected? What is their average water consumption?	
How many households connected to the same pump station?	
How will the pump station be powered:	From the house ☐ By a separate power supply ☐
What are the ground conditions (arable and pasture land, rock, etc.)?	
What is the groundwater level?	
Map including elevations attached	☐
Digital format (pdf, jpg, dwg)	☐

Service and monitoring	Select/ Value
Who will receive a possible alarm?	
Is there a need to read the running information? (level, alarm log, pump current, running hours, number of starts, etc.)	Yes ☐ No ☐
Is there a need to log the pumping information? (level, alarm log, pump current, running hours, number of starts, etc.)	Yes ☐ No ☐
Is there a need for remote survey and control of the pump station?	Yes ☐ No ☐
If yes, is it possible to:	
Get the alarm to a mobile phone?	☐
Communicate with a higher sophisticated system like SCADA?	☐
What is the need for supply of inspection and maintenance support? Type of system? Communication protocol?	
Is there a need to monitor phase failure?	Yes ☐ No ☐

Scope of delivery	Select/ Value	Comments
What is the required scope of delivery?		
Equipment only:	☐	
Complete contract:	☐	
Other, please specify:	☐	
Who executes the excavation?		
Who executes the electrical, pipe and pump station installation?		
Who executes the start up?		
Scope of delivery from consultant		

Sewer and water pipe information (for complete contract)

Household piping	Select/ Value	Comments
Please verify that there are shut-off valves at the reticulation pipe.	Yes ☐ No ☐	
Will drinking water piping be installed?	Yes ☐ No ☐	Diameter?
Will heating cable be installed?	Yes ☐ No ☐	
Temperature control of the heating cable?	Yes ☐ No ☐	
Earth fault breaker included?	Yes ☐ No ☐	
Are frost isolation boxes used?	Yes ☐ No ☐	The dimension of the box depends on the pipe diameter

Reticulation piping data	Select/ Value	Comments
Is there an existing reticulation pipe?	Yes ☐ No ☐	
Reticulation pipe dimension		
Material		
Pressure class		
Existing heating cable?	Yes ☐ No ☐	
Temperature control of the heating cable?	Yes ☐ No ☐	
Earth fault breaker included?	Yes ☐ No ☐	
Are frost isolation boxes used?	Yes ☐ No ☐	The dimension of the box depends on the pipe diameter

8.5 Terminology, abbreviations and symbols

Term	Explanation
Air pockets (in the piping)	Air can enter the sewer and / or gas can develop in the sewer. For piping with peaks, air and / or gas can accumulate in these peaks.
Air release valves	Automatically open when gas is present and close as soon as the gas disappeared.
Anaerobic	Anaerobic means without oxygen, as opposed to aerobic.
Anoxic conditions	No air or oxygen is available for the wastewater bacterium's to consume.
Bio-film	See chapter 7.
BOD	Biochemical oxygen demand or BOD is a chemical procedure for determining the amount of dissolved oxygen needed by aerobic biological organisms in a body of water to break down organic material present.
Calcium nitrate	Calcium nitrate is an inorganic compound with the formula $\text{Ca}(\text{NO}_3)_2$.
Check valve	Prevents backflow from the pressure sewage system into the tank (essential for a well functioning PSS).
Circuit breaker	Stops electrical equipment when the amperage exceeds the allowed level (e.g., 10A, 20 A).
COD	In environmental chemistry, the chemical oxygen demand (COD) test is commonly used to indirectly measure the amount of organic compounds in water.
D-O-L start of pumps	Direct On Line. (On - Off). When using DOL, keep an eye on the starting current and make sure that the electrical system (fuses, junction boxes, etc.) can handle it. It can peak as high as 6 to 7 times the full load current.
Duty point	The head and the flow a pump produces in its pipe system.
Flow rate	Volumetric flow through the pipe per unit of time.
GPRS	General Packet Radio Services. GPRS usage charging is based on volume of data.
GSM	Global System for Mobile Communications.
Head	See pressure.
High-pressure water flush connection	Connection to flush the pipes with high pressure hot water (often from a truck) when pipe has been blocked.
Hydrogen peroxide	Hydrogen peroxide (H_2O_2) is an oxidizer commonly used as a bleach.

Term	Explanation
Hydrogen Sulfide, H₂S	Hydrogen sulfide is a colourless, flammable extremely hazardous gas with a smell of “rotten egg”.
Impeller	The impeller is located in the pump housing. Different types of impellers are used for different type of liquids and head and flow requirement.
Level regulator	A level regulator signal when the liquid level reaches a certain level, for example starts or stops a pump or starts the high level alarm.
LON	Local Operating Network. LON, a communication protocol to be used for power lines or with potential free twisted pair. LON is suitable for short distances (<1000 m).
Mechanical seal	A mechanical seal consists of two (very) flat metal rings with (very) smooth surfaces, one stationary and one rotating. Due to their flatness, liquid cannot pass the rings (a small amount of liquid lubricates the surfaces).
Nitrates	Nitrates are the ions NO ₃ ⁻ .
Organic material	Organic material is a large class of gaseous, liquid, or solid chemical compounds whose molecules contain carbon.
Performance curve	A performance curve, or pump curve, shows how much flow (Q) a pump can deliver against a corresponding head (H).
pH	pH is a measure of the acidity or basicity of an aqueous solution. Pure water is said to be neutral, with a pH close to 7.0 at 25 °C (77 °F). Solutions with a pH less than 7 are said to be acidic and solutions with a pH greater than 7 are basic or alkaline.
ppm	Parts per million.
Pressure	In pumping, pressure is often denominated as head. The pump generates a pressure in the discharge pipe which decreases as the liquid moves along the pipe.
PSTN	Public Switched Telephone Network.
Pump station	A pump station contains sump (tank), pump, and monitoring and control equipment for the pump(s). Liquid enters the sump and when a certain level is reached the pump starts and stops when the stop level is reached (on/off regulation). Larger pump stations can have a house (to make supervision easier).
Pump sump	A tank, or basin, to collect the wastewater to be pumped away. A good design of a wastewater pump sump and proper pump control is crucial to avoid sediments on the bottom and surface crust build up.
Radio	Radio communication most often used in close range.
Redundancy	In wastewater pumping usually an extra pump to ensure full operation even if one pump stops.
Retention time	Here, the time the wastewater stays in the sewer (inflow to pump station / pipe volume).
SCADA system	Supervisory Control And Data Acquisition. By connecting RTUs (Remote Terminal Units) you can precisely and effectively monitor and control the flow in and out of your system. For instance, generate alarms in case of failure, log data for reports, trends and events, and continuously monitor the state of linked pumps, mixers and valves.

Term	Explanation
Scour (pipe)	Settled solids (which occur when liquid movement stops) are re-suspended when the liquid is moving (i.e., pumping).
Sedimentation	Sedimentation of wastewater solids occurs when the liquid velocity is too low. Sedimentation can cause pipe blockage and following wastewater transport system failure.
Sewage pump	Pump with hydraulic end designed to pump liquid containing human waste. Often a submersible pump.
Sewage sludge	Sludge is thickened wastewater (the water is separated). In the wastewater treatment plant the wastewater is thickened to sludge in different process steps.
Sewer	Piping for wastewater and / or stormwater.
Shut off head	The maximum pressure a centrifugal pump can produce.
Shut-off valve	Used to isolate the tank from the sewers when maintenance of the equipment in the tank takes place.
Siphon breaker	See chapter 4.5
Snoring	When the water level is close to the pump inlet, a vortex might form and air is sucked into the pump, i.e., the pump snores.
Sodium hydroxide	Sodium hydroxide (NaOH), also known as lye and caustic soda. A water solution of sodium hydroxide has a high pH (alkaline solution).
Specific energy	With specific energy, E_s, it is possible to compare different pump selection alternatives to find the least energy consuming solution. The definition is as follows: $E_s = \frac{E}{V} = \frac{\frac{Q \cdot H \cdot \rho \cdot g}{\eta} \cdot t}{Q \cdot t} = k \cdot \frac{H}{\eta}$ Where k is a constant, $k = g \cdot \rho$ E is the consumed energy V is the pumped volume A pump system consists of two head loss components: the static part and the dynamic part. For pump systems with mostly static head loss, the total efficiency of the pump determines the system efficiency. For systems with relatively small static head loss, the pump efficiency can have much less importance than the dynamic losses which is related to the liquid velocity on the energy consumption. The specific energy will vary significantly in such systems depending on the liquid pipe velocity and can be used as a measure to optimize the pump selection and system solution.
Stormwater	Sewage from heavy rain.
Sulfuric acid	Sulfuric acid is a strong mineral acid with the molecular formula H_2SO_4 . Sulfuric acid is soluble in water at all concentrations.
Viscosity	Liquid thickness.
Volatility	Volatility is a measure of the tendency of a substance to vaporize.

Symbol	Dimensional formula	Definition
t	[s]	Retention time of the liquid inside the pipe system
V	[m ³]	The pipe's total volume
Q	[m ³ /s, l/s, m ³ /hrs, USGPM]	Flow
q_{in}	[m ³ /s, l/s, m ³ /hrs, USGPM]	Inflow to pump station
f	[-]	Pipe friction factor
l	[m, feet]	Pipe length
v	[m/s, feet/s]	Liquid average velocity
d, ϕ_{pipe}	[m, mm, inch]	Pipe diameter
g	[m/s ²]	Gravitational constant
P	[-]	The probability that a certain number of pumps are running simultaneously
R	[-]	The number of pumps for which P is estimated
N	[-]	The total number of pumps or number of EDUs (Equal Dwelling Units)
q_p	[m ³ /s, l/s, m ³ /hrs, USGPM]	The pump flow
q	[l/s]	The average produced peak waste flow
VW	[l/day]	The produced wastewater per inhabitant per day
NI	[-]	The number of connected inhabitants
q_d	[m ³ /s, l/s, m ³ /hrs, USGPM]	The design flow for each pipe uses the above calculated flow, adjusted to the closest number of pump design flows
h, H	[m, feet]	Pressure head

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- 1) the tissue in plants that brings water and nutrients upward from the roots.
- 2) a leading global water solutions company.

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