

A close-up photograph of a waterfall with multiple streams of water cascading over rocks, creating white foam and splashing. The background is dark and out of focus.

WASTEWATER ENGINEERING MANUAL 1

For small and medium sized wastewater pumps

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INTRODUCTION

This Wastewater Engineering Manual 1 is intended to assist pumping station designers, planners, application engineers, consulting engineers and users of pumping stations for smaller wastewater transport systems using wastewater pumps with motors from 0.15 kW to 30 kW. Recommendations for larger and more complex systems will be discussed in Wastewater Engineering Manual 2 (wastewater pumps with motors up to 520 kW).

Drainage, effluent and sewage applications and installations are dealt with separately to ensure the right pump selection and installation.

The manual covers the following: guidance for both submersible and dry-pit submersible installation and operation; pump sump design with layout and benches in the wet pits and requirements for concrete foundations in dry-pit installation for optimised operation; and recommendations for anchoring of the pipe system. Proper anchoring of connecting pipes is crucial for optimal hydraulic conditions.

In addition, factors such as sound, noise, air entrainment, vorticity and vibration, and the special considerations to be taken are discussed, with recommendations for avoiding these types of destructive forces. Pump performance data and practical examples are for 50 Hz pumps.

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[1]

DRAINAGE, EFFLUENT AND SEWAGE

1. Wastewater

Wastewater can be divided into different groups, depending on where it comes from and the content of impurities such as sand, gravels, fibres and solids. Normally wastewater is divided into drainage, effluent and sewage.

To most people, wastewater in the form of dirty water from sinks, washing machines, toilet waste and discharge from industry is something that just disappears down the drain, and in most cases it does.

1.1. DISCHARGE SYSTEMS

The correlation between human activities, houses with bathrooms, showers, toilets and the natural water cycle requires establishment of discharge systems for wastewater, shown in Fig. 1. The purpose of the discharge system is to handle the wastewater so that inconvenience and health risks are as low as possible for the population and surroundings.

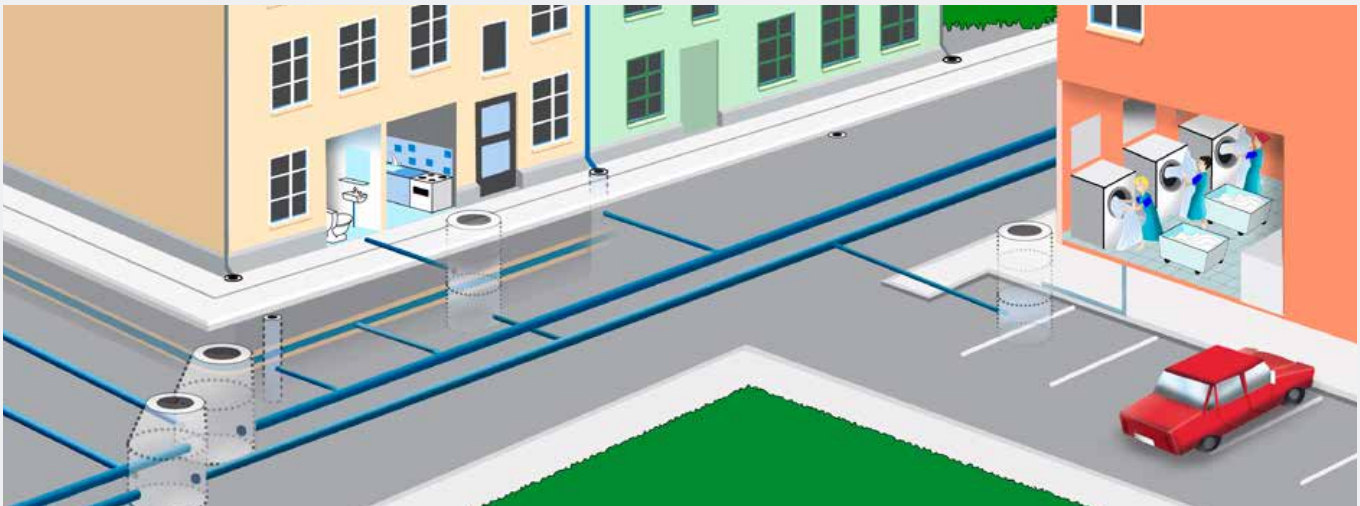


Fig.1

Type of wastewater		Discharge from
Drainage	Drain and infiltration water	Drain around buildings with basement, drained areas, leaking pipes and connections
Rainwater/surface water	Rain and melt water	Roads, streets, parking areas, courtyards, roof surfaces etc
Effluent	Industrial wastewater without toilet waste	Economic activity (water which has been used for production, including cooling and flushing water)
Sewage	Wastewater with discharge from toilets	Residential buildings, hotels, hospitals, institutions, public buildings etc

1.2. DRAINAGE

The establishment of impermeable and paved surfaces prevents rainwater from discharging naturally, and runoff is led by gravity from drains around buildings, roofs, parking areas, developed urban areas, build-up areas, to collecting pits and drain pipes to the recipient. This is shown in Fig. 2.



Fig. 2

If gravity feed of wastewater to the recipient is not possible, it must be pumped.

Grundfos submersible drainage pumps type Unilift KP with 10 mm free passage and Unilift AP with 12 mm free passage and semi-open impellers are suitable for both temporary and permanent free-standing installation in pump pits. They can be used for pumping drain water or industrial wastewater without impurities, such as fibres, and other suspended matter.



Unilift KP and Unilift AP

1.2.1. INSTALLATION OF DRAINAGE PUMPS

Grundfos drainage pumps for permanent installation in the pit are available with or without level switches for automatic start and stop of the pump. Pumps with level switches are meant for simple installations, where they start and stop automatically dependent on the water level. For high water alarm, a separate level sensor needs to be installed.

Pumps without level switches are meant for portable use or permanent installation together with separate level switches for start, stop and alarms. In this case, it will require a separate control panel, such as Grundfos LC controller.

1.3. EFFLUENT

Effluent can be defined as dirty water and untreated wastewater without discharge from toilets. Effluent may contain fibres and suspended matters not bigger than 35 mm.

Effluent may come from dewatering systems, domestic wastewater systems and applications within agriculture, horticulture, dairies, breweries etc.

Grundfos submersible effluent pumps type Unilift AP 35 and Unilift AP 35 B with 35 mm free passage and vortex impeller are suitable for both temporary and permanent free-standing installation in pump pits. They can be used for pumping effluent from buildings without toilet waste or industrial wastewater with impurities such as fibres from washing machines, for example.



Unilift AP 35



Unilift AP 35 B

1.3.1. INSTALLATION OF EFFLUENT PUMPS

Grundfos effluent pumps type Unilift AP 35 and Unilift AP 35 B for permanent installation in pits are available with or without level switches. Installation is as described for Grundfos drainage pumps.

1.4. SEWAGE FROM PRIVATE HOMES

It is usual to distinguish between sewage from private homes and sewage from public buildings. The owner of a single family house with a pumping station connected for the discharge of the wastewater can avoid inappropriate items in the drain system like floor cloths, dishcloths, nappies, and so on.

Grundfos submersible sewage pumps type Unilift AP 50 and Unilift AP 50 B with 50 mm free passage and vortex impellers are suitable for both temporary and permanent free-standing installation in pump pits. They can be used for pumping wastewater from private homes with toilet waste or industrial wastewater with impurities such as fibres and solids not larger than 50 mm.



Unilift AP 50



Unilift AP 50 B

Grundfos submersible grinder pumps type SEG are also applicable for transfer of wastewater with toilet waste from private homes.



SEG pumps are discussed further in section 10.

1.4.1. INSTALLATION OF EFFLUENT AND RESIDENTIAL SEWAGE PUMPS

Grundfos effluent and residential sewage pumps type Unilift AP 50 and Unilift AP 50 B for permanent installation in pit are available with or without level switches. Installation is as described for Grundfos drainage pumps.

1.4.2. MORE DEMANDING APPLICATIONS

For more demanding applications, Grundfos cast iron drainage, effluent and sewage pumps with cast iron impellers are the right choice.



Drainage pumps type DP are supplied with semi-open impellers with 10 mm free passage. Effluent pumps type EF have open channel impellers with 30 mm free passage. Residential sewage pumps type SE1 have closed single channel impellers with 50 mm free passage, and SEV sewage pumps have SuperVortex impellers with 65 mm free passage.

The main reason for differentiating between drainage, effluent and sewage is to select the right pump for a specific application. The smaller the free passage in the pump hydraulics, the better the hydraulic efficiency, and the smaller the motor required.

1.5. SEWAGE

Sewage contains everything that possibly can be found in wastewater. Worth noting here is that sewage may contain drainage and effluent, when the wastewater is drained off in a combined system.

Sewage can be defined as unscreened wastewater with toilet waste from public buildings, hotels, hospitals, institutions, resorts etc.

Grundfos submersible sewage pumps type SL1 and SE1 with the S-tube® impellers have free passage from 75 mm to 160 mm, and type SLV and SEV with SuperVortex impellers from 65 mm to 100 mm free passage in the housing. These are suitable for transferring unscreened sewage.

A sewage pump can be used to pump drainage and effluent when the required pump capacity is more than the performance of the available drainage and effluent pumps, but a drainage pump and effluent pump will not be able to pump sewage due to the smaller free passage.



SL1 and SLV pumps



SE1 and SEV pumps

1.5.1. INSTALLATION OF SEWAGE PUMPS

Grundfos sewage pumps type SL1 and SLV are for submersible installation on an auto-coupling system, or free standing installation at the bottom of the pit.

SE1 and SEV pumps are for submersible installation on auto-coupling and dry-pit installation either vertically or horizontally installed. Auto-coupling and dry-pit installation are discussed in section 2.

1.5.2 SEWAGE PUMPING WITH GRINDER PUMPS

SEG grinder pumps with a grinder system in front of the inlet to the pump are suitable for pumping wastewater with toilet waste through small pressure pipes with diameters of 40 mm, 50 mm, 65 mm or 80 mm.

Their ability to deliver high head and to effectively cut nappies, rubber gloves, towels, plastic toys etc. to small fragments make them the right choice for pressurised wastewater systems.



SEG and SEG AUTOADAPT pumps

Grundfos grinder pumps type SEG and SEG-AUTOADAPT are for submersible free-standing installation at the bottom of the pit and installation on an auto-coupling system with double guide rails.

2. Pump system layout

The layout of wastewater systems in private, public, municipal and industrial systems, as well as rainwater discharge systems, must be made in accordance with local regulations. This engineering manual is a supplement to such regulations.

2.1 LOCATION OF WASTEWATER PUMP SYSTEM

The following should be considered when selecting the best location for the pump system:

- Inlet layout to prevent cavitation problems
- Preparation for later capacity extension and the destructive forces of water hammer
- Service access
- Environmental considerations, including access for flushing
- Operation and maintenance

Additionally for wastewater pits located outside buildings:

- Minimum distances to foundations
- Soil and groundwater conditions
- Area reservation/site acquisition
- Route for pump system outlet
- Power supply
- Location of flood-proof electrical panel
- Emergency overflow or flood protection
- Dry or wet pump installation
- Valve position (dry or wet pit)
- Prefabricated pit or pit built on-site
- Velocity in the pipe system m/s

Additionally for wastewater pits located inside buildings:

- Special room
- Hermetically sealed, prefabricated tanks with ventilation to the open air with minimum 50 mm pipe
- Emergency overflow
- Flood protection
- Pipe dimensions and penetration of wall

3. Types of pump system

This manual distinguishes between three basic wastewater types as described above:

1. Drainage and sump pumping
2. Effluent and screened water pumping
3. Sewage and solid pumping

Pump selection, pipe dimensions and the consequences of pump failure will be different for the three wastewater types.

3.1. DRAINAGE AND SUMP PUMPING

10 mm to 12 mm is the expected maximum particle size in pumped liquid with only a limited content of long fibres.

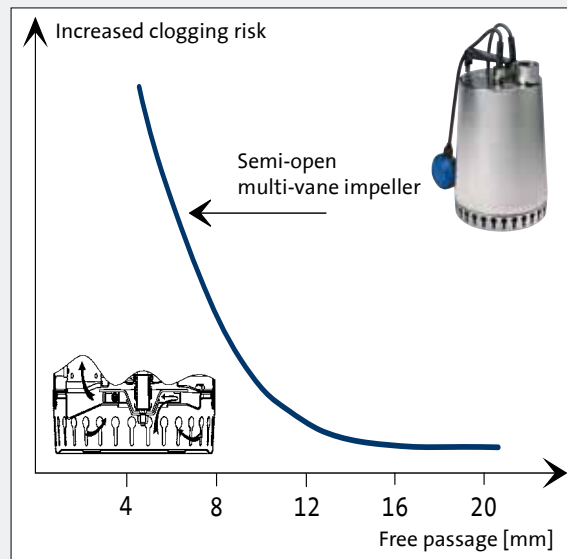


Fig.3 Diagram showing the relation between risk of clogging and dimension of free pump passage. Good protection against clogging is achieved with 10 to 12 mm free passage in the hydraulic.

For portable use

If the drainage pump is not permanently installed, it can be used as a portable pump for basement drainage, fountains, contractor pumping from excavations and any application using flexible vertical discharge hoses.

Pump failure in drainage applications will normally only result in flooding that requires normal cleaning. If this is not acceptable, the installation should be upgraded with an effluent type of pump in order to reduce the risk of clogging as much as possible. This will increase both initial and operating costs of the pump by more than 60 %.

3.2. EFFLUENT AND RESIDENTIAL WASTEWATER PUMPING

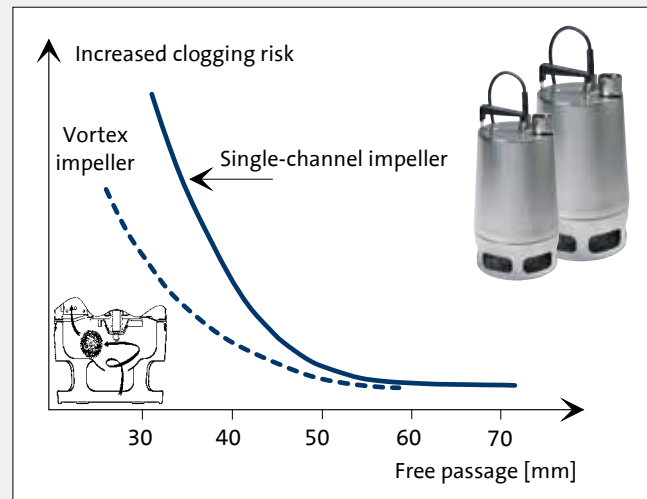


Fig.4 Diagram showing the relation between risk of clogging and dimension of free pump passage. Good protection against clogging is achieved with 35 mm free passage for transfer of effluent and 50 mm for residential sewage.

25 mm to 35 mm is the expected maximum particle size in pumped liquid with a moderate content of long fibres, for example human hair, pet hair, brushes and fibres from private and industrial washing machines.



Fig. 5

For portable use

The portable versions of Unilift AP 35, Unilift AP 50 Unilift AP 35 B and Unilift AP 50 B are usable for pumping at purification plants, pumping from septic tanks, rainwater pits along roads and other types of wastewater, except toilet waste from public buildings.

3.3. EFFLUENT PUMP FAILURE

Pump failure in effluent and residential sewage applications will normally cause great expense for considerable cleaning and disinfection before drying-out can take place.

If this is not acceptable, then to reduce the risk of clogging as much as possible, the installation should be upgraded to a sewage pump type or a grinder pump. This will increase both initial and operating costs of the pump by more than 60 %.

When discharge pipes from pumping stations are smaller than DN 80, or if the pump sump is very small, use grinder pumps for flows up to 7 l/s.

It is usually cost-effective to use sewage pumping equipment with either **SuperVortex** impellers or **S-tube®** impellers for effluent handling duty only when Q is > 10 l/s.

3.4. WASTEWATER WITH TOILET WASTE FROM INSIDE BUILDINGS

Lifting stations are all-in-one solutions designed for the collection and pumping of residential wastewater from selected sanitary appliances. These appliances may be in a single room, or on a complete floor.

Lifting stations are designed to be placed inside a building, and their discharge pipes connected to the wastewater collecting lines for the building. Lifting stations will be discussed in section 7.



Fig.6 Multilift station installed in basement, collecting and discharge wastewater from one toilet

3.5. SEWAGE AND SOLID PUMPING

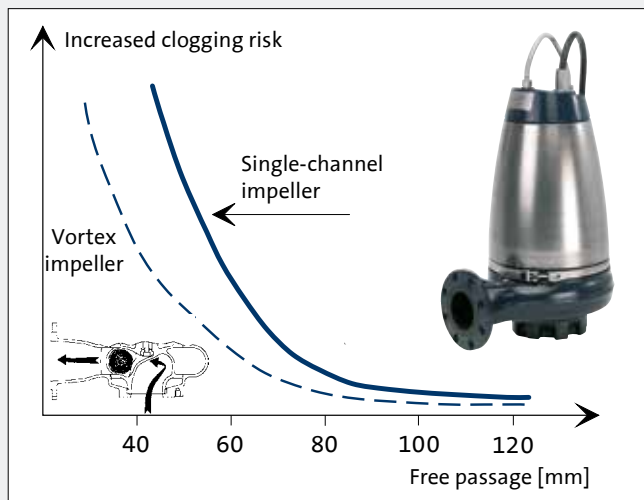


Fig. 7 Diagram showing the relation between risk of clogging and dimension of free pump passage. Good protection against clogging is achieved with 65 mm to 100 mm free passage for transfer of sewage with vortex impeller pumps and 75 mm to 160 mm free passage in S-tube® impeller pumps.

70 mm solids size must be expected in the pumped wastewater from public buildings, institutions, etc. with a high content of solids content such as, for example, children's shoes, toys, tooth brushes and tampons.

Where, particularly in southern Europe and the United States, water closet discharges are only 50 mm, it is possible to install 50 mm to 65 mm vortex pumps for residential sewage.

The Grundfos SuperVortex pumps are the ideal choice for applications which feature:

- Large quantities of solids
- Large quantities of fibres
- Gassy sludge
- Abrasives in the liquid

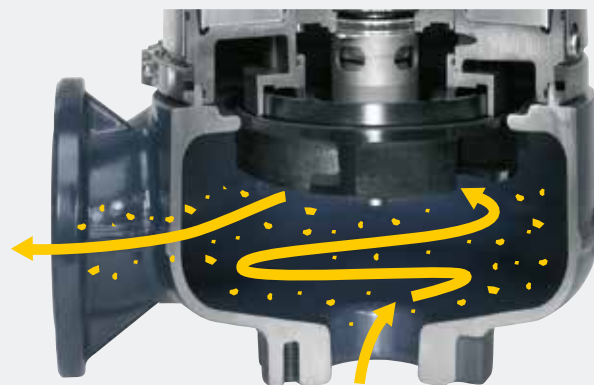


Fig. 8 Grundfos SuperVortex pump with 100 mm free passage in the pump housing. No liquid or solid is passing through the impeller.

Field of application

Designed for pumping in a municipal network pumping system and main pumping stations with discharge mains and sectional discharge systems including toilet connections and pumping in systems with unknown connections and discharges.

3.6. SEWAGE PUMP FAILURE

Pump failure in sewage applications may additionally result in evacuation and rehousing of people and storage of furniture and equipment for up to 30 days due to contamination risk.

If the risk of clogging is to be reduced as much as possible, the installation must be upgraded to a vortex pump with minimum 100 mm free passage. This will increase both initial and operating costs of the pump by more than 100 %.

It is usually cost-effective to upgrade to two-pump installation with either SuperVortex impeller pumps or S-tube® impeller pumps when Q is > 10 l/s. Municipal network pumping stations are normally furnished with two- or three-pump equipment for alternating operation where one pump is 100 % spare capacity.

4. Aspects of wear and tear in heavy duty pumping of mixed sewage

The impeller type with least wear and tear is the **SuperVortex**, shown in Fig. 9. The most energy efficient is the wet-balanced **S-tube®** impeller, which is a closed channel impeller. See Fig.10.



Fig. 9 **SuperVortex** impellers for 65 mm, 80 mm and 100 mm free passage in the pump housing.



Fig.10 **S-tube®** impeller in SL1 and SE1 pumps with stainless steel threaded sealing system mounted in the pump housing and impeller

Grundfos SL1 and SE1 pumps in the range from 9 kW to 26 kW are furnished with the **S-tube®** impeller without wear ring and seal ring. To maintain peak pumping efficiency after wear and tear, these pumps are equipped with the unique **SmartTrim** system for radial trimming of impeller clearance between the impeller and the pump housing. This is shown in Fig.11.

The **SmartTrim** system enables easy restoring to factory-set impeller clearance.



Fig.11 **S-tube®** impeller without wear ring and seal ring in pump housing with **SmartTrim** system.

Grundfos SEG and SEG **AUTOADAPT** pumps in the 1.5 kW to 4 kW range are supplied with semi-open impellers and grinder system. The grinder system will cut destructible items in the wastewater so it can be transported through small discharge pipes with a diameter down to 40 mm. To maintain peak pumping pressure, the impeller clearance is adjustable.



Fig. 12 Grinder system with stationary ring and grinding head.

5. Life cycle cost comparison

Life cycle costs (LCC) are in this case the costs estimated for investment, installation, commissioning, operation, maintenance, repair and power consumption, over the full life span and residual value at the end of ownership. The best balance among cost elements is achieved when the total LCC is minimised.

The following comparison of life cycle costs is between pumps with different types of impeller:

- **SuperVortex** impeller
- semi-open and single-channel impeller
- closed single-channel impeller with wear ring
- **S-tube®** single-channel impeller with **SmartTrim**

Q = 20 l/s = 72 m³/h at 12 m head.

Price per kWh: EUR 0.1

Pumped volume at intermittent operation: 108,000 m³ a year = 1,080,000 m³ over 10 years.

Life cycle costs (see Figs. 13 and 14)

Pos. 1 Investments

Pos. 2 Installation and commissioning costs

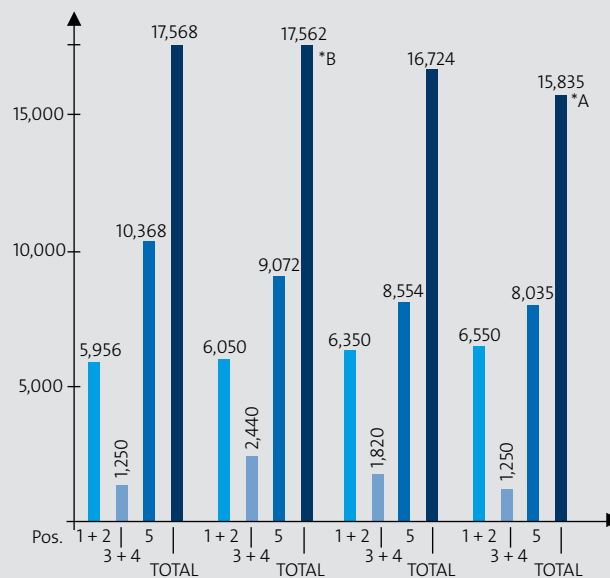
Pos. 3 Maintenance costs over 10 years for oil check, megging, trimming and replacement of shaft seals when leaking: EUR 1,250.

Pos. 4 Repair costs over 10 years

- **SuperVortex** impeller: no foreseeable costs
 - *Semi-open impeller*: 9 times dismantling of pump for impeller adjustment, one replacement of impeller and wear plate
 - *Closed impeller*: one replacement of wear ring
- **S-tube®** single-channel impeller with **SmartTrim**: no foreseeable cost as impeller trimming is performed from the outside in connection with oil check (see diagram).

Pos.5 Average power consumption:

Average Watt hour/m³/m head x capacity x head x 10 years x price per kWh



Column 1 = SuperVortex

Column 2 = Semi open and single channel impeller

Column 3 = Closed single channel impeller with wear ring

Column 4 = **S-tube** single channel impeller with **SmartTrim**

*A

The saving by using a 100 mm smart trimming impeller instead of a 100 mm SuperVortex impeller amounts to 11 %.

*B

The saving by using a 100 mm single-channel semi-open impeller running against a wear plate with cutting grooves compared with a 100 mm SuperVortex impeller amounts to less than 1%. This saving will seldom compensate for the increased clogging risk of the semi-open impeller.

Fig.13 Diagram for lifetime costs

Lifetime cost in euro of pumps with different impeller types

(see also Figs. 6 & 7)

	SuperVortex	Singlechannel, semi-open	Wear ring	S-tube® with SmartTrim
Pos. 1	3,400	3,500	3,800	4,000
Pos. 2	2,550	2,550	2,550	2,550
Pos. 3	1,250	1,250	1,250	1,250
Pos. 4	0	1,190	570	0
Pos. 5	10,368	9,072	8,554	8,035
Total	17,568	17,562	16,724	15,835

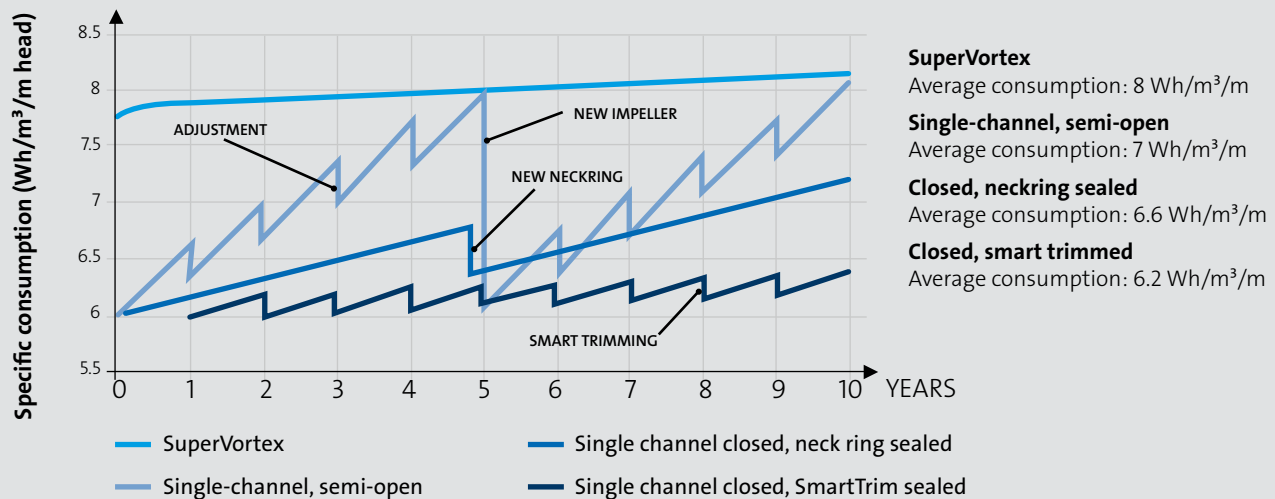


Fig.14 Power consumption per m³ raised one meter (kWh/m³/m head)

6. Inflow

Calculation of inflow to the pumping station in relatively large systems must be made by companies and/or persons who are insured against faulty estimates and calculations.

Calculation of inflow from smaller systems such as dwellings, office buildings, hospitals, hotels, restaurants and schools can be calculated by following the specifications below.

6.1. KEY FIGURES AND DIAGRAMS

A building's wastewater flow rate is calculated by using the flow rates of the wastewater discharge units (toilets, floor gullies, etc.) connected to the sewer system, by the number of discharge units, and by their frequency of use.

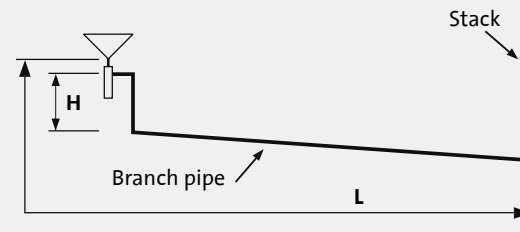
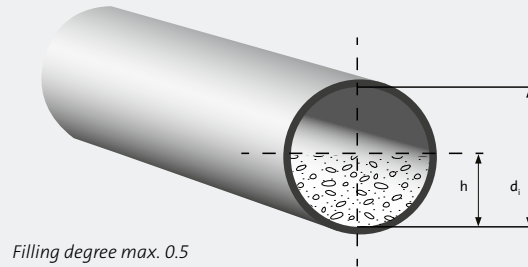
A wastewater system within a building may be designed in several ways according to national and/or local regulations and practices. EN standard 12056-2 offers four different system types with distinctive characteristics.

System type I:

Single discharge stack system with partially filled branch pipes for connection to sanitary appliances. The partially filled branch discharge pipes are designed with a filling degree of max. 0.5 and connected to a single discharge stack.

Characteristics and limitations for ventilated pipes, type I:

- Maximum length, $L = 10$ m
- Maximum drop, $H = 3$ m
- Minimum gradient 0.5 %
- Unlimited number of 90° bends



Sewage pipes within a building

System type II:

Single discharge stack system with partially filled branch pipes for connection to sanitary appliances. The partially filled branch discharge pipes are designed with a filling degree of max. 0.7 and are connected to a single discharge stack. In general, a type II system is characterised by having smaller pipe sizes and a larger minimum gradient than a type I system.

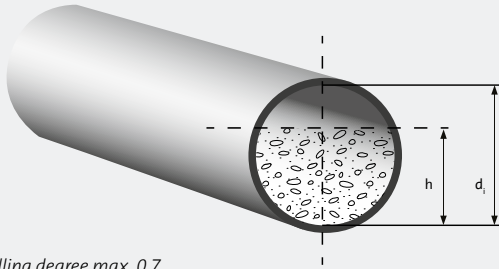
System type II is typically preferred in commercial buildings.

Limitations for ventilated pipes, type II:

- Unlimited length, L
- Maximum drop, $H = 3$ m
- Minimum gradient 1.5 %
- Unlimited number of 90° bends

Limitations for unventilated pipes, type II:

- Maximum length, $L = 10$ m
- Maximum drop, $H = 3/6$ m depending on size
- Minimum gradient 1.5 %
- No more than one 90° bend



Filling degree max. 0.7

System type III:

Single discharge stack system with filled branch pipes for connection to sanitary appliances. The filled branch discharge pipes are designed with a filling degree of 1.0 and are connected to a single discharge stack.

Type III limitations for both ventilated and unventilated pipes are numerous. For specification according to appliance type, see EN 12056-2.

System IV:

Here, systems of type I, II or III are divided into separate discharge stack systems for wastewater with discharge from toilets and urinals, and for wastewater without toilet waste. If wastewater without toilet waste and without drain from urinals in the building is collected and treated for reuse, the system will have to be designed according to type IV.

6.2. CALCULATING WASTEWATER FLOW RATE

Determining the flow rate from sanitary appliances is straightforward.

EN 12056-2 offers a table with typical flow rate values per appliance. Simultaneous discharge from appliances has to be predicted by means of statistical data, based on the building type, occupancy and likely usage pattern.

EN 12056-2 provides the following formula for the calculation

of real or expected flow rates in whole and partial sewage systems where only domestic sanitary appliances are connected.

$$Q_{ww} = K\sqrt{\Sigma DU} \quad \text{Where}$$

Q_{ww} = Wastewater flow rate (l/s)

K = Frequency factor

DU = Sum of water flow rate discharge units (l/s)

The frequency factor K is determined by consulting the table below. If the sewer system serves a multi-purpose building with varying occupancy patterns, each of these areas will have to be calculated separately with the appropriate factor K . The resulting flow values are then accumulated.

The total flow rate Q_{tot} , i.e. the design flow rate, is calculated from:

$$Q_{tot} = Q_{ww} + Q_c + Q_p \quad \text{Where}$$

Q_{tot} = Design flow rate (l/s)

Q^{ww} = Wastewater flow rate (l/s)

Q_c = Continuous flow rate (l/s)

Q_p = Pumped water flow rate (l/s)

Q_{tot} is the total flow rate from continuous, non-continuous and local pumping stations. Water flows from continuous appliances and local pumping stations connected to the system should not be reduced with a frequency factor.

Branch pipes, stack pipes and pumping stations should be sized on basis on the maximum flow rate Q_{max} , which is the larger of:

1. Q_{ww} (l/s)
2. Q_{tot} (l/s)
3. The highest flow rate of any appliance connected to the system (l/s) (see Discharge Unit table, next page)

Appliance / discharge unit	System I DU l/s	System II DU l/s	System III DU l/s	System IV DU l/s
Wash basin, bidet	0.5	0.3	0.3	0.3
Shower without plug	0.6	0.4	0.4	0.4
Shower with plug	0.8	0.5	1.3	0.5
Single urinal with cistern	0.8	0.5	0.4	0.5
Urinal with flushing valve	0.5	0.3	-	0.3
Slab urinal	0.2*	0.2*	0.2*	0.2*
Bath	0.8	0.6	1.3	0.5
Kitchen sink	0.8	0.6	1.3	0.5
Dishwasher (household)	0.8	0.6	0.2	0.5
Washing machine up to 6 kg	0.8	0.6	0.6	0.5
Washing machine up to 12 kg	1.5	1.2	1.2	1.0
WC with 4.0 l cistern	**	1.8	**	**
WC with 6.0 l cistern	2.0	1.8	1.2 to 1.7***	2.0
WC with 7.5 l cistern	2.0	1.8	1.4 to 1.8***	2.0
WC with 9.0 l cistern	2.5	2.0	1.6 to 2.0***	2.5
Floor gully DN 50	0.8	0.9	-	0.6
Floor gully DN 70	1.5	0.9	-	1.0
Floor gully DN 100	2.0	1.2	-	1.3

* per person, ** not permitted, *** depending upon type (valid for WC's with siphon flush cistern only)
- not used or no data

Fig. 15 Water flow rates for various types of discharge units (DU) according to EN 12056-2.

Usage of appliances	K
Intermittent use e.g., in dwelling, guesthouse, office	0.5
Frequent use e.g., in hospital, school, restaurant, hotel	0.7
Congested use e.g., in toilets and/or showers open to public	1.0
Special use e.g., laboratory	1.2

Fig. 16 Frequency factor according to the building type and use. According to EN 12056-2.

6.3. PRACTICAL EXAMPLE:

CALCULATION OF WASTEWATER FLOW RATE, Q_{TOT}

A hotel's sewer system is connected to the outside building main sewer system. Guest rooms and the restaurant are located above street level, causing wastewater from these facilities to gravitate to the sewer main in the nearby street.

Wastewater from all other facilities will have to be pumped to the sewer main, as they are located in the building's basement.

In this building, there are no sanitary installations supplying a continuous flow rate Q_c and there are other pumping stations. Hence, Q_p is not relevant. In this building the design flow rate Q_{tot} will be equal to Q_{ww} .

$$Q_{ww} = K \sqrt{\Sigma DU} = 0.7 \sqrt{28.9} = 3.76 \text{ l/s}$$

$$Q_{tot} = Q_{ww} + Q_c + Q_p = 3.76 + 0 + 0 = 3.76 \text{ l/s}$$

The required pump must be able to handle a flow rate of at least 3.76 l/s during operation.

Discharge unit (DU), System II	Amount pcs.	Water flow-rate, l/s	Total water flow-rate, l/s
Kitchen & staff facilities			
Dishwasher, large	1	1.2	1.2
Kitchen sinks	4	0.6	2.4
Floor gullies, DN 70	6	0.9	5.4
WC's	4	1.8	7.2
Showers	4	0.4	1.6
Guest rest room facilities			
WC's	5	1.8	9.0
Urinals	3	0.3	0.9
Wash basins	4	0.3	1.2
Sum, DU			28.9

Fig. 17 Number of discharge units and total wastewater flow rate

6.4. RAINWATER SYSTEMS

In most commercial buildings, rainwater will be discharged to a recipient. The need for pumping capacity will depend on how much of the naturally occurring rainwater there is take away by gravity or absorbed into the ground.

Rainwater run-off originates from precipitation or snowmelt from:

- Building facades
- Building rooftops
- Balconies
- Drives and sidewalks
- Grass lawns

Rainwater may contain sand, gravels, leaves and other dirt with solids. Rainwater may hold various pollutants as well. When run-off flows towards the sewer system, it can pick up different road contaminants, such as petroleum, tire waste, metal species, pesticides or fertilisers.

6.5. RAINWATER RUN-OFF FLOW RATE

Sizing and design of rainwater systems requires an assessment of the likely worst-case rainfall intensity, frequency and duration on buildings and the site.

The following tabulated values of typical rainwater intensities can be used in the planning of rainwater removal systems. **n** is the probability of a rainfall event with the same or higher intensity than the given intensity, **i**. If **n** is 1/2, a rainfall of the given intensity or higher is likely to occur once every two years. The table shown is based on many years of rainfall registration in Northern Europe. All intensities are based on a rainfall duration of 10 minutes.

Note:

Since rainfall events around the world may vary in intensity, duration and occurrence, rainwater systems should always be sized in accordance with national guidelines and legislation.

Run-off coefficient, **c**

The amount of run-off is dependent on the surface permeability and describes the amount of rainwater that appears as run-off in relation to the total rainwater amount.

$$c = \frac{\text{run-off amount}}{\text{rainfall amount}}$$

Examples of run-off coefficients, **c** according to surface type:

Unimproved areas	0.10 - 0.30
Residential areas	0.30 - 0.75
Lawns	0.05 - 0.35
Asphalt streets	0.70 - 0.95
Concrete streets	0.80 - 0.95
Brick streets	0.70 - 0.85
Playgrounds	0.20 - 0.35
Drives and walks	0.75 - 0.85
Roofs and facades	0.75 - 0.95

Application	n	Rainwater i l/sm ² (l/sha)
Separate systems: Where there is only a risk of inconvenience, e.g. flooding outside building	1	0.011 (110)
Common systems: Where there is only a risk of inconvenience, e.g. smell. Flooding is not acceptable	1	0.011 (110)
Where there is a risk of minor damage to buildings, furniture, machines or equipment. Resumption of normal service should be possible with ordinary cleaning and short-term drying.	1/2	0.014 (140)
Where there is a risk of severe damage to buildings, machines or equipment	1/10	0.023 (230)
Where there is a risk of accidents or health hazards to animals or human beings	~ 1	Maximum expected rainwater intensity to be used

Fig. 18 Run-off applications for rainwater

The total rainwater flow rate Q_r is calculated from:

$$Q_r = A \cdot i \cdot c \quad \text{where}$$

Q_r = Design flow rate (l/s)

A = Run-off area (m²)

i = Rainfall intensity (l/sm²)

c = Run-off coefficient (-)

6.6. EXAMPLE: CALCULATION OF RAINWATER RUN-OFF RATE

A rainwater system for a commercial building has to be designed. The building's roof is 460 m² and the facade area 3,000 m². The catchment is determined by reviewing the building(s) surface run-off areas and the site on which the property stands. Run-off coefficients are used to reduce the quantity, depending on the likely surface absorption:

Catchment areas

Horizontal area (roof(s)): 460 m²

Vertical area

(facade on one side): 3,000 m² 1/3 = 1,000 m²

Playground, gravel: 800 m²

Driveway, asphalt: 500 m²

Lawn: 1,500 m²

Rainwater intensity of 140 l/s/ha is used to prevent risk of minor building damage.

Total flow, $Q_r = A \cdot i \cdot c$

Roof 460 m² * 0.014 l/s m² * 0.95 = 6.1 l/s

Facade 1,000 m² * 0.014 l/s m² * 0.95 = 13.3 l/s

Playground 800 m² * 0.014 l/s m² * 0.35 = 3.9 l/s

Driveway 500 m² * 0.014 l/s m² * 0.85 = 6.0 l/s

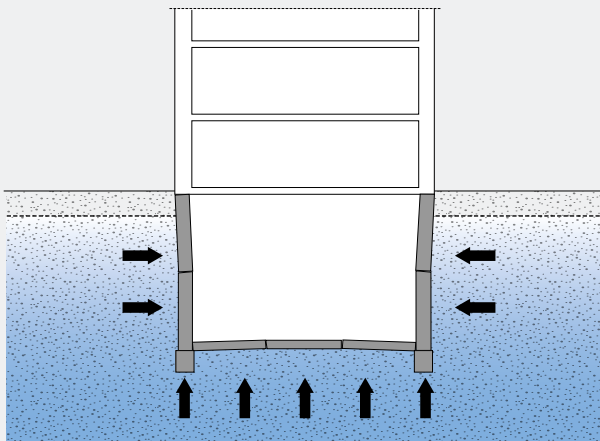
Lawn 1,500 m² * 0.014 l/s m² * 0.35 = 7.4 l/s

Rainwater flow rate, $Q_r = 36.7$ l/s

7. Water drainage of buildings and structures

Water drainage is applied to buildings and structures for a variety of purposes:

- Foundation draining to remove water that may damage buildings and interior: Water penetration might cause corrosion of steel reinforcements, and it can cause basement fungus in the building.
- Groundwater lowering in order to reduce or stabilise groundwater pressure: Reduced pressure on slabs and basement walls founded below groundwater level can prevent overall structural failure. Too high hydrostatic pressure can lift the whole building.
- Consolidation of soil. Water-saturated soil and backfill can be unstable and unsuited for construction. Water draining can improve the strength of the material.
- Soil conditions: Soil classification (clay, sand, silt etc.) and soil layer build-up, strength, permeability and capillarity.
- Groundwater level: Measurement of water table in primary and secondary aquifers should be conducted and seasonal variations predicted.
- Impact on soil and surroundings: Installation of drain systems will often impact the primary and secondary groundwater table, which can lead to terrain settlements and settlement of constructions. A reduced groundwater table will reduce soil saturation and may provoke decay in wooden constructions.
- Chemistry: Groundwater chemistry should be evaluated or analysed in relation to precipitation of unwanted limestone or iron ore. Precipitation of these two components can clog a draining system, while aggressive water can attack drainage systems and constructions.



Building exposed to hydrostatic water pressure

7.1. PRE-INVESTIGATIONS

Existing soil, future soil and groundwater conditions should be investigated thoroughly before construction. At minimum, the following parameters should be investigated:

7.2. CLASSIFICATION OF SOIL AND GROUNDWATER CONDITIONS

In order to determine whether a building or structure should be drained or not, and in order to calculate drainage water flows, groundwater and soil conditions should be categorised.

Note:

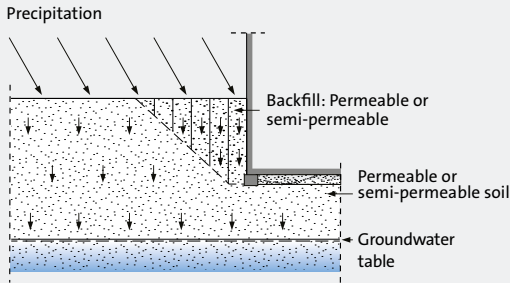
This chapter's drainage procedures are based on Danish standard DS436. Drainage of buildings and structures should always be based on local legislation and guidelines.

Note:

Artesian water is not discussed in this guide. Artesian water can occur where impermeable soils are found on top of permeable layers saturated with water.

Class 1:

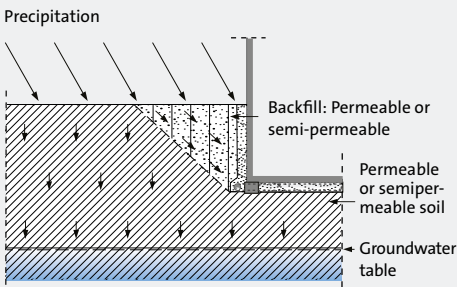
Sandy or other permeable soils with the groundwater table below drainage level. Drainage is not required. Seasonal variations in groundwater table are not predicted to increase to drainage level. Storm water or other surface water will soak vertically to the groundwater table.



Draining in sandy or very permeable soils where the groundwater table is below drainage level

Class 2:

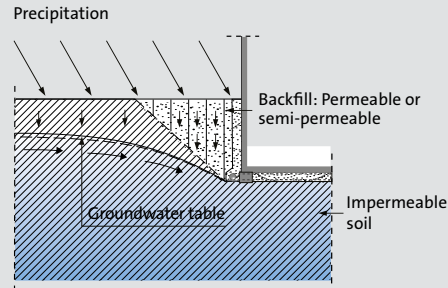
Impermeable soil with groundwater level below drainage level. Here, storm water from within the backfill area should be drained. Seasonal variations in groundwater table are not predicted to increase to drainage level. Storm water or other surface water will soak vertically to the groundwater table.



Draining in low-permeability soils where the groundwater table is below drainage level

Class 3:

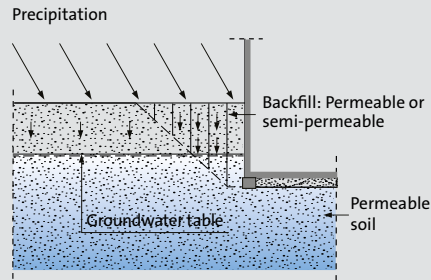
Low-permeability soil with groundwater level above drainage level. Here, groundwater draining will protect the building from hydrostatic water pressure. Storm water or other surface water will soak vertically to the groundwater table. Storm water from within the backfill area and intact soil should be drained.



Draining in low-permeability soils with groundwater table higher than drainage level

Class 4:

High-permeability soil with groundwater level above drainage level. Here, attempts to drain groundwater will result in very high drain water amounts. Furthermore, such attempts will lead to a general lowering of the groundwater table, which may damage surrounding constructions. In this case, groundwater draining cannot be carried out. Here, the building must be water tight, sufficiently anchored to avoid lift and reinforced to withstand hydrostatic water pressure. Storm water or other surface water will soak vertically to the groundwater table.



Draining in low-permeability soils with groundwater table higher than drainage level

Soil type	Water velocity	Coefficiency of permeability, k (m/s)
• Clean gravel	Rapid	-10
• Clean sands • Clean sands and gravel mixtures		-10 ⁻¹ -10 ⁻²
• Very fine sands • Organic and in-organic silts • Mixtures of sand, silt and clay • Stratified deposits, etc.	Moderate	-10 ⁻³ -10 ⁻⁴ -10 ⁻⁵
• Stratified soils, eg. homogeneous clays below the weathering zone		-10 ⁻⁶ -10 ⁻⁷ -10 ⁻⁸
	Slow	-10 ⁻⁹ -10 ⁻¹⁰ -10 ⁻¹¹

Coefficients of permeability, depending on soil type

8. Drain water flow rate

The drain water flow rate should be estimated before the design of drainage system and sizing of pumps. Compared to rainwater flow rates, drain water flow rates are usually modest.

Walls:

Class 1: Typically not drained

Class 2: Water flow rate per sq. meter wall:

$$q = 0.01 - 0.03 \text{ l/s m}^2$$

Class 3: Water flow rate per sq. meter wall:

$$q = 0.03 - 0.1 \text{ l/s m}^2$$

Class 4: Typically not drained

Floors:

Class 3: Water flow rate per sq. meter floor:

$$q = 0.001 - 0.005 \text{ l/s m}^2$$

Class 4: Typically not drained

Note:

Water flow rates per m^2 wall or floor are estimated on the basis of climate conditions with moderate precipitation intensities, frequencies and duration. Drain water flow rates should always be based on national guidelines and legislation.

The drain water flow rate, Q_d is calculated from:

$$\text{Drain water flow rate, } Q_d = A \cdot q$$
$$Q_d = A \cdot q \quad \text{where}$$

Q_d = Drain water flow rate (l/s)

A = Wall or floor area (m^2)

q = Water flow rate per m^2 , wall or floor

8.1. EXAMPLE: CALCULATION OF DRAIN WATER FLOW RATE

A commercial building is in the design phase. Groundwater and soil conditions have been investigated and the building will need a drainage system around its perimeter and under the basement floor.

Building dimensions:

Basement height: 4 m

Basement length: 40 m

Basement width: 20 m

The building soil is impermeable and the groundwater table is higher than the drainage level, making this a class 3 building.

$$\text{Walls: } 2 (20 \text{ m} + 40 \text{ m}) 4 \text{ m } 0.06 \text{ l/s m}^2 = 28.8 \text{ l/s}$$

$$\text{Floor: } 20 \text{ m } 40 \text{ m } 0.003 \text{ l/s m}^2 = 2.4 \text{ l/s}$$

$$\text{Drain water flow rate, } Q_d = 31.2 \text{ l/s}$$

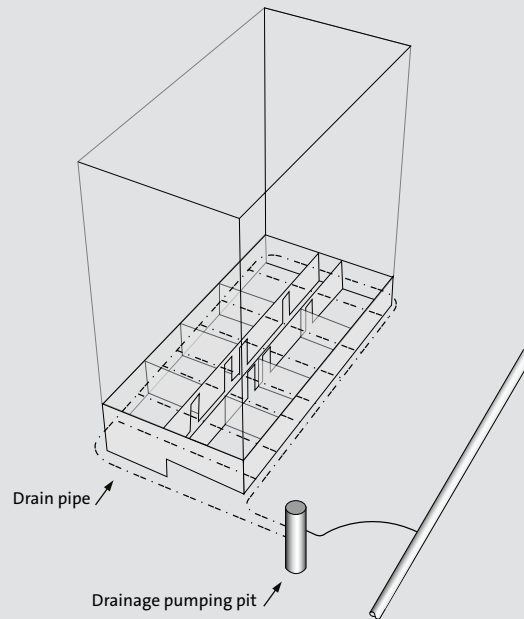


Fig. 19 Drainage pipe around a building with basement, leading the drain water to the pump pit.

9. Calculating the pump capacity

Calculation of the capacity of the pump system depends very much on inflow and variations of this, which should be carefully estimated.

The amount of inflow will fluctuate from day to night and from one day to another. Especially the inflow from run-off rainwater (**surface water**) gives strong fluctuations while the inflow of **sewage** and **drain water** follows a more regular movement.

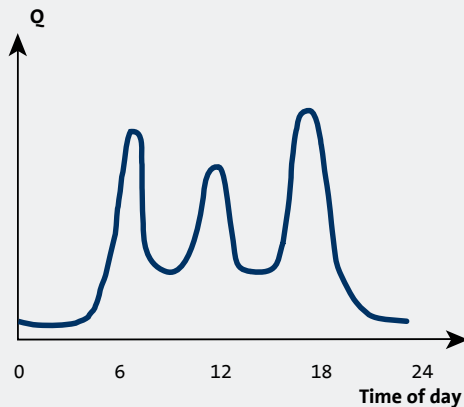


Fig. 20 Typical discharge pattern for wastewater with toilet waste where the peak inflow is late in the afternoon.

The amount of inflow from single-family and semi-detached houses is usually so small that it is the self-cleaning ability of the vertical discharge pipe in the pit and the horizontal discharge pipe in the ground which determines the required capacity of the pump system.

Inflow typically consists of one or more of the following types of wastewater as elaborated above:

- Wastewater from buildings (with toilet waste)
- Rainwater
- Drain and infiltration water

10. Rated inflow in combined systems

In combined systems the different types of wastewater are drained of in the same discharge system.



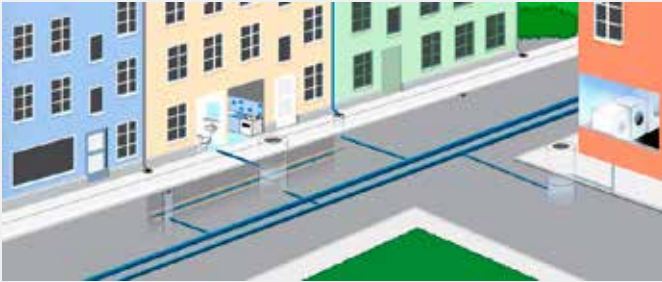
The rated discharge (Q_{tot}) can be calculated like this:

- Wastewater flow rate, (with toilet waste) Q_{ww}
- Rainwater flow rate, Q_r
- Drain water flow rate, Q_d

$$Q_{tot} = Q_{ww} + Q_r + Q_d \text{ (l/s)}$$

11. Rated inflow in separate systems

In a separated system, rainwater will be drained off in its own discharge pipe and wastewater with toilet waste together with effluent in another discharge pipe.



The rated discharge flow in separate systems is calculated like this:

$$Q_{ww} \text{ in wastewater pipes (l/s)}$$

$$Q_r = Q_r + Q_d \text{ in rainwater pipes (l/s)}$$

When dimensioning pipes transporting both pumped and un-pumped water, the probability of simultaneously occurring peak water flows must be taken into consideration. Because of this it may be necessary to minimise the rated discharge flow by increasing the accumulation capacity in the pump sump. If a gravitational pipe transports pumped water, the self-cleansing gradient can be reduced, based on the rated discharge flow.



Fig.21 Unilift KP, Unilift AP and heavy-duty DP10.
Typical pumps for drain water applications



Fig.22 Unilift AP35, Unilift AP35B and EF 30
Typical pumps for effluent applications

If the required pump capacity is more than the performance of the above listed drainage pumps and effluent pumps, a sewage pump with a bigger motor should be used. A sewage pump can be used for pumping drainage, effluent and sewage, but a drainage and effluent pump cannot pump sewage due to the small free passage.



Fig. 23 Unilift AP50, Unilift AP50B in stainless steel and SLV.50 and SLV.65 pumps
in cast iron. Typical pump for transfer wastewater with toilet waste from private households



Fig. 24 SL1. and SLV. pumps with either S-tube® impeller or Super-Vortex impeller
Typical pumps for transfer unscreened wastewater with toilet waste from commercial buildings and small municipal pumping stations.



Fig. 25 SE1 and SEV pumps with either S-tube® impeller or SuperVortex impeller
Typical pumps for transfer unscreened wastewater with toilet waste from commercial buildings and small municipal pumping stations.



Fig. 26 Unilift AP35B, Unilift AP50B, EF30, SL1.50 and larger sewage pumps can be installed on auto-coupling system with guide rails.
More about auto-couplings in section 3.

12. Pumps and Performance

Grundfos submersible wastewater pumps are compact units with integrated hydraulics and motor. They operate directly in the liquid being pumped. Operating submerged, they take up less space, and noise and cooling problems are virtually eliminated.

Lifting stations are non-submersible units with compact integrated hydraulics, submersible motor, collecting tank and controller for collecting and removing wastewater from inside buildings. Operating dry installed, these compact lifting stations take up a limited space, and noise and cooling problems are virtually eliminated.

This series of pumps has an extensive performance range and can be used in a variety of applications. Pump performance data are for 50 Hz pumps.

12.1. LIGHT-DUTY PUMPS

12.1.1. UNILIFT KP



Residential drainage pumps in stainless steel for solids up to 10 mm.

Head max: 7.7 m
Liquid temperature: 0° C - 50° C
Max flow: 4.17 l/s

12.1.2. UNILIFT AP



Residential drainage, effluent and residential sewage pumps in stainless steel for solids up to 50 mm.

Head max: 15.8 m
Liquid temperature: 0° C - 55° C
Max flow: 9.44 l/s

12.1.3. DP10, EF30, SL1.50 AND SLV.65

Residential and industrial drainage, effluent and sewage pumps in cast iron for solids from 10 mm (0.39 inches) to 65 mm.

12.1.4. DP10



Head max: 23.47 m (77 ft)
Liquid temperature: 0° C - 40° C
Max flow: 13.6 l/s

12.1.5. EF30

Head max: 15.05 m
 Liquid temperature: 0° C - 40° C
 Max flow: 12.2 l/s

12.1.6. SL1.50 AND SE1.50

SE pumps with stainless steel motor jacket can operate in submerged or dry installed applications.



Head max: 33 m
 Liquid temperature: 0° C - 40° C
 Max flow: 27 l/s

12.1.7. SLV.65 AND SEV.65

Head max: 29.5 m
 Liquid temperature: 0° C - 40° C
 Max flow: 12.2 l/s

12.1.8. SEG.40 AND SEG.50

Residential and municipal, effluent and sewage pumps in cast iron with grinder system in front of inlet to the pump.



Head max: 42.9 m
 Liquid temperature: 0° C - 40° C
 Max flow: 5.2 l/s

12.2. MIDDLE-DUTY PUMPS

Municipal and industrial sewage pumps in cast iron for submersible or dry-pit installation. Hydraulics with 75 mm to 160 mm free passage and discharge flanges DN 80 to DN 300.

12.2.1. SL1.80 ...100 AND SE1.80 ...100

1.5 kW to 7.5 kW



Head max: 24.5 m
Liquid temperature: 0° C - 40° C
Max flow: 85 l/s

12.2.2. SLV.80 ...100 AND SEV.80 ...100

1.1 kW to 11 kW



Head max: 44.8 m
Liquid temperature: 0° C - 40° C
Max flow: 40 l/s

12.2.3. SL1.75 ...160 AND SE1.75 ...160

13 kW to 26.5 kW



Head max: 52 m
Liquid temperature: 0° C - 40° C
Max flow: 278 l/s

12.2.4. SLV.80 AND SEV.80

13 kW to 26.5 kW



Head max: 71.5 m
Liquid temperature: 0° C - 40° C
Max flow: 50.2 l/s

12.3. MULTILIFT LIFTING STATIONS

Multilift lifting stations are all-in-one solutions for dry installation, with collecting tanks, pumps and controller for collection and pumping of wastewater from residential and multi-family houses from selected sanitary appliances. Multilift lifting stations come with either vortex impeller pumps, channel impeller pumps or grinder pumps.

12.3.1. MULTILIFT MSS, M AND MOG WITH ONE PUMP



Head max: 46 m
Liquid temperature: 0° C - 40° C
Max flow: 8 l/s

12.3.2. MULTILIFT MC, MLD AND MDG WITH TWO PUMPS



Head max: 46 m
Liquid temperature: 0° C - 40° C
Max flow: 16.5 l/s

12.3.3. MULTILIFT MD1 AND MDV DUPLEX UNITS WITH TWO PUMPS



Head max: 24.5 m
Liquid temperature: 0° C - 40° C
Max flow: 28 l/s

12.4. HEAVY-DUTY PUMPS

Municipal and industrial sewage pumps in cast iron for submersible or dry-pit installation. Hydraulics with 1, 2, 3 or 4 channel impeller and discharge flanges DN 150 to DN 800.

Head max: 110.6 m
Liquid temperature: 0° C - 40° C
Max flow: 2400 l/s

Heavy-duty submersible and larger dry-pit sewage pumps is discussed in Wastewater Engineering Manual 2.





[2]

SIZING OF PUMPS

1. Calculation of capacity and number of pumps and duty mode

The capacity of the pump system is calculated in such a way that it exceeds the maximum inflow, normally using the factor 1.05. The additional capacity depends on the accuracy of the calculation of inflow.

Furthermore, compensation for wear and capacity tolerances must be taken into consideration for flow, head and power for mass produced pumps, according to DIN standard ISO 9906:2012, Grade 3B.

For small systems, for example single-family houses, semi-detached houses and so on, where wastewater with toilet waste is pumped, the self-cleaning ability of the riser main will often determine the minimum pump capacity:

	l/s
DN 50 / 2"	2.2
DN 65 / 2.5"	3.3
DN 80 / 3"	4.2
DN 100 / 4"	7.0

Fig. 1 Self-cleaning effect of the pipe system is obtained with a minimum velocity of 1 m/s in vertical pipes and 0.7 m/s in horizontal pipes

The above figures are **independent of inflow**.

1.2. SMALL PUMP SYSTEMS

In the case of light-duty pump systems (1 to 2.2 l/s) for wastewater including drainage and rainwater only, maximum pump capacity is set to be equal to the maximum inflow that the pipes and sump can accumulate. In such pump systems, it is common to use simplex-pump operation.

1.3. VARIATION OF INFLOW

Depending on the size and variation of the inflow and the degree of inconvenience in case of pump failure, it may be a good idea to split up the capacity between two or more pumps.

The amount of inflow will fluctuate from day to night and from one day to another. Especially the inflow from run-off rainwater (surface water) gives strong fluctuations, while the inflow of sewage and drain water follows a more regular movement. See Fig. 2.

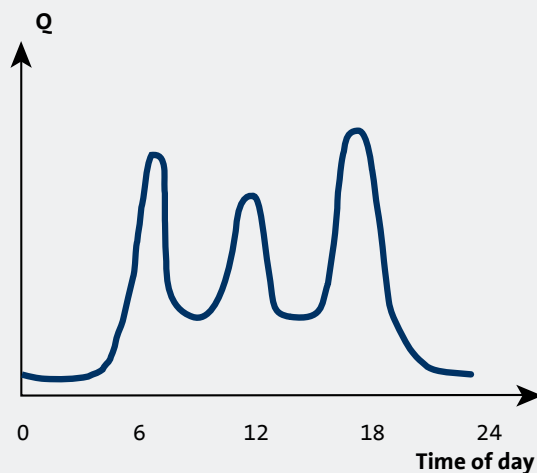


Fig. 2 Typical discharge pattern for wastewater with toilet waste.

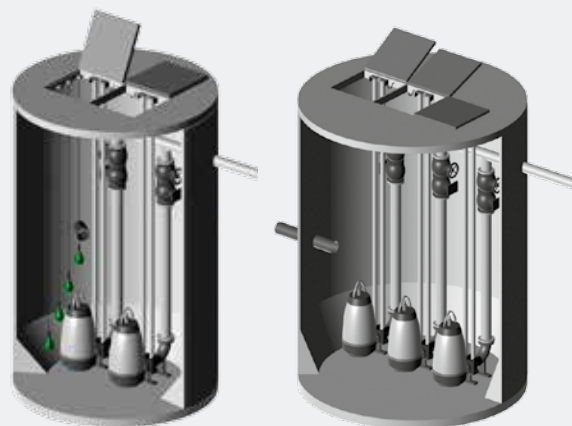


Fig. 3 Two and three pump installation of submersible sewage pumps on auto-coupling with guide rails.

When dimensioning the pumping station, it must be considered which type of discharge system is used. Especially for separate systems, the rainfall and the run-off surface water must be known, because there can be big variations from area to area.

For light-duty pump systems it is common to use one pump for the full discharge. Middle-duty pumps are in some cases also used as a one-pump installation, but it is more normal to have two identical pumps operating in alternating operation, where one pump is 100 % spare capacity.

The decision of the need for spare capacity must be based on the consequences of one pump being out of operation, but in commercial building services and municipal installation two or more installed pumps is the most common.

2. Discharge systems

In the combined system where rainwater, effluent and sewage drains off in the same discharge pipe, the inflow to the pit will not only fluctuate between day and night, but also between summer and winter. In this case, two, three or more similar pumps could be installed and operate in parallel to secure the necessary pump capacity in heavy rainfall. It is possible to have a group of pumps dimensioned for the inflow in the dry season and another group of larger pumps to operate when the majority of the inflow is rainwater.



Fig. 4 Combined system for sewage, effluent and rainwater.

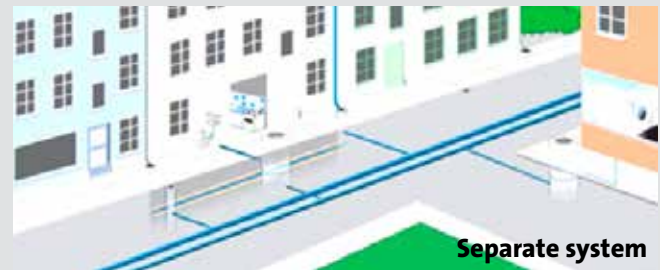


Fig. 5 Separate system where rainwater drains off in its own discharge pipe and effluent and sewage in another discharge pipe.

3. Alternating operation and parallel operation

3.1. ALTERNATING OPERATION

When two pumps alternate in operation there will be a uniform wear of the pumps and possibility for constant check of operational availability. The two pumps are identical, each with a capacity of 1.05 times the maximum incoming flow according to the discharge pattern where the peak load is in the late afternoon.

The inflow to the pit is coming from a system where sewage and effluent drains into the same pipe. Rainwater drains into a separate pipe.

In Fig. 6, there are four level sensors in the pit to operate the pumping station with two pumps. Pump A and pump B.

- Sensor 1: Stop level
- Sensor 2: Start level 1
- Sensor 3: High water alarm level
- Sensor 4: Start level 2

The lowest hanging sensor number 1 is a stop sensor for both pumps. Sensor number 2 will start pump A and it will operate until the water level have reached the stop level. The controller will switch to pump B and it will start next time the water level has increased to the start level.

The volume between sensor 1 and sensor 2 is the effective sump volume.

Sensor number 3 is the alarm sensor for high water alarm. If one pump fails to start, the water level will increase to the alarm level and the controller will send an alarm to the person in charge of the pumping station.

The water level will increase further to level sensor number 4 and it will start the stand-by pump. In this case, the system has 100 % spare pump capacity.

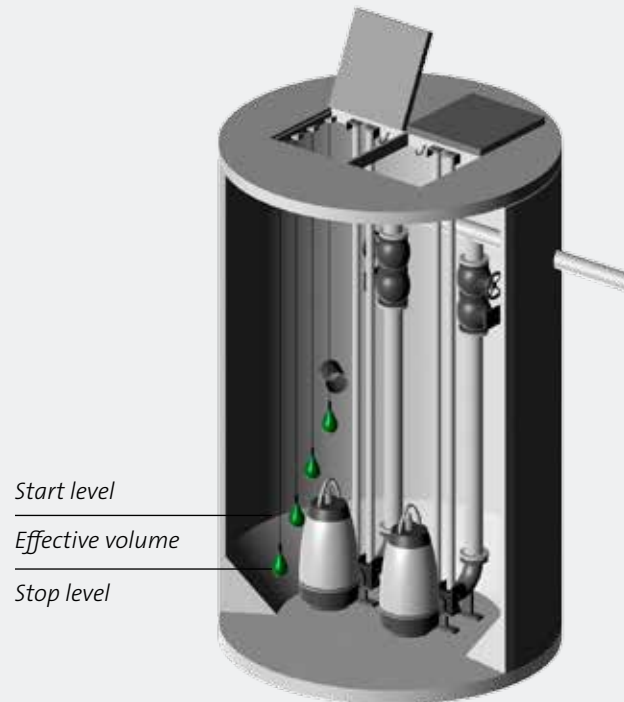


Fig. 6 Two pump installation with four level sensors

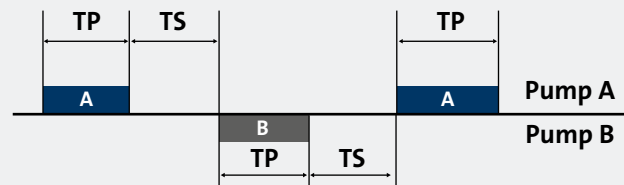


Fig. 7 Two pumps in alternating operation where the incoming flow is less than the capacity of one pump.

- TP is pumping time
- TS is stopping time
- TP + TS is the pumping cycle time

3.2. PARALLEL OPERATION

Parallel duty mode can also ensure uniform wear of the pumps. The two pumps are identical, with a total capacity in parallel operation of 1.05 times the maximum incoming flow according to national guidelines and legislation.

The inflow to the pit is coming from a combined system for sewage, effluent and rainwater.

As for the alternating operation there are four level sensors in the pit:

- Sensor 1: Stop level
- Sensor 2: Start level 1
- Sensor 3: Start level 2
- Sensor 4: High water alarm level

In daily operation, pump A and pump B will alternate as described above. In rainy weather, the inflow to the pit could be more than the capacity of one pump and, even though the pump is operating, the water level will still rise. When the water level reaches level sensor 3 the stand-by pump will start and the two pumps will operate in parallel down to the common stop level.

If one pump fails and the inflow to the pit is less than the capacity of one pump, there will only be an alarm when the water level increases to level sensor 4, meaning only one pump is available in the system. In this case, an additional alarm indicator should be added to the controller, to send an alarm if one of the pumps fails to start while the pumps are in alternating mode.

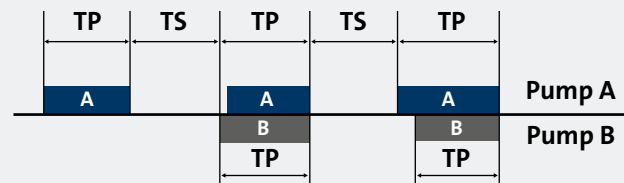


Fig. 8 Two pumps in alternating and parallel operation where the incoming flow can be more than the capacity of one pump.

- TP is pumping time
- TS is stopping time
- TP + TS is the pumping cycle time

In parallel operation, it is not unusual to have a third pump – a spare pump – and a fifth sensor that is placed above the alarm sensor. Should pump 1 or 2 fail there will then be a backup to avoid flooding.

3.3. SINGLE PUMP OPERATION

If a pumping station serves only a few households, the inflow is often limited and a single pump will be enough to deliver the appropriate capacity. The pump capacity selected must, however, be much larger than the inflow to effectively prevent sedimentation in the pressure pipe by maintaining the necessary high velocity.

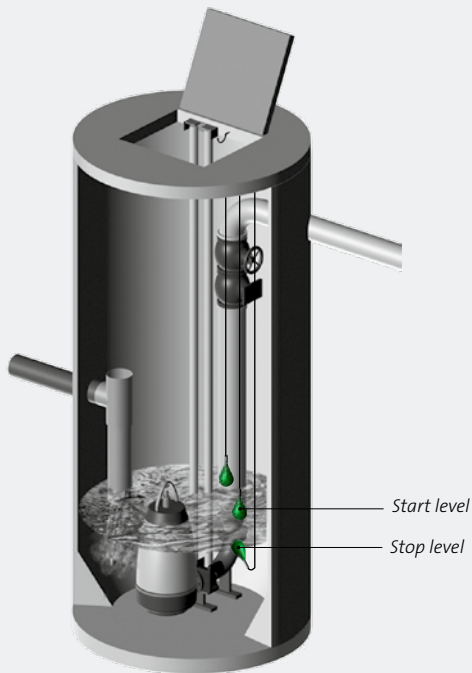


Fig. 9 One pump installation where the incoming flow is less than the capacity of the pump.

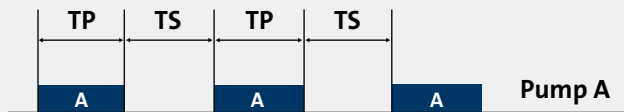


Fig. 10 The operation procedure for one pump operation.

- TP is pumping time
- TS is stopping time
- TP + TS is the pumping cycle time

In the examples above, float switches are used as level sensors but it could also have been a pressure transducer, an ultrasonic sensor or electrodes, and such like.

4. Pump durability

The service life of a pump is the number of hours of operation, or in the case of low usage, the time elapsed since the previous overhaul or check-up. At each overhaul, bearings and other wear parts, cables and barrier oil may have to be checked or replaced, but the pump remains fundamentally the same.

Typical pump service life is between 200 and 2000 hours of operation depending on pump type and application. Drainage, effluent and sewage pumps need periodic checks, as the operating conditions are often tough.

The frequency for checks depends on the specific application and the liquid type. In the warranty period, it will often be every 2,000 hours of operation or at least once a year. At the check-up, damaged or worn components are replaced. It is recommended to follow the guidance written in the Installation and Operation Instruction for the specific pump to avoid unscheduled break down of the pumps.

If properly serviced, the pump may last for 10 years or more, equal to 20,000 hours' operation. However, the durability of the pump is affected by several factors:

1. Abrasive liquids (Page 45, part 5.)
2. Impeller type (Page 46, part 5.4)
3. Corrosive liquids (Page 47, part 6.)
4. Cavitation (Page 135, section 9.)

5. Abrasive liquids

If a standard sewage content existed, it would contain approx. 0.005 vol. percentage of sand and silt. Sand content is expressed as either a percentage by volume (pv) or by weight (pm).

The relation between the two is:

$$P_m \sim 3 \times P_v$$

with sand density estimated at 3,000 kg/m³

This means that if pv is 0.005 %, pm will be 0.015 %. For sewage with this content, any type of wastewater pump and any material could be used.

For certain periods, however, the sand content may be much higher, for example following heavy rainfall or when snow melts. It may be up to 1,000 times higher for several hours. The amount of sand carried into parts of a sewage system by infiltration of drain water or groundwater may be so high as to cause extensive pump wear.

Factors that affect the wear of the pump are:

1. Sand content
2. Shape of sand grains
3. Pump material
4. Impeller type
5. Pump head

5.1. SAND CONTENT

Often a sand problem can be traced to a hillside with extensive erosion during heavy rainfall. Rapidly flowing rainwater runoff carries large quantities of humus, sand and silt to roadside gullies and so to the collecting pit. From here, the water is transferred from pumping station to pumping station until trapped at the inlet of the treatment plant. All the way through the sewer system, the sand will cause trouble. The sand may also come from a construction site, discharged directly into the sewage system. To reduce the worst problems, there should be a runoff barrier with sand trap or settling basin before the wastewater is led into the sewage system.

Sometimes a sand problem can be traced to an old or incorrectly dimensioned section of the sewage system with collapsed or leaky joints. When it rains, infiltration of water will carry sand and silt into the sewage system. In such cases, the sewage pipe section should be relined or replaced. Generally, such problems are best solved by trapping and retaining the sand before it reaches the first pumping station; this is usually the most economical solution.

5.2. SHAPE OF SAND GRAINS

Depending on the shape and sharpness of the grains, pump lifetime may be much reduced do to wear.

5.3. PUMP MATERIAL

When pumping abrasive liquids, one way of minimising wear (for example) of the hydraulic components and thereby extending pump lifetime is to select a pump with hardened stainless steel impeller and rubber-coated diffuser. Grundfos DW (dewatering) contractor pumps are of this type. As an alternative to the costly change in material, a protective coating like Belzona, and such like could be considered for cast iron parts.

5.4. IMPELLER TYPE

Often a good way of solving a sand wear problem is to use a pump with a SuperVortex impeller instead of a pump with a single-channel impeller, S-tube impeller and closed impellers in general.

Grundfos SL pumps, SE pumps and S pumps with SuperVortex impellers will pump most of the sand along the pump housing until it is discharged. This reduces wear on the impeller and the mechanical shaft seal. The price for the improved durability is an increased power consumption of approximately 20 %.

5.5. PUMP HEAD

In case of severe sand problems, a change in the discharge pipe system may be considered to reduce the head requirement and to introduce a sand trap. As pump head and velocity through the impeller are related, a lowering of the required head will give longer pump life.

Changing to a pump type with the same flow, but with a lower discharge head, will usually extend service life at the same sand content.



Fig. 11 Grinder pump with grinder system and impeller after one year of operation in an application with sand problems.

6. Corrosive liquids

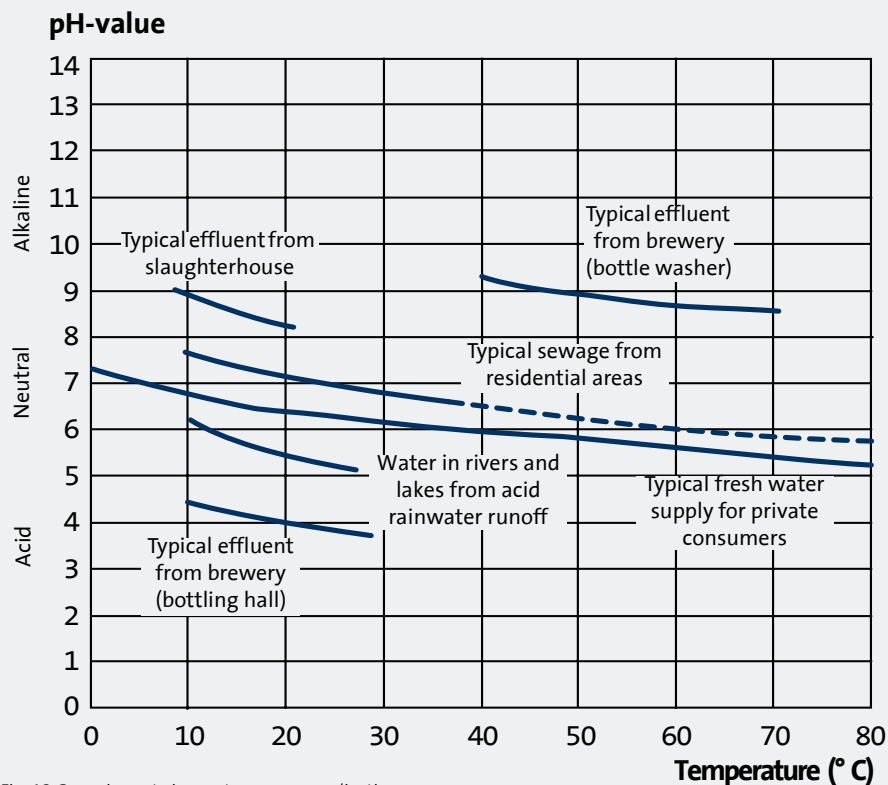


Fig. 12 Corrosion rate in most common applications

The corrosion rate depends on many factors, e.g. pH, temperature, and content of salt and metal ions.

Relation between choice of material and service life		
Material	Reduced service life	Acceptable service life
Cast iron	pH < 6.5	pH > 6.5
Epoxy lining (200 microns) or cathodically protected cast iron	pH < 5	pH > 5
Bronze	pH > 8.5	pH < 8.5
Stainless steel, W.nr. 1.4301	pH < 3	pH > 3
Cathodically protected stainless steel	pH < 1	pH > 1

Fig. 13 Acidity of various effluent types

The above graph and table shows that cast iron components have an acceptable service life in “ordinary” sewage at low temperatures. The service life of cast iron can be extended by introducing a coating (e.g. of epoxy) and on top of that a layer of wear resistant paint, at least 200 microns thick. To match this increased protection of cast iron components, fabricated steel parts and steel pipes should be hot-dip galvanised.

Bronze should only be considered at a pH value lower than 8.5.

For acid rainwater runoff and hot industrial effluents, the corrosion resistance of cast iron may not be sufficient, especially for components subject to high flow velocities, such as impellers and pump housings. In these applications, the coating and protective natural layer of rust may be eroded, leading to rapid corrosion. Here stainless steel will be the obvious choice to get acceptable service life.

Because of the risk of corrosion, aluminium should only be used for stator housings on portable lightweight contractor pumps.

Submersible pumps made entirely of high-grade stainless steel, protected by an epoxy coating and zinc anodes, are the natural choice for seawater and highly corrosive liquids such as hot industrial process water.

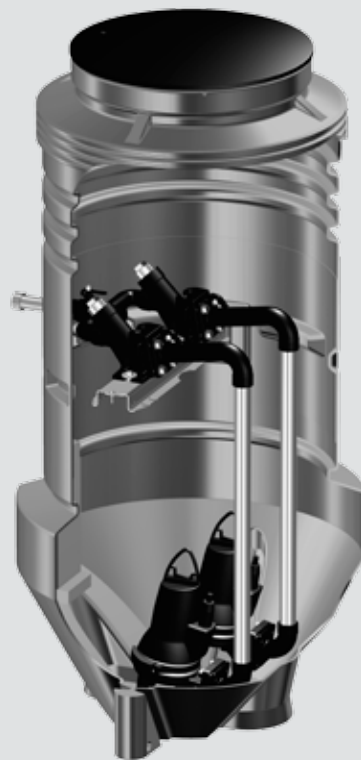


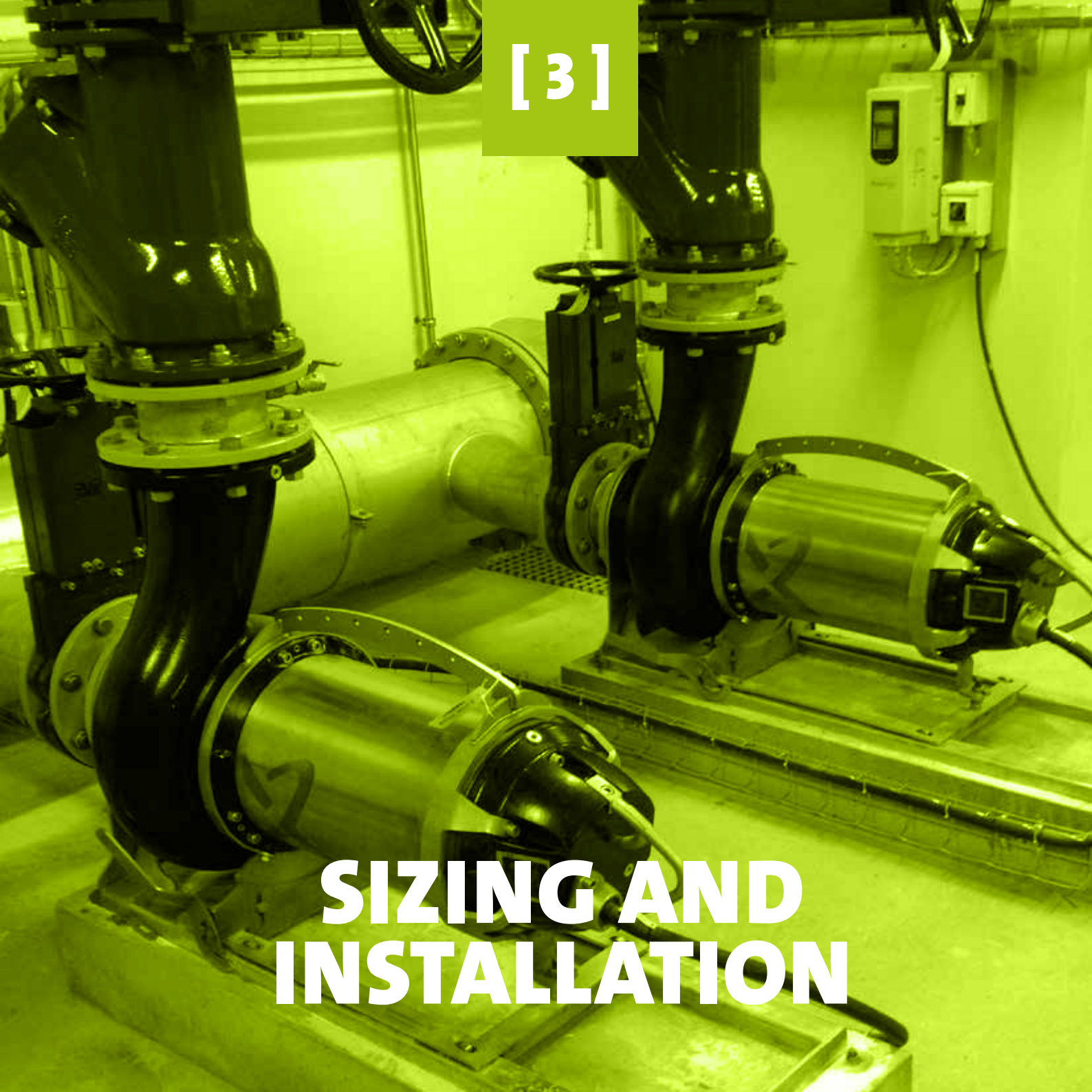
Fig. 14 The best installation design for highly corrosive liquids. Any sealing defects are easily detected when the pump is pulled up for service as all piping and gaskets are out of the water.



Fig. 15 For larger flow of highly corrosive liquids, the right choice is a complete stainless steel submersible sewage pump and auto-coupling with stainless steel guide rails and upper guide rail folder.

[3]

SIZING AND INSTALLATION



1. Sizing and installation of pumps

When the number of pumps and any split of duty is decided, the next consideration is the type of installation:

- Submersible free-standing installation
- Submersible installation on auto-coupling
- Vertical or horizontal dry-installation

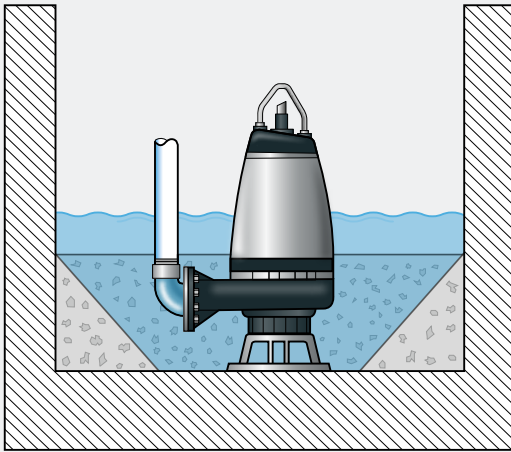


Fig. 1 Submersible freestanding installation where the pump rests on a ring-stand

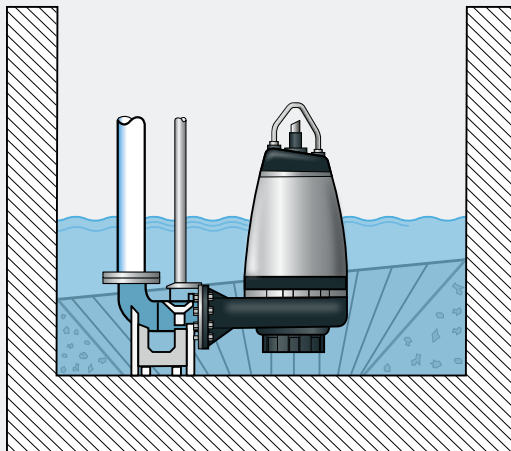


Fig. 2 Submersible installation on auto-coupling with guide rails

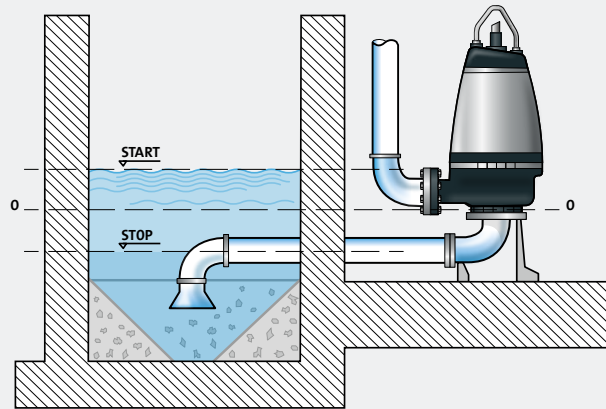


Fig. 3 Submersible vertical dry installation with base-stand for fixing to the foundation

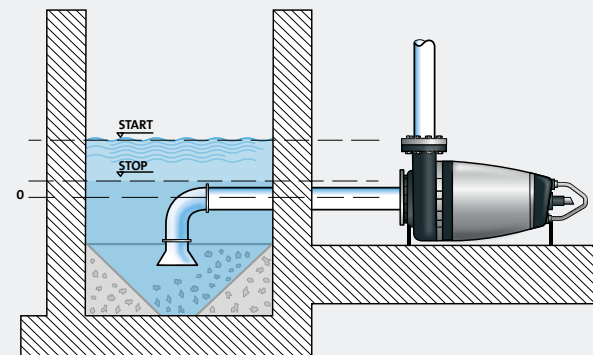


Fig. 4 Submersible horizontal dry installation with brackets for fixing to the foundation

When the type of installation is decided, the pipe layout can be determined. The following should be considered:

- Type and position of fittings on internal and external discharge pipes
- Flanges and unions
- Isolating and non-return valves
- Bends, manifolds and branching
- Pipe reductions and expansions
- Cleaning and inspection sockets
- Air vent
- Flow meters or volumetric flow test equipment
- Adaptors and compensators
- Draining and pressure gauge sockets

The pipe layout should be made as simple as possible but still with consideration to minimum and maximum velocity, optimised flow conditions and in such a way that it does not make access difficult for inspection, maintenance and replacement.

Each pump is fitted with its own vertical discharge pipe, which can either have a gooseneck or non-return valve with an isolating valve to prevent backflow. For dry installed pumps, the suction pipe should have an isolating valve.

The discharge pipe can be connected directly to separate external discharge pipes or to a manifold, which itself is connected to a common external discharge pipe outside the pump pit.

For very small pump systems, where backflow does not occur, valves can be left out and be replaced by a vented pipe, placed above the discharge level so that the pipe below the vent is self-evacuating. This will clean the impeller of any rags or other solids when the pump is stopped, and the water in the vertical discharge pipe backflushes the hydraulic part of the pump. The backflush will also help to keep the bottom part of the pit clean.



Fig. 5 Layout of simple pump installation with gooseneck and airvent.

The internal discharge pipes should be made of a material that enables them to resist impact from:

- Pressure and pressure variations
- Water velocity
- Atmosphere (humid, corrosive air)
- Temperature-dependent expansion
- Mechanical impact
- Electrolytic action

For systems pumping normal household wastewater with toilet waste and rainwater, hot-galvanised steel pipes or stainless steel pipes are usually used. PEM, PEH and PVC plastic pipes are often used for small pump systems with low pressures.

The pipes must allow all solids and a small amount of sand and gravel passing through the pump to be transported in both internal and external discharge pipes. The question of self-cleaning must also be taken into consideration.

2. Velocity in discharge pipes

The water velocity should not be less than 1.0 m/s in vertical discharge pipes, otherwise harmful deposits of sand and fat may occur inside the pipes.

Note that this is also the case during parallel operation, where the velocity in the manifold will drop due to the larger pipe diameter.

If the velocity is too low, sand can build up inside the pump housing and wear down the impeller within a short period of time.

Usually the dimensions of the vertical discharge pipes are chosen so that the velocity during parallel operation is between 1 to 3 m/s.

In horizontal pipes (both internal and external), the aim is a velocity of 0.7 to 0.8 m/s. This should ensure trouble-free operation without harmful deposits. To avoid unnecessarily high pressure losses in the system, the velocity should not exceed 2 to 3 m/s. Too high velocity will create noise in the pipe system and also wastes energy.

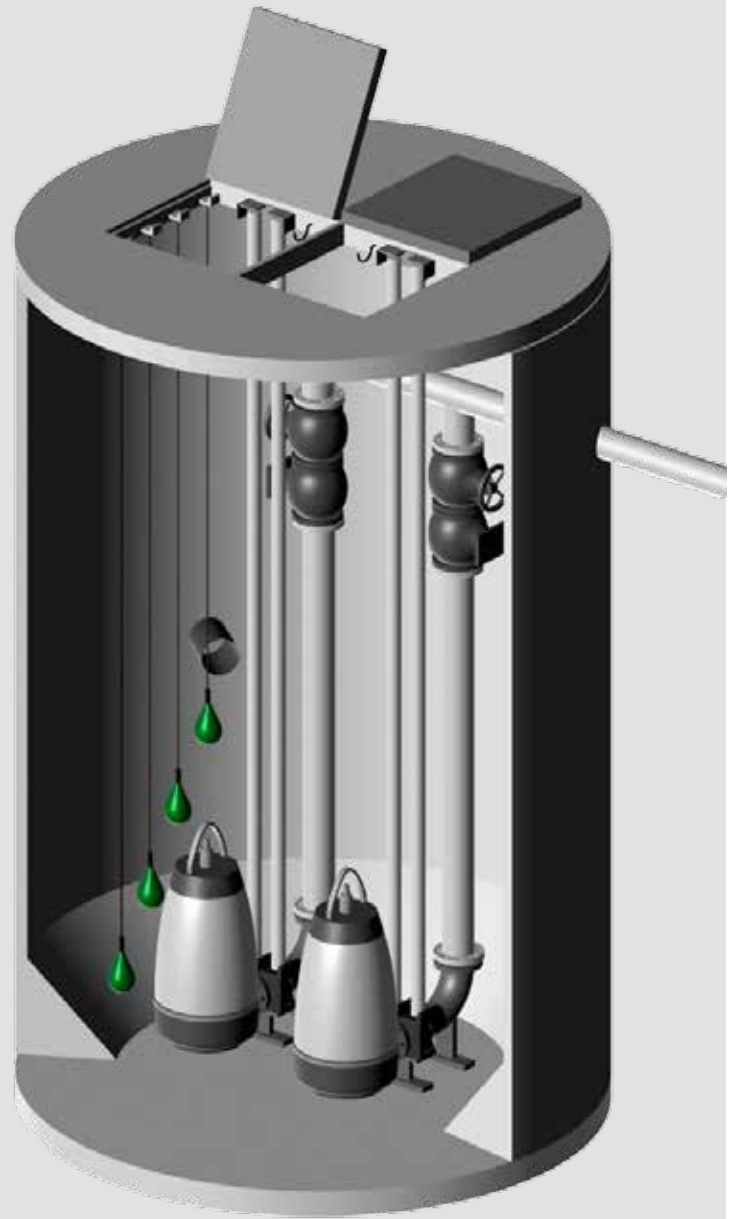


Fig. 6 Pump installation on auto-coupling, with vertical and horizontal discharge pipes

3. Determination of system characteristics

The pump pressure must overcome various resistances in the pipe system.

The total head varies with the amount of water in the system and the water level in the pit.

The pump's discharge head, H_p , should be equal to or greater than the total head in the system, H_{tot}

The total head is calculated as shown below:

$$H_{tot} = H_{geo} + H_v \quad \text{where}$$

$$H_v = H_{v,A} + H_{v,R} \quad \text{where}$$

H_{tot} = Total head (m)

H_{geo} = Static head (m)

H_v = Dynamic head losses (m)

$H_{v,A}$ = Head losses in valves and fittings etc. (m)

$H_{v,R}$ = Linear friction losses in discharge pipework (m)

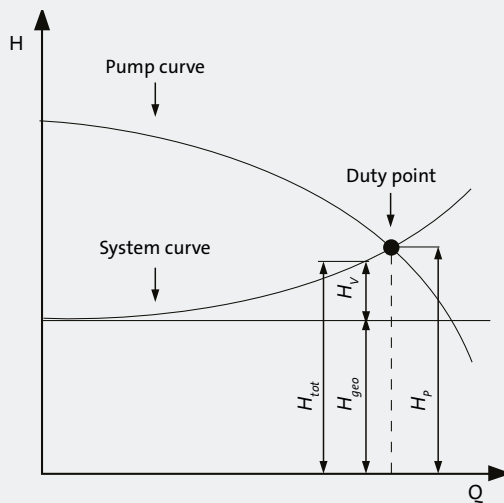


Fig. 7 Pump performance curve, with geodetic head, system curve, total dynamic head and duty point for the pump.

3.1. GEODETIC HEAD/STATIC HEAD, H_{GEO}

Static head or geometric height is independent of the flow and describes the height difference the pump should lift the wastewater and is normally calculated as the difference between the pump's stop level and the height of the discharge pipe outlet. If a water backflow level is defined, this has to be taken into account. If the backflow level is higher than the discharge pipe outlet, the backflow level should be used for calculating static head.

If the difference between the upper and the lower water levels in the pump sump is considerable, the average level is used as stop level.

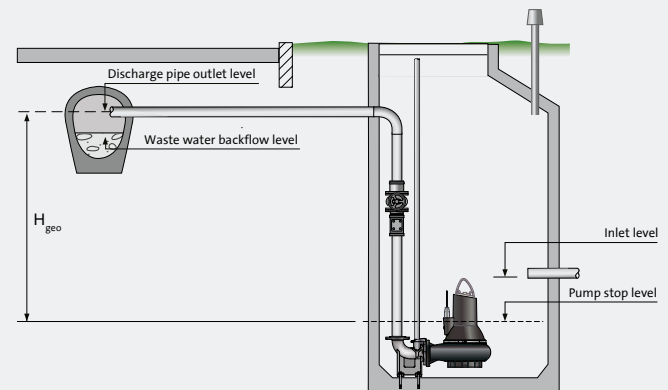


Fig. 8 Wastewater backflow level is defined lower than discharge pipe outlet. Static head should be calculated up to the level of the discharge pipe outlet.

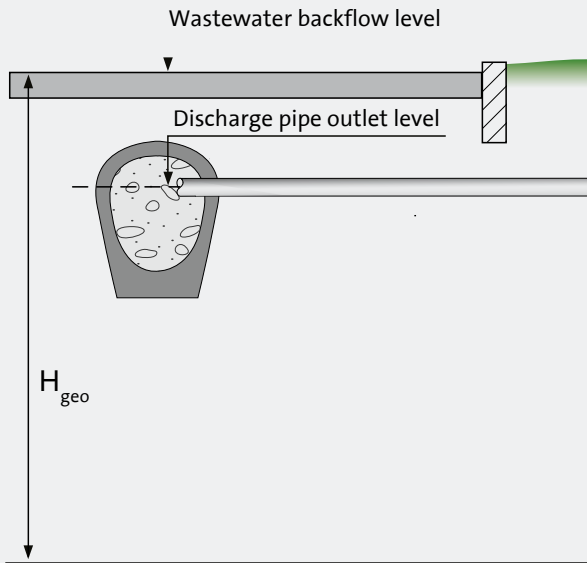


Fig. 9 Here, the wastewater backflow is equal to street level and higher than discharge pipe outlet. Static head has to be calculated up to street level.

3.2. LOSSES IN VALVES AND FITTINGS, $H_{v,A}$

When water passes through valves, bends, reductions and expansions, etc., energy is lost.

This loss varies with the velocity of the water and consequently the flow rate.

These losses are calculated using:

$$v = \frac{Q}{A} \quad \text{where}$$

v = Pipe velocity (m/s). Horizontal pipes: 0.7 to 3.0 m/s,
vertical pipes: min. 1.0 m/s

Q = Wastewater flow rate (m^3/s)

A = Internal pipe area (m^2)

It is important to determine the resistance coefficient as accurately as possible, as individual losses can be considerable in cases of high velocity.

When the discharge pipe size has been selected, it is possible to calculate head losses in the valves and fittings in the discharge pipe system as follows:

$$H_{v,A} = \sum_i \zeta_i \frac{v_i^2}{2g} \quad \text{where}$$

(Zeta) = Resistance factor (Z) (-) from table.

$H_{v,A}$ = Head losses in valves and fittings etc. (m)

v = Velocity in valve or fitting (m/s)

g = Gravitational constant (m/s^2)

Type of resistance	Zeta value
Isolating valve	0.5
Non-return valve	2.2
Bend 90	0.5
Bend 45	0.3
Free outflow	1.0
T-pieces 45	0.3 - 0.6
T-pieces 90	0.5 - 1.5
Increase in diameter	0.3

Fig. 10 Examples of types of resistances in a discharge pipe with Zeta values to match

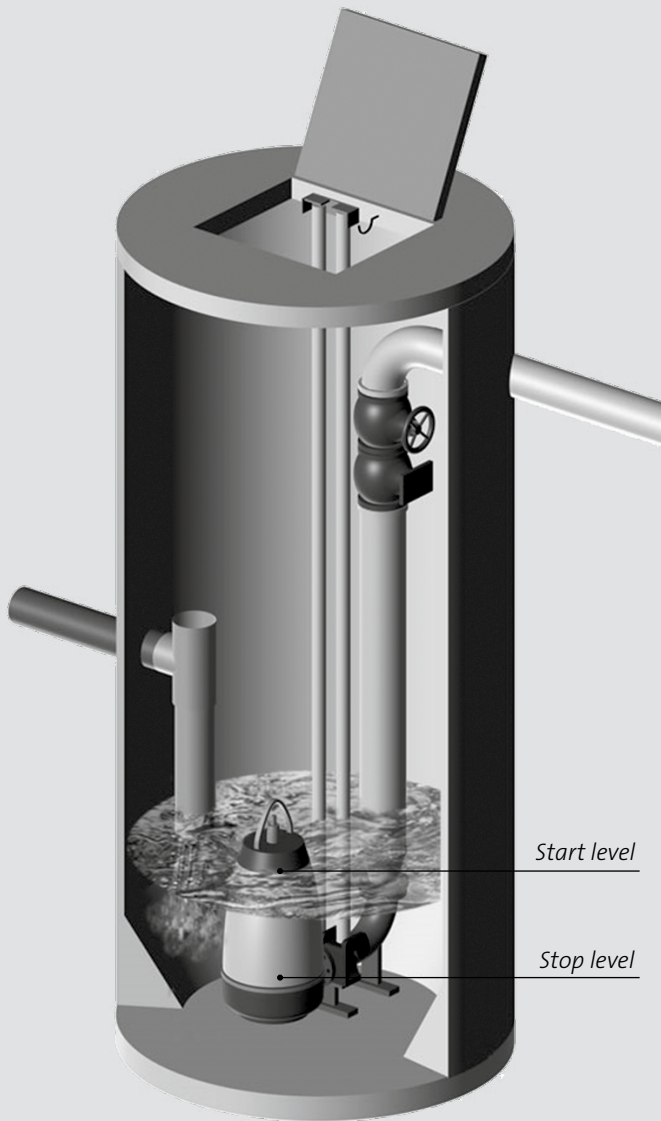


Fig. 11 Submersible pump installation with discharge pipes and valves. The inlet to the pit and water level in the pit vary all the time according to the discharge pattern

3.3. LINEAR FRICTION LOSSES IN DISCHARGE PIPE, $H_{v,R}$

The frictional loss in straight pipes depends on the flow through the pipe system and a number of other factors, of which the most important is roughness. Here it is important to consider roughness as the roughness of the pump system, i.e. including the influence of pipe connections, deposits on pipe walls and air pockets. Experience shows that the roughness figures for brand new pipes stated by the manufacturers cannot be relied on. For steel pipes and plastic pipes, the roughness should therefore not be estimated at less than 1.0 mm and 0.25 mm respectively. Often a roughness of 1 mm is used for both pipe types.

If the external discharge pipe is not constantly rising towards the outlet but has top and bottom points, the risk of air pockets and deposits in the pipe increases and the roughness may increase considerably. In such cases, the pipe characteristics should be determined for alternative roughness, e.g. 1.0 mm and 2.0 mm, and the pump selection made according to this.

Pipe loss nomograms are very much used and, if they are made in a practical way and are used correctly, allow pumps to be selected quickly and safely. It is important that the nomogram is based on recognised resistance formulas so that water temperature and roughness correspond to the conditions in question and that the internal pipe diameter is used in the nomogram.

The total pressure loss in the discharge pipe can now be determined:

$$H_{V,R} = H_{V,J} L_{V,i} \text{ where}$$

$H_{V,R}$ = Linear friction loss in discharge pipe work (m)

$H_{V,J}$ = Head loss as a function of flow rate (-)

$L_{V,i}$ = Pipe length (m)

3.4. TOTAL DYNAMIC HEAD H_{TOT}

When the system characteristics are calculated and inserted in the diagram of the pump performance, it will cross the performance curve for Q and H. The intersection point is also the duty point for the pump in the system.

For a more advanced sizing by application, type of liquid and pump details please visit Grundfos Product Center:
www.product-selection.grundfos.com

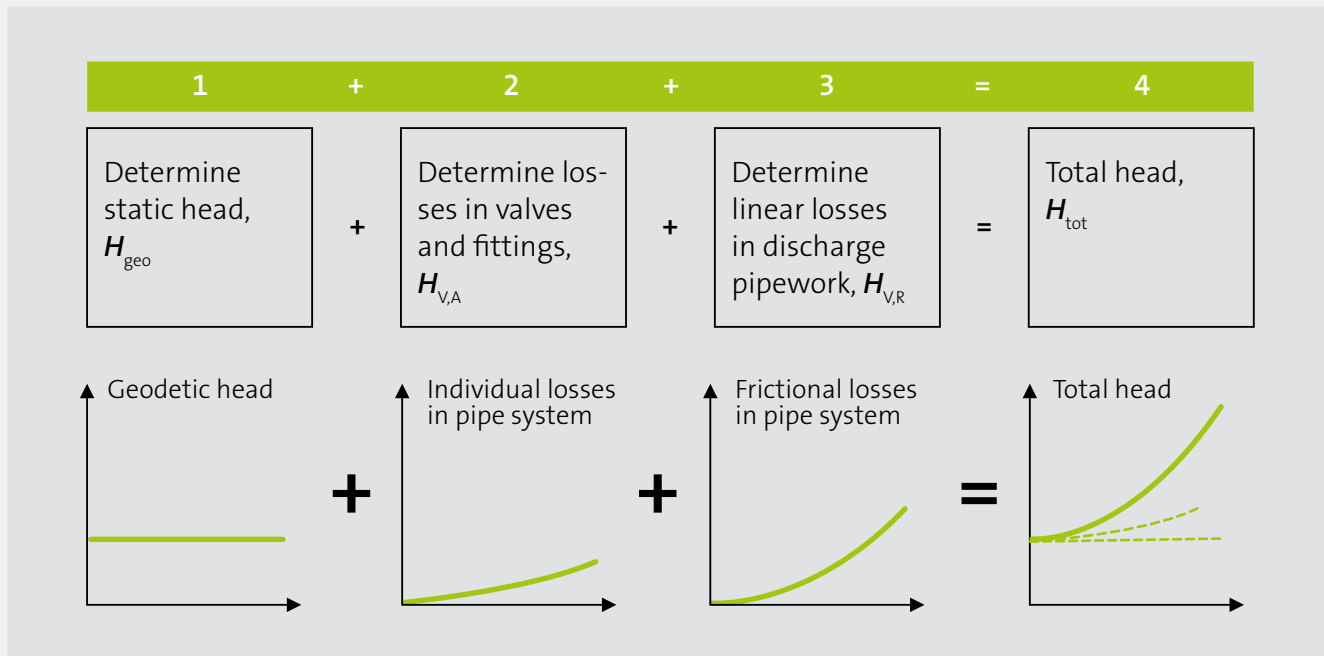


Fig. 12 Calculation of total head H_{TOT}

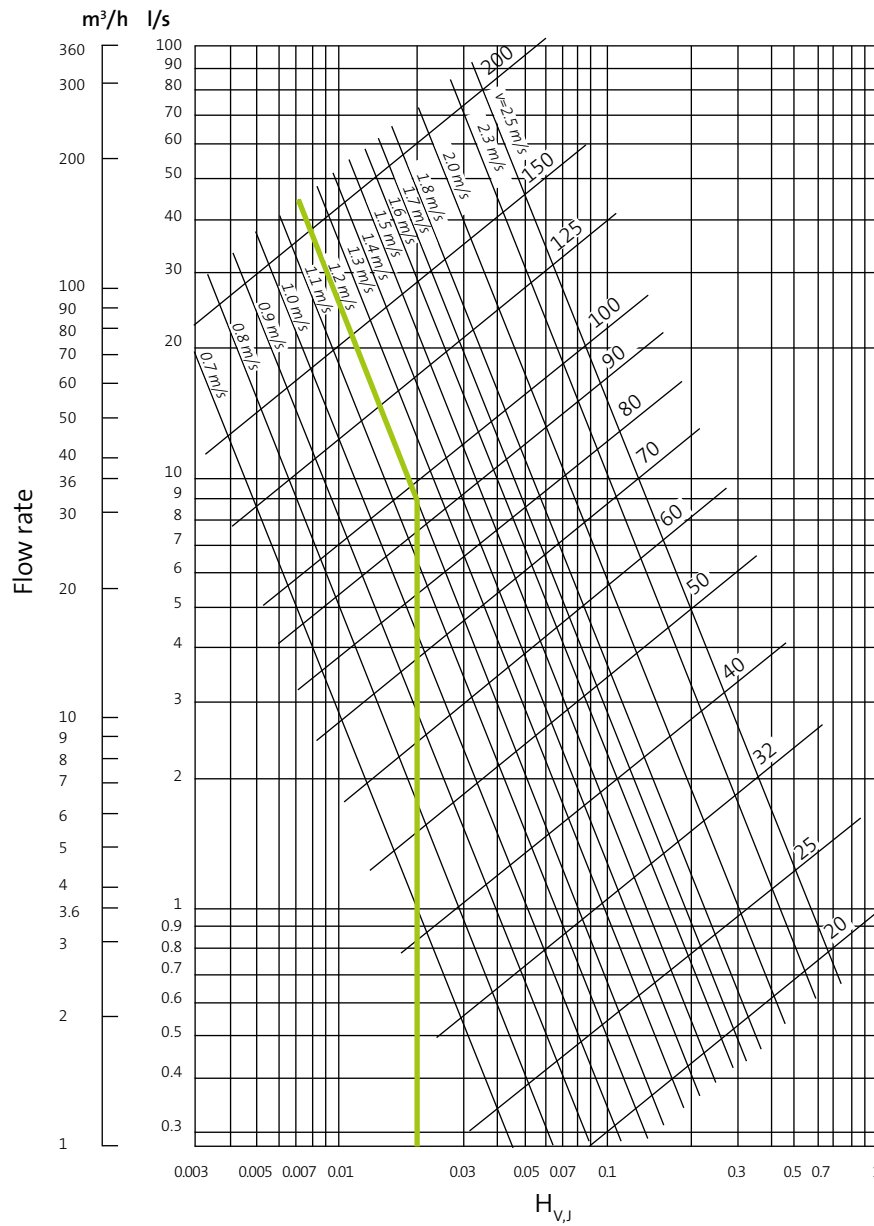


Fig. 13 Nomogram used to find $H_{v,j}$
 Example: linear friction loss in 125 m long DN 100 discharge pipe with a flow rate of 1.2 m/s.

$$H_{v,R} = H_{v,j} \times L_{v,i} = 0.02 \times 125 = 2.5 \text{ m}$$

4. Pump selection and pump characteristics

Pump suppliers will normally offer several different pumps within a given capacity range and a choice has to be made between these.

The selection should ensure:

- The pump meets the capacity requirement, possibly by using several pumps.
- The duty point of the pump is as optimal as possible. The pump should run at maximum efficiency for as long as possible.
- Good self-cleansing properties in the pipe system, also during parallel operation when connected to a common external discharge pipe. In this case, the performance of each pump drops compared with the performance at single pump operation.
- A pump with a suitably steep pump characteristic is chosen (especially for small pump systems). This ensures sufficient excess pressure, which makes it easier to remove deposits, thus reducing the risk of complete blockage.
- The passage through the impeller is suitable for the contents of the water to be pumped.

Normal requirements for free passage through pump and riser main and for water velocity:

1. Drainage and infiltration water

Minimum free passage 10 mm, self-cleansing velocity in riser main 1 m/s.

2. Rainwater and wastewater without toilet waste (effluent)

Minimum free passage 30 to 50 mm, self-cleansing velocity in riser main 1 m/s.

3. Wastewater with toilet waste from single-family households

Minimum free passage 50 to 65 mm, self-cleansing velocity in riser main approximately 1 m/s.

4. Wastewater with toilet waste from public buildings and municipal wastewater

Minimum free passage 75 to 160 mm, self-cleansing velocity in riser main approx. 1 m/s.

- That the pump choice is always based on the following curves:
- Pump performance (Q/H curve)
- Power curve
- Efficiency curve
- NPSH curve

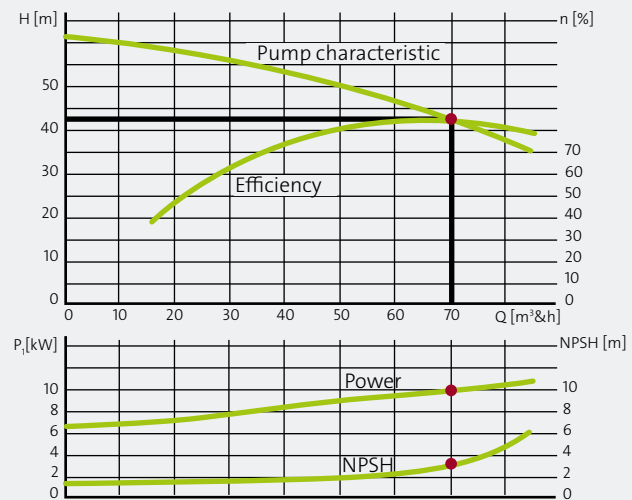


Fig. 14 Typical performance curves for a centrifugal pump with Q/H curve, power curve, efficiency (η) curve and NPSH as a function of the flow.

For submerged pumps, the power and efficiency curves must be for the whole unit, i.e. pump and motor. The power curve is the shaft power (P_2)

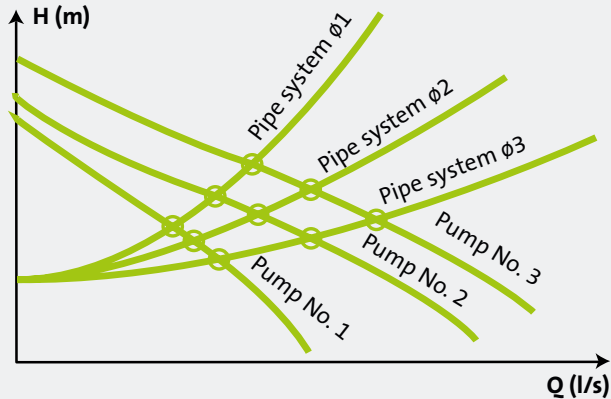


Fig. 15 Relation between pump and pipe system

4.1. PUMPS IN SINGLE OPERATION

Fig. 15 shows that it is often necessary to consider different alternatives or to make calculations prior to the final pump selection. Pump selection and sizing is clearly shown graphically. The system characteristics, which could be for different geodetic heads or pipe dimensions or materials, are calculated and plotted on a suitable scale. In the same diagram, the pump performance for alternative pumps can be drawn, which makes comparison easier. Be careful when plotting the supplier's pump performance in the diagram including the system characteristics and think of scale and units on the axes.

The duty point of the pump is the point of intersection between system characteristics and pump performance.

It is the point where the pump develops exactly the total dynamic head required to overcome the geodetic head plus hydraulic losses (individual resistance losses and frictional losses) in internal and external pipes.

It is also possible to draw the efficiency curve in such a way that it can be immediately seen whether a given duty point is acceptable in relation to the efficiency of the pump unit. The optimum pump selection is obtained when the duty point is right above the top point (maximum value) of the efficiency curve (Fig. 16).

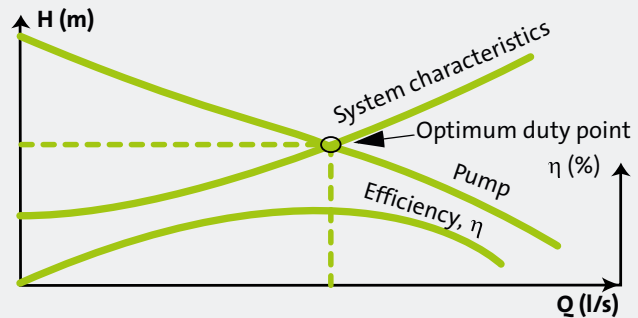


Fig. 16 Optimum duty point for a new pump in a pipe system without deposits

If the geodetic head varies, which should be checked, (for instance, with great variation of the water level in the sump when used as a reservoir), this means vertical parallel displacement of the system characteristics and consequently the duty point will vary within a certain range. In this case, the pump selection should result in efficiencies around the top point (maximum value) of the efficiency curve (Fig. 17).

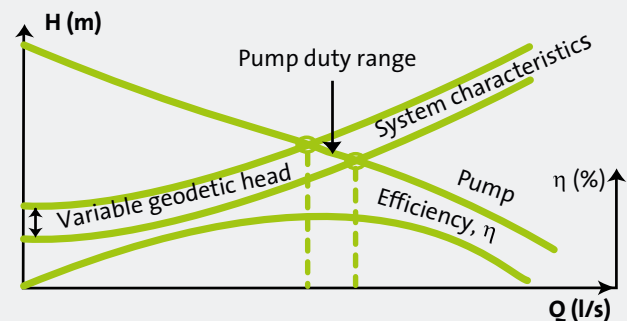


Fig. 17 Duty point for a new pump in a pipe system with variable geodetic head

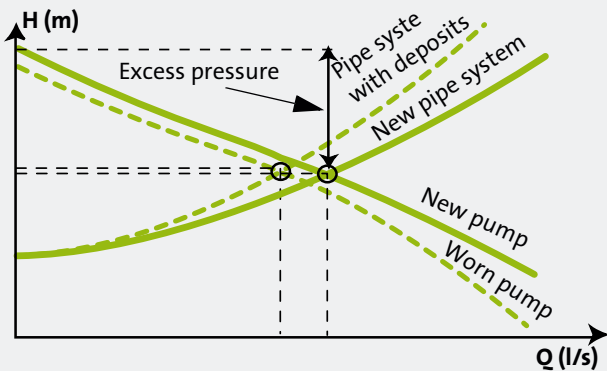


Fig. 18 Moving of duty point over time due to pump wear and deposits in pipe system

Fig. 18 illustrates how the duty point moves if the losses in the pipe system increase, for example due to deposits on the pipe walls. When the losses increase, the flow in the pipe system decreases, and thereby the velocity with the risk of even more deposits inside the pipe walls. This starts the process that ends with the pipe blocking. The illustration also shows how pump wear gives declining pump characteristics.

4.2. PUMPS IN PARALLEL OPERATION

Two or more pumps can be installed so that they can run in parallel, connected to a common discharge pipe.

The common characteristics for both or all pumps in operation is constructed by horizontal summation (at the same head) of the individual pump characteristics. We only talk about parallel coupling if the pumps are connected to the same discharge pipe so that the pressure loss in the pipes close to the pumps is insignificant compared to the pressure loss in the common discharge pipe.

The individual pump performance and the common characteristics can be plotted together with the system characteristics and the efficiency curve – as in the case with one pump.

The duty point is the point of intersection between the system characteristics and the common pump characteristics. The principle is shown in Fig. 19.

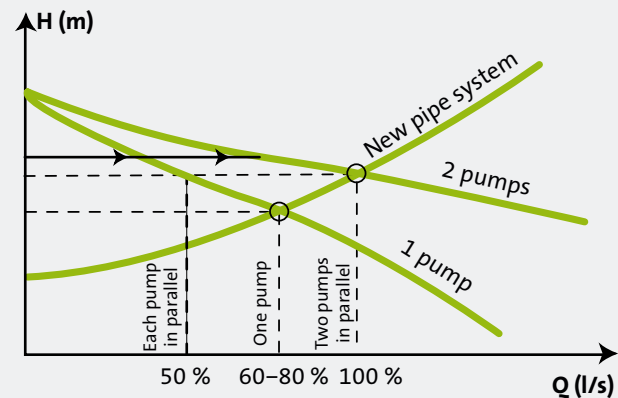


Fig. 19 Principle of graphical determination of duty point with two similar pumps in parallel operation. The characteristics of the two pumps are summed horizontally at the same head.

[4]

PUMPS & PUMP PITS

1. Liquid temperature

A standard cast iron or stainless steel submersible drainage, effluent, sewage or grinder pump can operate continuously or intermittently when it is fully submerged or partly submerged in a liquid of 40° C, if the following items are as specified for the pump:

1. Power supply
2. Number of starts/stops
3. Pump flow
4. Running time for intermittent duty

If the liquid temperature increases to 50° C for more than five minutes of operation, the motor life will be shortened due to:

1. Reduced ball bearing life
2. Reduced winding insulation life
3. Reduced motor cable life



Fig. 1 Grundfos submersible SL pumps and other smaller cast iron pumps without cooling system can operate continuously with a liquid level at the top of the motor.



Fig. 2 Grundfos submersible SE pumps with motor jacket and cooling system can operate continuously with a liquid level down to the top of the pump housing

For applications with a liquid temperature higher than 40° C, it may be necessary to do the following to keep a reasonable service life:

- The motor must be de-rated.
- A heat resistant cable must be fitted or the existing cable de-rated.
- Service check intervals must be halved and the ball bearings replaced more frequently.
- The inlet pressure must be increased.
- All cast iron parts must be protected with a coating of wear resistant protection.

A de-rating factor of 0.5 means that an 11 kW motor is to be equipped only with an impeller requiring a 5.5 kW motor. With a higher load, a reduced motor life is to be expected.

2. SE pumps with cooling system

SE pumps for submersible and dry-pit submersible installation in the motor range 1.1 kW to 30 kW are designed for intermittent or continuous operation in a liquid temperature: 0° C to + 40° C. For short periods (maximum 1 hour), a temperature of up to + 60° C is permissible for standard pumps (non-Ex versions only).

3. S pumps without or with cooling jacket

Pumps without cooling jacket in submerged installation can operate:

- Continuously when the pump is fully submerged to top of motor.
- Intermittent with maximum 20 starts per hour when the pump is submerged to middle of motor and with short periods of operation down to the top of the pump housing in a liquid temperature: 0° C to + 40° C.

For short periods (max. 1 hour), a temperature of up to + 60° C

Note: Explosion proof pumps must always be fully submerged in the liquid with a maximum temperature of 40° C.

Pumps with cooling jacket in submerged and dry installation can operate:

- Continuously and intermittent with maximum 20 starts per hour with water level down to the top of the pump housing.

3.1. EXTERNAL COOLING

With all these precautions required to maintain a normal pump service life, one might instead consider the use of a cooling jacket for external cooling, provided cold water is available.

In case of liquid temperatures above 60° C for periods of more than one hour, cooling jackets with connections for external cooling water should be used.



4. SmartTrim

On conventional submersible and dry-pit submersible sewage pumps, maintaining factory-set impeller clearance can be a time-consuming and costly task. The pumps need to be disconnected from the pipework and the pump housing disassembled before replacing the neck ring and wear ring can take place. New parts need to be installed in order to maintain full pumping efficiency.

This is not the case with Grundfos SmartTrim. All Grundfos heavy-duty submersible and dry-pit submersible sewage pumps from 9 kW and larger with closed impeller are equipped with the unique SmartTrim system for adjustment of the impeller clearance.

This enables easy restoring to factory-set impeller clearance, thereby maintaining peak pumping efficiency. Simply trim the adjustment screws on the exterior of the pump housing. This can be done on site, without dismantling the pump and without using special tools.

Trim screw in the middle



Fig. 3 Grundfos submersible SE pumps with SmartTrim. In total, there are three sets of trim screws and setscrews

4.1. IMPELLER CLEARANCE

In conventional sewage pumps, the hydraulic part has a wear ring and in some cases also a neck ring. The wear ring is placed in the pump housing at the inlet to the hydraulic. The neck ring is mounted on the neck of the impeller. In this design, the impeller clearance is the gap between the wear ring and the neck ring.



Fig. 4 Impeller clearance in conventional sewage pumps

Grundfos sewage pumps with SmartTrim system do not have wear rings and neck rings. The impeller clearance is a radial clearance between the pump housing and the impeller. The adjustment of the clearance is done by trimming the pump housing up against the impeller with the trim screws.



Fig. 5 Impeller clearance in Grundfos pumps with SmartTrim

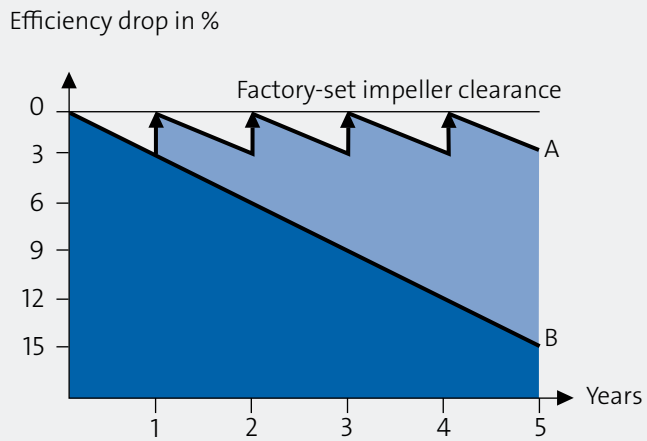


Fig. 6 SmartTrim enables restoring to factory-set impeller clearance and thereby maintain peak pumping efficiency

- A:** With Grundfos SmartTrim impeller clearance adjustment system
- B:** Without impeller clearance adjustment system

5. Pump sump

In the wastewater pumping station, the pump and the pump sump are parts of an overall system that also includes, benching, pipe system, valves, level sensors, air release, access cover, and much else. Trouble free operation is achievable with effective planning during the design stage.

Often wastewater pits are over-dimensioned to make sure they are big enough – but the good intentions are likely to have the opposite effect.

Optimum operating conditions are achieved when effective sump volume – the volume between start and stop levels – is calculated correctly, and there are established proper benches at the bottom of the pit.

One of the main disadvantages of over-dimensioning a pit is that it may cause the wastewater to stay in the pit too long, which leads to sedimentation with odour problems due to creation of hydrogen sulphide and ultimately clogging in the pump.

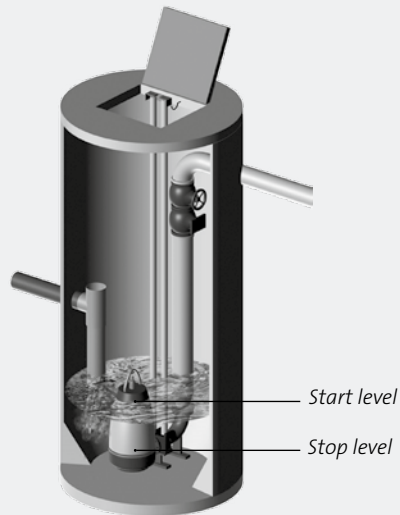


Fig. 7 Pump pit with start and stop levels

Say that the optimum pit diameter is 1.5 m but instead is made with a diameter of 2 m to provide extra volume, just in case. The pump's start and stop level is, however, the same as it would have been with the smaller diameter so it takes longer for the wastewater to reach the start level. And with less frequent starts, the wastewater stays longer in the pit.

5.1. DIMENSIONING THE PUMP PIT

When dimensioning a pit, the following must be known:

- Inflow
- Pump capacity
- Starting frequency
- The effective volume
- The pit diameter
- The distance between start and stop

5.2. INFLOW

The first thing that must be established when dimensioning a pit is the inflow. This figure is typically provided by companies or consultants insured against faulty estimates and calculation. The amount of inflow fluctuates from day to night and from one day to another (see page 40, part 1.3), and also depends on the nature of the wastewater inflow. Run-off rainwater has strong fluctuations while sewage has more regular movements.

5.3. PUMP CAPACITY

As an example, where the peak inflow is set at 9.5 l/s, the required pump capacity is found by multiplying with 1.05. This means a pump that is able to pump 10 l/s at peak load is needed to make sure the pit never floods.

When selecting the pump it is essential to look at the maximum number of starts it is able to perform per hour to make sure it can keep up at the busiest hours of the day. The more starts/h the better is a good rule of thumb.

6. Starting frequency and effective sump volume

In a pumping station, the wastewater volume comprises the volume below the lowest pump stop level and the effective volume above this level. The effective volume fluctuates with pump usage and incoming flow rate. The starting frequency of the pumps depends on the available pumpable volume and the incoming flow rate.

The starting frequency Z is a function of the ratio between

Q_{in}/Q and V_h , where

Q_{in} = incoming flow rate (l/s)

Q = pump capacity (l/s)

V_h = effective volume between start and stop (m^3)

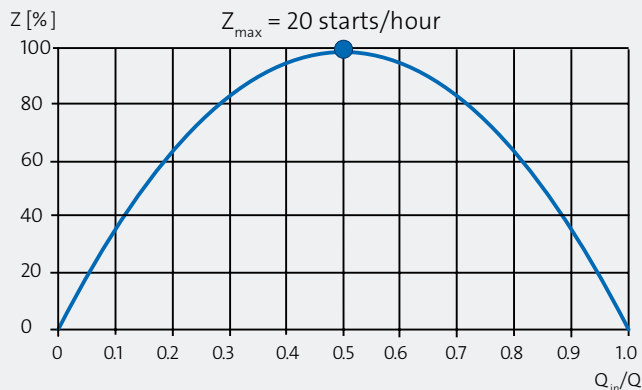


Fig. 8 Starting frequency curve Z for a single-pump pumping station as a function of the ratio between incoming flow Q_{in} and pump capacity Q .

Note: If the maximum inflow is equal to the pump capacity, the pump runs continuously.

Most frequent start, Z_{max} , will always appear when the inflow is half the pump capacity.

All Grundfos motors in SL and SE sewage pumps are designed for maximum 20 starts per hour.

$$Z_{max} = \frac{Q \times 3.6}{4 \times V_h} \quad (Z_{max} = \text{maximum starts per hour})$$

By isolating V_h :

$$V_h = \frac{Q \times 3.6}{4 \times Z_{max}}$$

Before calculating the effective volume, it is essential to know if the pumps are to run in parallel or alternating operation.

In discharge systems with two pumps operating in parallel, the two pumps deliver the required capacity jointly. In other words, the pumps combined are able to pump 10 l/s at peak load.

6.1. EXAMPLE

$Q = 10$ l/s

$Z_{max} = 20$ starts/hour

Necessary minimum effective volume between start and stop:

$$V_h = \frac{10 \times 3.6}{4 \times 20} = 0.45 \text{ m}^3$$

The effective volume in a system with alternating operation is calculated using the exact same formula, however based on only one pump's capacity and not two as in parallel operation.

So when sizing the pumps it is important to take into account that each pump must be able to deliver 100 % capacity on its own, meaning that pumps in this example will be bigger than the pumps in parallel operation.

6.2. PIT DIAMETER

Next, determine the pit diameter. The right pit diameter is essential to ensure optimum operating conditions. If the pit is too big, there is a risk that the number of starts and stops will not be enough to prevent sedimentation.

The required diameter is determined based on the number of pumps and the extra space needed for piping, etc.

Using the example with two pumps in parallel operation, this system will require a pit diameter of 1.8 m – or a radius of 0.9 m.

6.3. DISTANCE BETWEEN START AND STOP

Finally, calculate the distance between the start level and the stop level – or the effective height in a circular pump pit.

The effective volume is 0.45 m³ and that the pit radius is 0.9 m.

To calculate the effective height, the following formula gives an effective height of 0.18 m.

$$H_{\text{effective}} = \frac{0.45}{0.9^2 \times \pi} = 0.18 \text{ m}$$

The start level 1 can now be set in the pit according to the pump manufacturer's recommendation. Very often start level 1 should be set at the top of the motor, the stop level should then be 0.18 m below start level 1. For pumps with an internal cooling system, the common stop level can be set at the top of the pump housing and start level 1 should be set 0.18 m above.

For two pumps in alternating operation, the alarm level should be set 0.1 m above start level 1 and start level 2 should be set 0.1 m above the alarm level.

It is important to have the correct distance between start and stop. Too long a distance reduces the number of pump cycles and may cause sedimentation in the sump because the water stays in the pit too long. Sediment may cause clogging at start and noxious gases may build-up. Blockages of this sort are one of the most common causes of unplanned downtime.

On the other hand, if the distance between the start level and the stop level is too short the motor is potentially overloaded at the peak load due to too many starts and stops – which may again cause downtime. For this reason, it is important to always take into account the maximum number of starts per hour a pump and motor is designed to deliver.

If a pumping station serves only a few households, the inflow is often limited and a single pump will be enough to deliver the appropriate capacity. The pump capacity selected must, however, and then be larger than the inflow to effectively prevent sedimentation in the pressure pipe by maintaining the required velocity for the dimension of the discharge pipe.

Pits with more than two pumps are typically used in combined systems – either to increase capacity or to have spare backup pumps to account for sudden strong fluctuations, for instance during heavy rain.

7. Pumping Station Creator

Grundfos has developed a Pumping Station Creator design tool for designing a pumping station in a matter of minutes. The Pumping Station Creator is available from Grundfos Product Center under 'tools'.

The Pumping Station Creator will help you:

- Size a pumping station solution including pumps and controls
- Get full documentation including 3D drawings of the station
- Full CE certification for the solution

8. Benches

One problem that can occur in a wastewater pumping station is the build-up of sludge and solids of different densities.

To avoid this, benching is required from the bottom of the pit with an incline between 45° and 60° . Benching plays an important role in maintaining optimum operating conditions. The construction prevents dead zones at the bottom and minimises the risk of stagnation areas where sediments may accumulate.

The reduced bottom diameter contributes to increased water velocity, which facilitates the pumping of solids and floating debris.

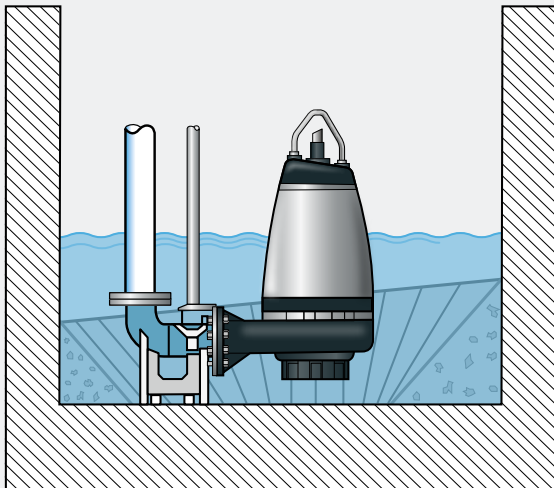


Fig. 9 Submersible sewage pumps on auto-couplings in a pump pit with benches

9. Distance between pump inlet and sump bottom

To provide the best possible inflow to the pump, the minimum distance from the sump floor to the pump inlet must be the same as the inlet diameter in the pump.

To achieve this bottom clearance, the auto-coupling may need to be mounted on a concrete plinth. For information about clearance distance, please refer to the dimensional drawings in the data booklet for each individual pump model.

9.1. LAYOUT OF PUMPING STATION INLET

Pump operating problems are frequently caused by entrainment of air and the accumulation of air in the liquid when it splashes into the pit.

Air in sewage water has a tendency to remain there for a long time because air bubbles will stick to the solid particles in the liquid.

The liquid inlet splash velocity is a function of the fall height. Direct fall should always be minimised, and it is advisable to interpose a screen in front of the inlet to prevent the direct fall and reduce the air entrainment. If the inlet is located high above the water surface, an impact breaker should be installed. A pipe leading the water down to a lower level is a good solution to prevent cascading flow and air entrainment during the pump cycle.

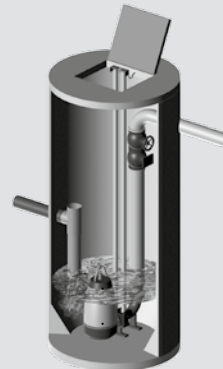


Fig. 10 Pump pit with benches and inlet with impact breaker

10. Formation of floating layer in wastewater pumping stations

A floating layer frequently occurs when operating wastewater pumping stations. Substances contained in wastewater such as faeces, oil, grease, and other fibers contribute to the accumulation of the floating layer.

Impurities lighter than water rise to the surface and collect in areas with low flow velocities. Impurities with a density similar to that of water will initially be suspended. This suspended condition can, for example be changed by air intake caused by falling water. In this case, small air bubbles will form a compound with the suspended solids. These compounds also rise to the surface. Substances whose density is considerably higher than that of water sink to the floor of the pump sump.

11. Hydrogen sulphide (H₂S) in the pump sump

If the wastewater remains in the sump for a prolonged period and a surface layer of accumulates, the wastewater is closed off from any oxygen supply. This will end the aerobic oxidation process and accelerate anaerobic digestion.

The reaction products from the digestion process should be considered as very problematic.

Hydrogen sulphide compounds are a particular nuisance. They are hazardous to health with a strong odour and are corrosive.



[5]

SUBMERSIBLE DRY-PIT PUMPS

1. General

Submersible wastewater pumps – originally developed for use in applications with the pump unit submerged in the pumped liquid – are widely used in dry-pit stations with the wet pit separated from the dry pump chamber.

Dry pit submersibles offer distinct advantages over conventional dry pit installations for both the installer and the user. Their compact design, installation versatility, and resistance to damage from flooding make them ideal for use in new and retrofit pumping stations.

In today's challenging environment, operators and municipalities face many financial issues due to ageing infrastructure and a reduction in service personnel budgets.

Medium and larger size pumping stations are often of the conventional dry pit design with the motor located floors above the pump connected by a shaft. This design requires increased labour for maintenance and can present problems with excessive vibration to the pump, motor, and structure.

The dry pits are prone to flooding, for example due to unpredictable weather with increased rainfall or damage to valves in the pump chamber.

Grundfos has designed a submersible motor that runs submerged or dry and requires little or no maintenance, and with no vibration problems for the pumping station. These motors are built directly with the pump and the units are for submersible installation as well as horizontal or vertical dry installation.

The submersible, integrated motor design of the pump offers operators trouble-free pumping, even in the event the dry pit becomes flooded.

Their compact, self-contained design offers significant savings in installation costs over conventional, coupled dry-pit pumps.

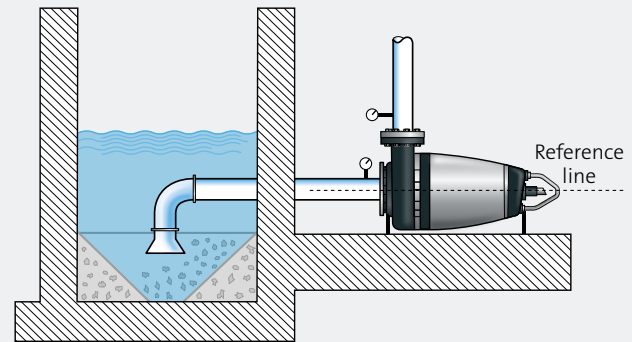


Fig. 1 Grundfos submersible dry-pit sewage pump installed horizontally in the dry pump chamber with inlet pipe to the wet pit furnished with benching.

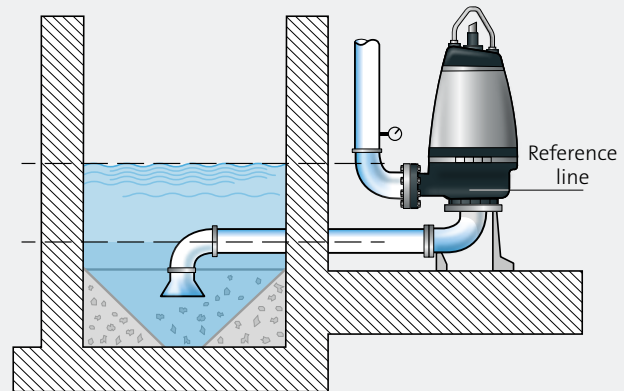


Fig. 2 Grundfos submersible dry-pit sewage pump installed vertically in the dry pump chamber with inlet pipe to the wet pit furnished with benching.

2. Installation advantages

Submersible dry-pit pumps offer the following installation advantages:

- No damage from flooding
- No vertical shafting
- No coupling alignment
- No packing or seal water leakage
- No seal water
- No hazardous rotating components
- No dry pit cooling

3. System advantages

Submersible dry-pit pumps offer the following system advantages:

- Simpler controls
- More frequent starts allowed
- Wider range of operation
- Reduced vibration
- Simpler support design
- Increased utilisation of available space
- Elimination of shaft losses



4. Installation of submersible dry-pit sewage pumps

The installation of the submersible dry-pit sewage pumps should be done so inspection and servicing is easy, and to ensure adequate space for dismantling. There should also be space for establishing suitable lifting equipment.

4.1. FOUNDATION

One of the most significant factors for a reliable and trouble-free pump installation is a good foundation.

All rotating equipment generates vibrations, where a mass such as an impeller or rotor turns at high speeds. A good foundation is sufficiently solid to provide stability and rigid support to minimise vibrations created by the pump and motor. Especially in wastewater applications where there is a risk for partly or full blockage of the impeller – resulting in imbalance – a solid foundation is an absolute necessity. In such situations, the equipment will vibrate heavily above the normal level and it is important that the foundation and the structure can handle such a situation for shorter periods. Imbalance and impeller vane pass in hydraulics are the two most important frequencies affecting vibration.

The foundation should begin with a firm footing. Fabricating a concrete foundation on solid ground is the most acceptable. Concrete is the best material for construction for foundations because it is low in cost.

The mass of the concrete foundation must be great enough to absorb any of the dynamic and static forces previously described. The Hydraulic Institute recommends in its Standards Ref.1 that the mass of the concrete foundation should be about five times that of the equipment it is supporting.

The foundation should stand independently, without contact to the surroundings. For maintaining separation between the

foundation and the solid ground and other building constructions, use a vibration dampening material such as Sylomer.



Fig. 3 Grundfos sewage pumps on individual foundations.

If the pump unit is mounted on other than a concrete foundation – such as a steel structure – the base should be supported on rigid steel beams along its length. It should also be mounted as close as possible to main structural members, other beams and the surrounding walls.

The Hydraulic Institute recommends in its Standards Ref.2 that pump units may be fastened directly to an existing concrete floor, if the floor meets the criteria of a foundation.

Pumps installed directly to the concrete floor, must be fastened with threaded bolts grouted into the floor.

Proper grouting of bolts requires many recommended practices; however, one should always follow the instructions and recommendations of the grout manufacturer. The instructions may differ between an expanding grout and a non-shrink grout.

For submersible vertical dry pit pump installations, similar to that shown in Fig. 4, where pump and motor are built direct together, the size and mass of the foundation must be maximised to insure the best possible rigidity.

In some cases, it can be difficult to establish a foundation with a mass five times that of the pump unit. Therefore, the new concrete foundation should be reinforced with pins to the floor when possible and thereby make the floor an active part of the foundation.

The floor and the concrete foundation should be of adequate strength to support the weight of the pump with pipes and valves plus the weight of the liquid passing through it, and the forces generated by the pump.

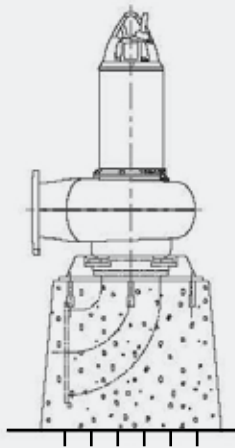


Fig. 4 Grundfos vertical dry pit submersible sewage pump on concrete foundation with pins to the floor.

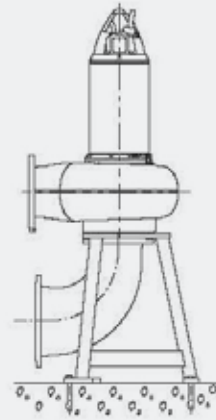


Fig. 5 Grundfos vertical dry-pit submersible sewage pump on fabricated base stand with threaded bolts grouted into the floor.

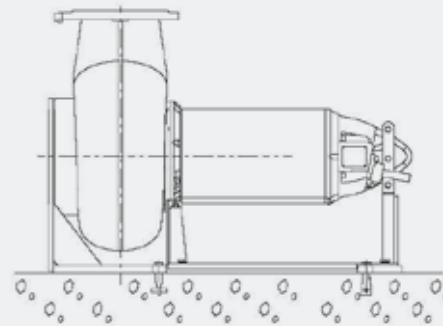


Fig. 6 Grundfos horizontal dry-pit submersible sewage pump on fabricated base stand with threaded bolts grouted into the floor.

The construction of the foundation and securing of the pump aggregate should be so that vibrations are minimised as much as possible and pipe stresses are absorbed or distributed.

5. Alignment of fabricated base stands

Align the base stand with the 'jacking screws' and grout the foundation bolts.
Adjust the position when the grout has hardened sufficiently.
Any height adjustment can be achieved with the nut.
Pour concrete to the upper side of the base stand.

6. Piping

Correct installation and anchorage of pumps and correct design of the foundation and installation of accessories can be affected by external factors. Proper engineering of the piping, pump sump and valves into the system is important. It is critical to limit vibration to achieve reliable, trouble free operation and likewise important to remember that all piping, fittings and supports that are mechanically connected to a pump are all part of a single system.

This is particularly important on the suction side. Errors here can increase the vibration level, reduce the hydraulic efficiency and cause cavitation.

6.1. SUCTION PIPE

Dimension the suction pipe so that the flow velocity does not exceed 2.0 m/s for vertical installed pumps and 2.5 m/s for horizontal installed pumps. Normally this will entail a pipe diameter one size larger than that of the pump inlet.

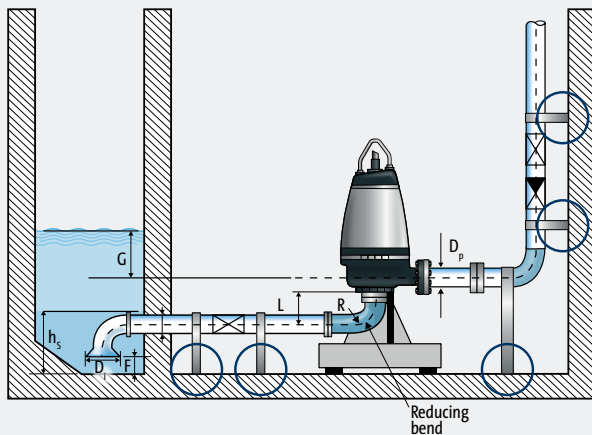


Fig. 7 Recommended installation dimensions for vertical dry-pit submersible pumps. $F \geq 0.5 \times D$, and minimum equal to free passage of pump, $v_{max} = 2.0$ m/s, min. start level $G \geq D_p$, $L \geq D_s + 100$ mm, $R \approx L$.

The suction pipe should be as short as possible - particularly for slurries and solids to avoid cavitation. Avoid pipes causing air pockets.

In vertical pumps, the suction pipe will have to turn 90° to reach the pump inlet, which will lower the pump efficiency because of the additional resistance and the flow around the perimeter of the impeller eye, which will be uneven. If the pump inlet dimension is smaller than the suction pipework, use a reducing bend. The increasing flow velocity in the reducing bend will alleviate the disadvantage of the bend and the pump will run more smoothly.

The narrowing of the straight inlet pipe to a horizontal pump should be eccentric to avoid air from collecting and possibly blocking the impeller.

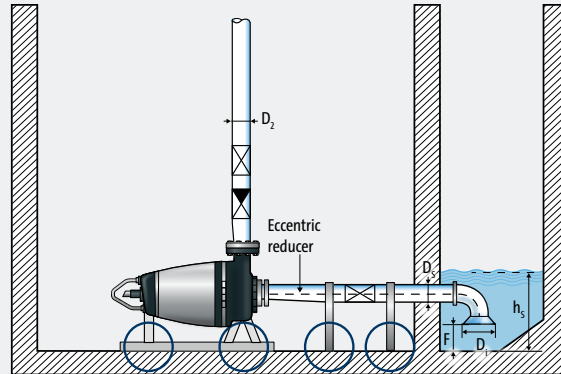


Fig. 8 Recommended installation dimensions for horizontal dry-pit submersible pumps. $F \geq 0.5 \times D_i$ and minimum equal to free passage of pump, $v_{max} = 2.5$ m/s

An inlet design with unfavourable flow characteristics may cause a pressure drop large enough to use up the available NPSH and lead to pump cavitation. The recommended NPSH margin should be observed in installations where the suction pipe geometry gives reason for concern.

7. Inlet bell mouth

To accelerate the flow smoothly into the suction pipe and to reduce inlet losses, provide the suction pipe with a bell mouth. Design the pump sump and intake with benches to avoid build-up of sediments.

See Figs. 7 and 8 for recommended suction pipe inlet designs. The downward suction exerts a sucking effect on the pit floor, and is less prone to suck air from the surface.

7.1. BELL DIAMETER

Choose the bell diameter (D_i) to keep the inlet velocities as follows:

$Q < 300$ l/s	$0.6 < v < 2.8$ m/s
$300 < Q < 1200$ l/s	$0.9 < v < 2.4$ m/s
$Q > 1200$ l/s	$1.2 < v < 2.1$ m/s
Optimum velocity: 1.7 m/s	

At the optimum velocity of 1.7 m/s, use the following formula for calculating the bell diameter (D_i):

$$D_i = 0.027 \times \sqrt{Q} \text{ (m)}$$

where Q = pump flow rate in l/s.

7.2. STOP LEVELS

The stop level setting for dry-installed pumps is dependent on suction pipe inlet height, shape and flow velocity. 200 mm above the suction pipe inlet is a good rule-of-thumb for this height, and useful for the designer.

For this inlet shape, use the following formula to calculate a provisional pump stop with an associated water level in the sump:

$$h_s = 0.04 \times \sqrt{Q} + 0.2$$

Where

h_s = stop level height, m

Q = pump flow rate, l/s

In pumping stations with several different stop levels, such as in frequency-controlled installations, it is important to program the control sequence to pump down to lowest stop level at least once per day to clean out the bottom.

7.3. START LEVELS

In pumping stations with dry-installed pumps, the starting levels have to be set above the pump housing in order to ensure that the housings are filled with water when the pumps start pumping. For vertical pumps, this height may be considerable and should be set with a margin according to Fig. 7.

7.4. GENERAL RULES

Although the suction pipe for a dry pit pump acts as a flow straightener, it can cause unsteady flow. Where bends are a part of the suction pipe, like where a bell mouth parallel to the sump floor is used, such bends should be selected with care to minimise disturbances to the flow.

Smooth bends are always preferred. As a rule, 5-10 pipe diameters of straight pipe between bends and between bend and pump are required to reduce the disturbances. This, however, is often not practicable.

8. Internal pipework

Select the internal discharge pipes in a pumping station for a flow velocity of 1 to 2 m/s.

If the flow velocity is more than 2 m/s, it can create noise and waste energy. The pressure pipe should have a dimension of at least the discharge flange of the pump and can be 80 mm in small pumping stations, provided pump free passage is 80 mm or less.

In multi-pump installations, the pump discharge pipes should be joined by branches designed to prevent settling of solids into the individual pipes when the pumps are not running, which may lead to valve blockage.

See Fig. 9 for good branch designs.

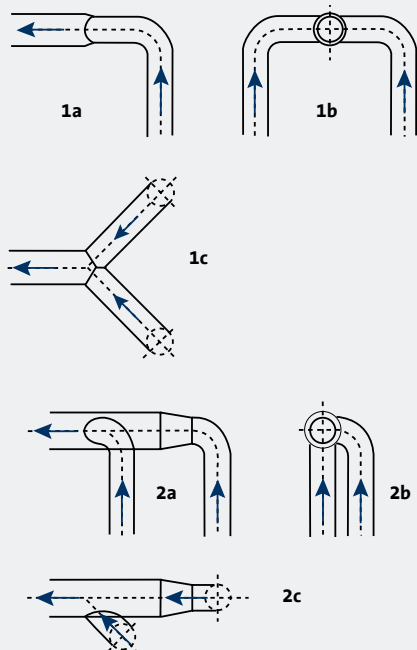


Fig. 9. Discharge pipework branch design. The design should emphasise smooth transition and prevent rising main sludge from settling on valves in pump risers when the pumps are not in operation.

Acute branches and sudden increases in diameter give unnecessary losses and may cause noise.

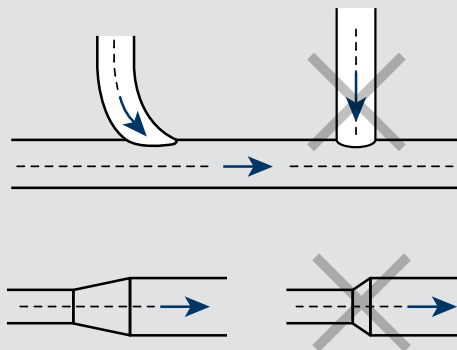


Fig. 10 'Right' and 'Wrong' ways of connecting to a common discharge pipe. The discharge pipe diameter should not be increased suddenly.

Avoid loads on the pump flanges arising from pipe stresses, and carefully support piping and valves. Excessive pipe stresses can deform the casing, resulting in impeller 'binding' and changed alignment.

Ensure that pipes and pump are properly cleaned internally before connection. Debris in the pipe can lead to unnecessary wear and pump failure. Bear in mind that the clearance between the impeller and the wear ring may be only a few tenths of a millimetre.

9. Valves

Valves in the suction pipe should be used for isolating only. During pump operation they should be fully open and of full flow type. Do not use butterfly valves, as these can catch paper, textiles etc. and will disturb the flow path, leading to increased suction losses.

Install a non-return valve and an isolating valve in the discharge piping close to the pump. The non-return valve prevents back flow after pump stop. The isolating valve should be fully open during operation and only be used if there is a need for inspection of the non-return valve.

10. Pressure testing of pipework

When pressure testing a complete pipe system, isolate the pump by blanking off to avoid damage to the shaft seal, for example.

11. Pressure transients and fluctuations

Each pump is designed for its stated pressure rating. If this pressure is exceeded, including instances of overpressure due to pressure transients (pressure fluctuations), continued satisfactory operation of the pump cannot be guaranteed.

Pressure transients occur if the flow velocity in a pipe is changed. The more rapid the rate of change, the larger the pressure fluctuation. In a long pipe, even a slow rate of change may cause a strong pressure surge.

Starting and stopping pumps or opening and closing valves are obvious causes of fluctuations.

Centrifugal pumps should be started against a closed or partially closed valve installed near the pump. Then slowly open the valve until fully open, and the pump is operating at the required duty point.

Quick acting valves and long pressure pipes, particularly those that are inadequately vented or gas or air-filled, call for special attention about pressure fluctuations.

If the power supply suddenly fails, the pump speed will drop and the flow in the system will change in an uncontrolled way. With very long pressure pipes, the possible consequences of such an interruption should be considered when the system is being designed.

12. Importance of duty point and problems with off-duty pumps

To achieve the best possible pump operation and to minimise disturbances from the pump in the system, it is of great importance to select a pump with the required capacity as close as possible to the best efficiency point.

13. Vibrations

Vibrations from machinery and other equipment can have serious consequences. Knowledge of the phenomena involved, together with design rules for pump installations, are necessary to reduce these unwanted effects and pump installations can be designed to achieve this.

13.1. EXCITATION FREQUENCIES

Vibrations are unavoidable when a mass, such as a rotor assembly, is turning at high speeds. The rotating mass motor together with forces from the hydraulics will generate an intrinsic set of disturbance or impulse excitation frequencies that are related to the speed of the motor and hydraulic parts. Imbalance and blade pass are the two most important frequencies affecting vibration.

Impellers with a small number of vanes fitted in wastewater pumps cause a pulsation of the fluid.

Excitation frequency = speed x number of vanes.

When these frequencies overlap with a natural frequency of the system, vibration levels will increase substantially. In variable speed applications, the likelihood of this phenomenon is more often because the pumps can operate over a range of speeds rather than a single constant speed. Most frequency converters have the option to exclude certain frequency ranges to avoid regions of high vibration.

13.2. MINIMISING VIBRATIONS

In addition, proper foundation and anchorage to the foundation and support is critical for minimising vibration. In installations with submersible vertical dry-pit pumps, the tall, unsupported mass of the vertical motor can intensify the vibration level at the upper bearing caused by imbalance, poor installation quality or hydraulic disturbances – more so than in submersible horizontal dry-pit installations. Therefore, eliminating system

resonances and ensuring high quality installation in vertical dry-pit applications is critical to achieving a smoother running installation.

Since vibration is unavoidable, the designer's goal is to keep the vibrations within acceptable levels, particularly at points where they can affect the performance of the equipment.

13.3. RECOMMENDATIONS

The following recommendations are consistent with industry standards and generally accepted good design practices for concrete anchorage of rotating equipment. These recommendations can be applied to all Grundfos pump installations. Failure to follow these good design and construction practices may result in higher levels of noise and vibration than desired. Consult a licensed Civil Engineer for specific construction design details for each individual installation.

- Anchor the piping to the floor or another solid structure
- Anchor the pump firmly to the floor if it fulfils the requirements for a foundation or for a properly dimensioned concrete foundation
- Concrete foundations are an integral part of the installation and should be designed to resist vibrations through proper reinforcement and dimensioning

13.4. DISTURBANCES

Grundfos pumps are manufactured to be of the highest quality to ensure compliance with ISO 10816-1 vibration test standard and Hydraulic Institute submersible pump test standard HI 11.6 for factory vibration tests. Although the pump itself can withstand rather high vibration levels when operating without noticeable life time reduction, the piping and supportive structure may suffer and crack if vibration levels are too high. For acceptable vibration levels in the field, ensure that all parts

of the system are adequately stiff and firmly anchored, so that the primary disturbances have frequencies below the lowest natural frequency of the system.

The most common disturbances resulting in unwanted vibrations in submersible dry-pit pumps are listed below in order, with the most likely first.

- Imbalance in rotating parts due to blockage of impeller
- Pressure impulses caused as the impeller vanes pass guide vanes
- Hydraulic forces that occur when a vane passes through zones of uneven pressure in the volute
- Insufficient concrete foundation
- Insufficient anchorage of base stands to floor
- Insufficient anchorage of piping to the floor
- Hydraulic forces caused by the volute
- Hydraulic forces caused by a single-vane impeller
- Other vibrational disturbances often come from the electric motor; they may cause noise, but are normally harmless in their impact on the structure involved

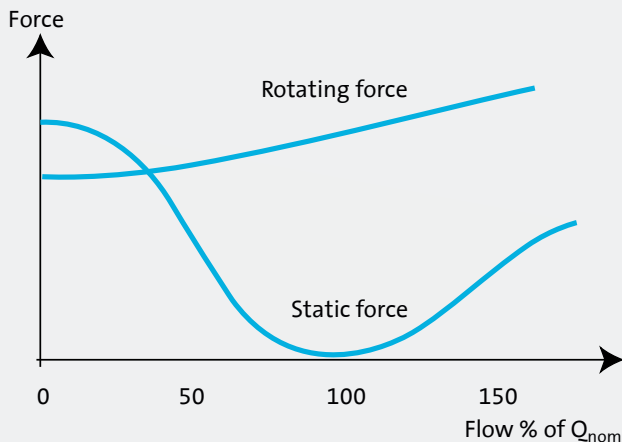
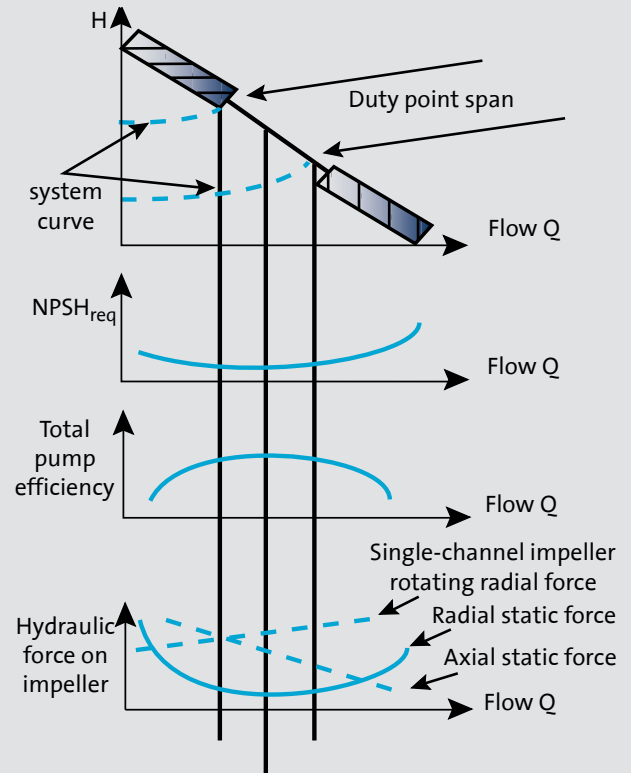


Fig. 11 The magnitude of the forces is dependent on the duty point



- Recirculation
- High radial and axial forces compared to Q_{opt}
- Low efficiency
- Instability (unstable operation due to recirculation)
- Higher $NPSH_{av}$ is required than at Q_{opt}

Recirculation causes unstable operation of the pump which creates a rumble or banging low frequency noise. Cavitation can cause cavitation erosion which may affect the performance.

- Higher $NPSH_{av}$ is required than at Q_{opt}
- Low efficiency
- High radial forces compared to Q_{opt}

Fig. 12 Factors affecting pump performance

14. Installation

Keep vibrations at acceptable levels by following a number of general rules.

All parts of a system should be sufficiently stiff and firmly anchored so that the primary disturbances have frequencies below the lowest natural frequency of the system. Consider the entire system, including foundation, piping, valves, pump, support etc.

14.1. PIPE BRACKETS

Pulsation in the flow from the pump causes the discharge pipe to vibrate. Resonance must be avoided and occurs when the excitation frequency of the pump equals the natural frequency of the piping. Resonance will lead to maximum vibration amplitudes and very high forces acting on the pipe brackets (supports).

To reliably rule out resonance, make sure that these two frequencies differ from each other by at least 10 % of the excitation frequency.

The excitation frequency cannot usually be changed, as this would mean changing the pump speed by more than 30 %. For this reason, adjust the natural frequency of the piping.

The natural frequency of the piping depends on:

- The mass distribution within the system (valve position, wall thickness, material)
- The bracket (support) concept

The bracket concept influences the natural frequency decisively. Adjust unfavourable natural frequencies by changing the position of or adding individual pipe brackets (supports) preferably near valves, outlets, etc. The position of large individual masses (valves) also has an impact on the natural frequency.

The exact bracket (support) positions and their natural frequencies can only be determined by a special static calculation of the pipes.

14.2. WALL THICKNESS OF PIPES

To a lesser extent, the natural frequency can also be influenced by the wall thickness of the pipe. Thicker walls cause higher natural frequencies than thinner walls, assuming the same pipe material (elasticity) and excitation. The vibration forces acting on the brackets (supports) can be derived from the harmonic excitation.

Select robust pipe brackets that are able to transmit safely the forces to the structure.

15. Insulation from structure

Insulate the pump from the structure by:

- Including a foundation of adequate mass, at least three times the mass of the rotation parts (pump and motor)
- Anchoring the pump firmly to the foundation
- Using a flexible support, e.g. anti-vibration feet or a rubber mat between the foundation and floor.
- Using flexible joints for the pipes
- Anchoring the pipe brackets to floor or other solid structure

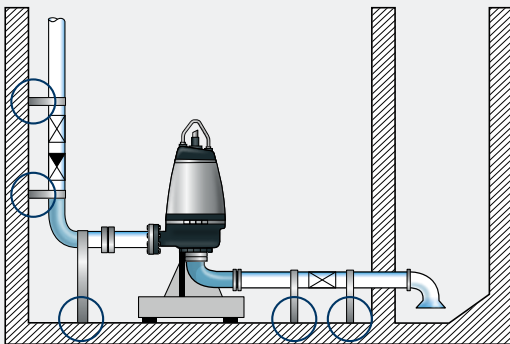


Fig. 13 Typical anchorage

If using weak parts such as bellows, they must be firmly attached at both sides. Because vibrations are independent of gravity, horizontal supports should be provided since they are as essential as vertical supports.

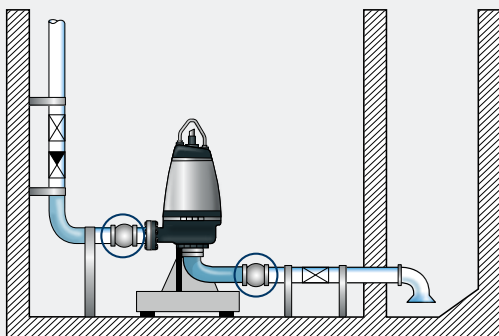


Fig. 14 Ways of minimising vibrations with the use of compensator's in the suction pipe and at the discharge flange of the pump.

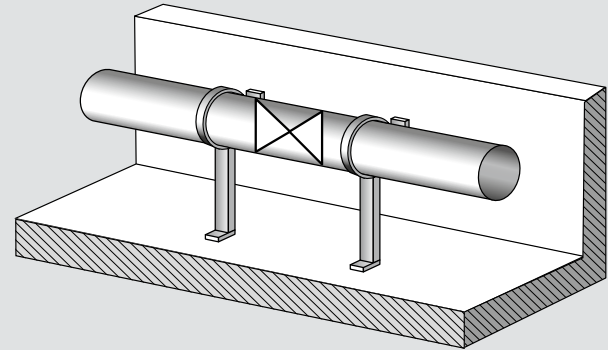


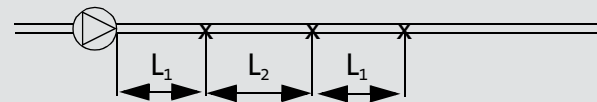
Fig. 15 Horizontal anchorage with brackets to the floor and to the wall.

15.1. ANCHORING DISTANCES

Heavy parts of the piping, like valves, must be properly supported.

The piping must be anchored if compensator's are used. Compensator's between pump and pipe can transform pressure fluctuations into disturbances, causing severe vibrations in the piping.

To avoid vibrations in the piping system, varying distances between the anchoring points are necessary. The maximum distances between the anchoring points should be as follows:



$$L_1 = \text{DN} \times 14$$

$$L_2 = \text{DN} \times 16$$

Where

L = max. distance between anchoring points

DN = nominal pipe diameter

16. Conclusion

Unwanted vibrations in installations with machinery such as pumps can be avoided or reduced to acceptable levels by following certain practices. Any improvements must be based on an understanding of the phenomena involved. Proper foundation and anchoring at correct positions is vital. With flexible installations, the mass ratio, (total to rotating mass) must be high enough to ensure low vibration levels. If a variable speed drive is used, make sure that the frequency converter has the option to exclude certain frequency ranges to avoid regions of high vibrations.

17. Pipe materials

The pipes within the pumping station should preferably be made of steel. For corrosion resistance, steel pipes are designed with thick walls and either coated (e.g. hot dip galvanised or a coating system) or made of stainless steel (material number 1.4571 / V4A).

When using cast pipes, take into account the availability of fittings and the weight.

For any other materials, e.g. plastic, especially when used for industrial wastewater, pay particular attention to providing sufficient pipe fasteners and separate supports for fittings such as valves.

18. Selecting valves

Valves are a functional part of the piping system and are required to implement the pumping process.

They mainly fulfil the following functions:

- Shutting off and opening the pipe passage
- Preventing backflow
- Controlling the flow
- Aerating and venting the piping

18.1. VALVES FOR WASTEWATER APPLICATIONS

The valve industry offers the following valves for the above functions:

- Gate valves (wedge gate valves, slide gate valves),
- Control gate valves (piston valves, spectacle valves, slide gate valves)
- Swing check valves (with lever and weight or with internal stem),
check valves (with diaphragm or discs), ball check valves
- Aeration and vent valves of various designs

18.2. KEY CRITERIA FOR SELECTING A VALVE

- Fluid handled
- Compatibility of design and function with the fluid handled
- Compatibility of materials with the fluid handled
- Nominal diameter depending on the flow velocity and the resulting head losses

The use of valves in wastewater applications requires a design that is suitable for handling fluids contaminated with coarse or clogging material as well as abrasive and other substances.

Such contamination requires the following design features, among others:

- Flow cross-section of the valves as clear as possible
- Clogging when the valve is actuated should be ruled out or largely prevented
- Suitable constructional features such as sealing design and material



[6]

GRINDER PUMPS AND PRESSURISED SYSTEMS

1. General

In 1960, the first prototype grinder pump was developed and with it the concept for collecting and disposing of domestic waste through pressurised sewer systems. Based on the favourable test result, the grinder pump concept was approved for use in a few states in the USA.

At about the same time, the US Environmental Protection Agency (EPA) developed an interest in methods for disposing of domestic waste for small communities and subdivisions as an alternative to onsite septic tank systems.

In the early 1970s, demonstration projects were installed in Pennsylvania, Oregon and Indiana. When pressurised sewer systems using grinder pumps became eligible for federal construction grants and in the mid-1970s, two submersible pump manufacturers designed a small grinder pump and began promoting the pressurised sewer system. This experimental concept for the collection and transport of domestic waste from the home to the sewage treatment facility is now a common practice.

2. Operation area

The physical size of the grinder pump and the integrated grinder system and low flow high head performance capacity are features that make grinder pumps unique. When pumping sewage at a flow less than 4-5 l/s and a required pump head higher than 5 m, a grinder pump should be considered.

2.1. SMALL DIAMETER PRESSURE PIPE

A pressurised sewer system consists of a small diameter discharge pipe interconnected to all building sites and is installed along the contour of the land, just below the ground level or below the frost line.

This ability to use small diameter pressure pipes as small as 40 mm, which gradually increases as more pumping stations are connected to the pressurised sewer, is the key factor in the attractiveness of the system. The pressurised sewer system using grinder pumps allows for property developments previously considered unsuitable. For this type of system to work, each building site on the sewer has a pumping station assembly that includes a grinder pump.



Fig. 1 Small diameter pressure pipe for pressurised systems.

2.2. PRESSURE VARIATION

The grinder pump – the heart of the system – can turn solids in the domestic waste into slurry and pump it through small pipes against the pressure in the sewer. That pressure varies due to the system design and the number of pumps that are operating simultaneously at any moment. The system pressure can be as high as 55 m head, but typically ranges between 7 m to 35 m of head, as it continuously varies during the day between peak inflow to the pumping station and off-peak periods.

3. Where to use pressurised sewer systems

Pressurised sewer systems are most cost-effective where housing density is low, where the terrain has undulations with relatively high relief, and where the system outfall must be at the same or a higher elevation than most or all of the service area.

Pressurised sewer systems can also be effective where flat terrain is combined with high groundwater or bedrock, making deep cuts or multiple lift stations excessively expensive. They can be cost-effective even in densely populated areas, where difficult construction or right-of-way conditions exist, or where the terrain will not accommodate gravity sewers.

Since pressure systems do not have the large excess capacity of conventional gravity sewers, they should be designed with a balanced approach, keeping future growth and internal hydraulic performance in mind.



Fig. 2 Pressurised sewer system with grinder pumps in a remote area with undulating ground.

3.1. ADVANTAGES

Pressurised sewer systems that connect several residences to a 'main' pumping station can be less expensive than conventional gravity systems. On-property facilities represent a major portion of the capital cost of the entire system and are shared in a cluster arrangement.

This can be an economic advantage, since on-property components are not required until a house is constructed and handed over to the homeowner. Low front-end investment makes the present-value cost of the entire system lower than that of conventional gravity sewerage, especially in new development areas where homes are built over many years.

Because wastewater is transferred under pressure, gravity flow is not necessary and the strict alignment and slope restrictions for conventional gravity sewers can be relaxed. Network layout does not depend on ground contours. Location of pipes is not important and extensions made in the street at a relatively small cost without damage to existing structures.

3.2. OTHER ADVANTAGES OF PRESSURISED SEWER SYSTEMS INCLUDE:

- Material and trenching costs are significantly lower because of reduced pipe size and depth requirements
- Low-cost clean outs and valve assemblies are used rather than manholes in a conventional system
- The user pays the electricity to operate the pump unit; the resulting increase in electric bills is small and may replace municipality or community bills for central pumping eliminated by the pressure system
- Because sewage is transported under pressure, more flexibility is allowed in siting final treatment facilities and may help reduce the length of outfall lines or treatment plant construction costs

4. Disadvantages

These systems require much institutional involvement, because the pressure system has many mechanical components throughout the service area.

The operation and maintenance cost for a pressure system is often higher than a conventional gravity system, due to the high number of pumps in use. However, lift stations in a conventional gravity sewer can reverse this situation.

Usually, preventive maintenance for grinder pumps in pressurised sewer systems takes place annually, whereas septic tank systems require pump-out at two to three year intervals.

Public education is necessary so the user knows how to deal with emergencies and how to avoid blockages or other maintenance problems.

The number of pumps that can share the same downstream force main is limited.

Power failure can result in overflows if standby generators are not available.

Life cycle replacement costs are expected to be higher, because pressurised sewer systems have a lower life expectancy than conventional systems.

Odours and corrosion are potential problems, because the wastewater in the pumping station is usually septic. Provide proper ventilation and odour control in the design and use non-corrosive components.

5. Grinder pumping station

The grinder pump is part of the pumping station assembly that also includes piping, auto-coupling, fittings, guide rails, valves, level sensors and operating controls.

The pumping station assembly usually is installed outdoors but can also be installed in a basement. Since it is installed 1.5 m to 4 m below terrain level, only the access cover and the electrical panel are located above terrain and often blend into the surroundings.

Grundfos prefabricated pumping stations allow for easy installation and provide a sturdy and well-designed polyethylene pump pit sized to suit requirements. Auto couplings are preinstalled, making it easy to mount up one or two SEG grinder pumps. In addition, all necessary components such as piping and valves in corrosion-resistant materials is a part of the package.

Grundfos has developed a Pumping Station Creator design tool for designing a pumping station in a matter of minutes. The Pumping Station Creator is available from Grundfos Product Center under 'tools'.

Dedicated controllers are included to ensure operational efficiency and required safety. A prefabricated package pump-ing station is delivered to the site pre-assembled for easy installation.



Fig. 3 Grundfos prefabricated pumping station with SEG grinder pump on auto-coupling



Fig. 4 Grundfos prefabricated pumping station for outdoor installation

6. Grinder pumps

Grundfos SEG grinder pumps are designed with a grinder system, which grinds solids in the domestic waste into small pieces so that they can be led away through discharge pipes of a relatively small diameter.

The pumps are made of wear-resistant materials, such as cast iron and stainless steel. These materials ensure reliable operation.

SEG grinder pumps for countries with 50 Hz power supply are available with motors of 0.9 kW and up to and including 4 kW. The nominal diameter of the pump discharge port is DN 40 or DN 50.

SEG grinder pumps for countries with 60 Hz power supply are available with motors of 1.5 kW and up to 4 kW. All motors are 2-pole motors.

All pumps are available for the following installations:

- Submerged installation on auto-coupling systems
- Submerged installation, freestanding

6.1. SEG CONSTRUCTION FEATURES

All pumps have the following features:

- Cable connection to motor via plug
- Corrosion-resistant cable entry filled with leakage proof polyurethane potting compound
- Clamp connection between motor and pump
- Cartridge shaft seal
- Heavy-duty bearings greased for life
- Patented grinder system ensuring extremely high efficiency and reliable operation
- SmartTrim system enabling quick and easy Impeller clearance adjustment in order to maintain peak performance

- Thermal switches built into the motor windings providing protection against overheating
- Explosion-proof motors for potentially explosive environments.



Fig. 5 Grundfos SEG grinder pump with design features

6.2. SEG AUTOADAPT ADDITIONAL FEATURES

The SEG AUTOADAPT pumps incorporate a controller, sensors and motor protection. The pump is ready for connection to the power supply.

The pumps offer the following benefits:

- Built-in level and dry-running sensors
- Built-in motor protection
- Pump alternation: If several pumps are installed in the same tank, the control logic incorporated in the pump will ensure that the load is distributed evenly among the pumps over time.
- Alarm relay output

The pump incorporates an alarm relay output. NC and NO are available and can be used as required, for example for acoustic or visual alarms. See table below for alarm parameters.

Alarm	Alarm log	Signal relay
Overvoltage	•	•
Undervoltage	•	•
Overload	•	•
Blocked motor/pump	•	•
Dry running	•	
Motor temperature	•	•
Electronics temperature (Pt1000)	•	•
Thermal switch 1 in motor	•	•
Thermal switch 2 in motor	•	•
Phase sequence reversed	•	•
High-level alarm	•	•
Sensor fault	•	•

- Random start delay in case of general power failure
- Pump does not start unless the phase sequence is correct
- Self-calibration after each pump cycle
- Anti-seizing function: The anti-seizing function starts the pump at programmed intervals to prevent the impeller from seizing up. This function will overrule the dry running sensor of non-Ex versions.
- After-run function (foam draining): The after-run function is used at programmed intervals if there is a risk of a floating layer.

To meet the demand for data communication, a Grundfos Communication Interface Unit (CIU) can be permanently or temporarily connected for changing the default settings, making further settings or reading the alarm log and operating parameters, such as number of starts and operating hours.



Fig. 6 Grundfos SEG AUTOADAPT grinder pump with design features

7. Design and layout of a pressurised sewer system

A pressurised sewer system differs from conventional gravity collection systems, because they use pumps instead of gravity to transport wastewater. The primary wastewater is running by traditional gravity to the collection tank in the pumping station, for grinding before pumping into the pressurised system. The pressurised sewer system is an effective solution in areas where traditional gravity systems are not available or impractical.

The main components of a pressurised sewer system with more than a single grinder pump connected are:

- Pumping station with collecting chamber
- Pump unit
- Pipework
- Valves, pipe joints, air compressor

7.1. DESIGN REQUIREMENTS

Pressurised systems should be designed according to national or local regulations such as the European standard EN1671 with recommendations for designing pressurised swage systems. Some of the requirements to be considered when designing a pressurised sewer system follow below.

7.2. PRESSURE PIPES

The pressure pipe should be equal or larger than the pump discharge.

The pipe size can increase in steps on the way from the pump to the discharge point. This would depend on the flow rate and distance to the discharge point. The dimension of the pressure pipe in the flow direction should be the same or larger, and not in the opposite direction.

7.3. MINIMUM VELOCITY

To reduce the possibility of sedimentation and to keep the self-cleaning function of the pipeline once or twice per day, a minimum velocity of 0.7 m/s is required.

7.4. MAXIMUM RETENTION TIME

The maximum retention time for the sewage in the pipe system is according to the European norm recommended as eight hours.

Reducing the retention time of the sewage in the system reduces the risk for development of H₂S and odour generation.

The retention time for the sewage in the pipe system can vary dependent on local or national regulations. The reason can be the nature of the wastewater, or the ambient temperature.

8. Emergency conditions

In case of power failure, the collecting chamber in the pumping station should have at least 25 % extra volume space above the pump start level to accumulate the exceeded inflow into the pit.

9. Power supply

There should be adequate power supply available at the site, so all the pumps can start after a power failure without overloading the system.

10. Valves

Depending on the shape of pressure pipe profile, it might be necessary to install air inlet or outlet valves.

For downhill pumping systems, installing a syphon breaker valve inside the pumping station is recommended.

11. Design of pressurised sewage systems

Sizing the pump and pipes depends on the inflow to the collecting chambers, distance to the discharge and number of pumps operating simultaneously.

There are two main approaches for designing a pressurised sewage system:

- Calculation of pressurised sewer systems
- Simulation of pressurised sewer systems

The designer should take any possible future expansion of the system into the consideration during designing stage.

11.1 CALCULATION OF THE SYSTEM NETWORK

Calculating the system network is the conventional way of designing pressurised sewage systems. In this method, the system is designed for extreme conditions such as highest flow, high static head and maximum number of pumps in simultaneous operation.

There are two main approaches for calculating the system network:

- The statistical method
- The peak flow method

The statistical method is a more accurate way of doing the calculation. The number of pumps in simultaneous operation in the system is estimated by probability rules, followed by manually defining the critical points in the system that will be used for later calculations.

In the calculations, the steady state with fully water-filled pipes is assumed, so the results for pumps would be shown as just one duty point.

Since a situation with all pumps running concurrently is rare and only can happen after power failure, there is no need to consider

this as an extreme condition for the system calculations.

11.2. SIMULATION OF THE SYSTEM NETWORK

This method uses transient analysis to simulate the reality of the system for specific periods.

For this type of simulation, special software is used to solve the complex equations along the time of operation period, and the simulated reality of the system shows how the pressure pipe fills with sewage and how the pumps interact with each other.

If the inflow data are accurate enough, this method provides a result closest to the reality, so it can output a histogram of the pump operation, which will show where the main duty point(s) are in the system and where pumps operate most of the time.

As this method simulates the system for a specific period, the system needs enough time to fill all the pressure pipes and collecting chambers in the pumping stations. Normally the simulation is done for one day to a week based on the system size and pipeline profile shape.

Another advantage of this method is that the water age (retention time) is estimated directly as an output of the analysis. The accuracy of retention time depends on the accuracy of the inflow to each collecting chamber in the pumping station.

Grundfos uses this method because it is the most accurate way of doing the calculation, and showing the customer benefits.

The SIMPS tool (SIMulation of Pressurised Systems) is developed for Grundfos and is not for pump or pipe selection, rather it is a system optimiser tool, meaning the first simulation is based on an initial best guess. In the following runs of the tool, the system is optimised based on the received results according to the EN1671 standard design criteria.



Fig. 7 Grundfos pressurised sewer system simulating software (SIMPS)

SIMPS output report contains the following results:

- Pump performance evaluation
- Pump operating histogram
- Pipe velocity
- Concurrent pump operation statistics
- Water quality (retention time)
- Estimated energy consumption

Following are some sample results out of the SIMPS, which would be included in the final simulation report. These results are extracted from a case in Sweden with 98 connected houses in the network.

Table 5 Pump operation result

Name	Start Level [m]	Stop Level [m]	Max. Velocity [m/s]	Average Flow [l/s]	Head at Average Flow [H]	No Pump Start [#]	Pump Operation [hh:mm:ss]	Pump Type [name]	Performance
Pump17	0.9	0.37	1.98	3.36	16.00	3	0:02:29	96878514 SEG.40.15.E.2.50B	😊
Pump1	0.9	0.37	1.25	2.63	29.63	3	0:03:10	96878518 SEG.40.31.E.2.50B	😊
Pump11	0.9	0.37	2.20	3.14	16.90	3	0:02:39	96878514 SEG.40.15.E.2.50B	😊

Table 6 Concurrent pump operations statistics

Number of pumps running concurrent	Percentage [%]
0	95.8
1	4.1
2	0.1
3	0.0

Table 7 Maximum pipe velocities

Name	Max Velocity [m/s]	Max Flow [l/s]	Performance
Pipe23	0.78	2.00	😊
Pipe2	1.69	3.00	😊
Pipe28	1.56	2.00	😊
Pipe22	1.98	3.00	😊
Pipe6	2	3.00	😊
Pipe24	2.26	3.00	😊

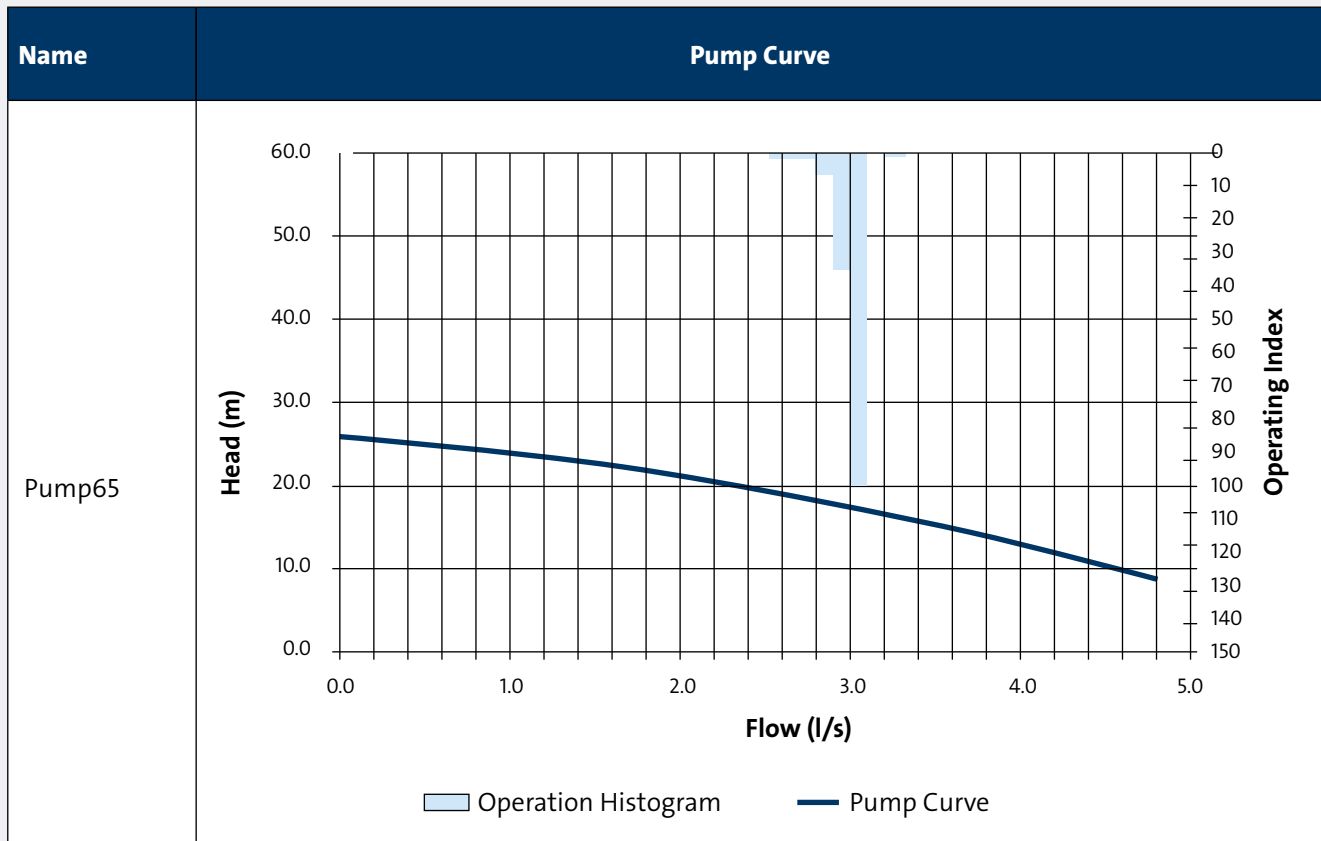
Table 8 Water quality summary

Name	Max Water Age [hour]
Pipe23	15.3
Pipe2	12.7
Pipe9	11.3
Pipe28	8.9
Pipe22	8.9

Table 9 Pump energy result summary

Name	Operation hours [hour/year]	Energy Consumption [kWh/year]	Energy Cost [SEK/year]
Pump17	15.1	30.3	30
Pump1	19.3	60.6	61
Pump4	10.8	38.3	38
Pump11	16.1	31.8	32

Table 10 Pump histogram curve



12. Operation and maintenance

Routine operation and maintenance requirements for grinder pump systems is minimal. Small systems that serve 300 or fewer homes do not usually require a full-time staff. Personnel from the municipal public works or highway department can perform service. Most maintenance activities involve responding to homeowner service calls usually for electrical control problems or pump blockages.

The inherent septic nature of wastewater in pressurised sewers requires that system personnel take appropriate safety precautions when performing maintenance to minimise exposure to toxic gases, such as hydrogen sulphide (H_2S), which may be present in the sewer lines, pump tip, or septic tanks. Odour problems may develop in pressurised sewer systems because of improper house venting. The addition of strong oxidising agents, such as chlorine or hydrogen peroxide, may be necessary to control odour where venting is not the cause of the problem.

Generally, it is in the best interest of the municipality and the homeowners, to have the municipality or the sewer utility to have responsibility for maintaining all system components. General easement agreements are needed to permit access to on-site components, such as pumping stations and grinder pump units on private property.



[7]

PREFABRICATED PUMPING STATIONS

1. General

In domestic and commercial wastewater systems and wastewater transport systems in general, a prefabricated pumping station is a cost-effective, flexible, and reliable alternative to traditional concrete solutions. With Grundfos pumping stations, you can add documented quality and full customisation in a modest or more complex system for collecting and transporting wastewater.

Grundfos offers a full range of functional modular pumping stations – complete with all necessary piping, valves, level controls and such like. A modular concept with increased sump volume. The pump pit, pumps and controls can be combined to suit specific requirements for each individual application.



Fig. 1 The range of corrosion-free polyethylene pumping stations.

Pumping stations for drainage, effluent and residential sewage are available in four diameters and ranging in depth from 1.5 m to 6 m. The different lengths make them suitable for various types of applications for drainage, effluent, sewage and grinder pumps, where gravity drainage or transport is neither possible nor economical.

2. Technical data:

Depth: 1.5 - 6.0 m

Outlet pipe size: DN40 - 100

Liquid temperature: Max. 40 °C

Pumping stations are made of corrosion-free polyethylene or glass-fibre-reinforced polyester. Pipes and valves are made of PE or stainless steel. Pumping stations are available with or without valve chamber for one pump or two pump execution.

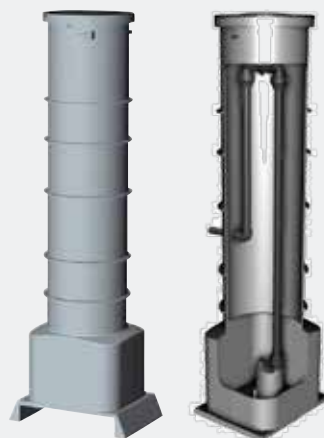


Fig. 2 Pumping stations for installation of one small drainage pump. Diameter of the main section 400 mm and sump dimension 500 x 500 mm



Fig. 3 Pumping stations for one or two pump installation. Main section diameter 600 mm, 800 mm and 1000 mm

3. Standard pumping station program:

All dimensions are in mm

Main section	Sump diam.	Total length			
		1500	2000	2500	3000
600	800	1500	2000	2500	3000
800	1000	1500	2000	2500	3000
1000 S	1200	x	2000	2500	3000
1000 D	1200	x	2000	2500	3000

1000 S is for a single pump installation
 1000 D is for a double pump installation



Fig. 4 Pumping station for single installation of a submersible SEG AUTOADAPT grinder pump on auto-coupling system. Sump diameter 800 and main section diameter 600 mm



Fig. 5 The nut in the sump bottom is used to hold the auto-coupling in the right position without fixation to the sump bottom

The pipe assembly with the auto-coupling can be lifted up without entering the pumping station.

Holes for inlet pipes, discharge pipe and cables and pipe for air release are positioned individually on-site by using a cup wheel cutter.

The light colour of the pit makes it easy to see the bottom of the tank without artificial light.



Fig. 6 Cup wheel cutters are available as an accessory to the pumping station



Fig. 7 Pumping stations for double installation of submersible sewage pumps on auto-coupling system. Sump diameter 1700 and main section diameter 1400 mm. Total length 2000 mm to 6000 mm

4. Unique pit design for reduced sludge and odour problems

The prefabricated pumping stations feature a benching bottom design with self-cleaning properties, as the slope guides the sewage to the pump inlet. This design minimises the risk of hydrogen sulphide creation, odour problems, clogging, and, in turn, maintenance costs.

5. Type of wastewater system

Prefabricated pumping stations are built to handle wastewater from residential, commercial, and industrial buildings as well as surface water from highways and roads. They are used in two main types of sewer systems:

5.1 GRAVITATION SEWER SYSTEMS

These pumping stations can be used as lifting stations in traditional gravitational networks as a cost-efficient, environmentally friendly, and highly reliable alternative to expensive concrete solutions – both in new-build and in refurbishment projects.



Fig. 8 Gravitation sewer system

5.2. PRESSURISED SEWER SYSTEMS

A pressurised sewer system is ideal for sparsely populated areas and areas where ground conditions make gravity installations too expensive.

Pressurised sewer systems is also ideal if a domestic or commercial building is located below sewer level or if there are obstacles between the building and the sewer mains which make the gravitation system impossible.

A prefabricated pumping station fitted with SEG grinder pumps prevent clogging in the narrow pipes of these systems.

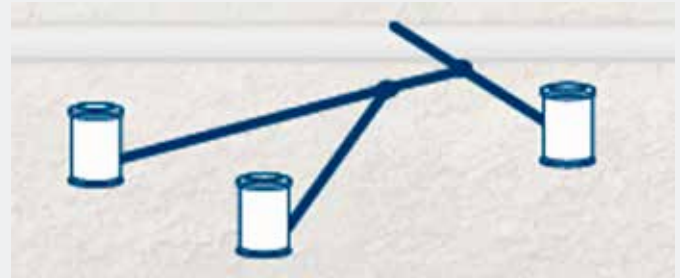
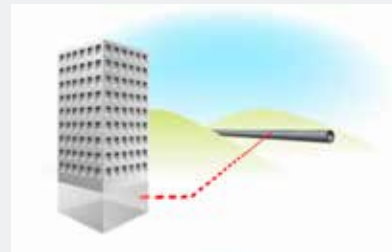


Fig. 9 Pressurised sewer system

5.3. A PRESSURISED SYSTEM IS NECESSARY WHEN



1. A building is located downhill in relation to the sewer main



2. If there is too long a distance to the sewer main.



3. If there are obstacles between the building and the sewer main

6. Installation.

The installation of pumping stations must be carried out by an authorised person in accordance with local regulations. Work in or near wastewater pits must be carried out according to local regulations.

With reference to DS/EN 1997 – 1: Eurocode 7: Geotechnical Category 2, we recommend that you complete a geotechnical investigation of the site conditions before you install the pit.

With reference to DS/EN 1997 – 1: Eurocode 7: Geotechnical Category 1, the geotechnical investigation can be judged to be unnecessary, if the conditions below are fulfilled:

- There is a negligible risk of overall instability, ground movements or adverse ground conditions
- Comparable local experience show that the ground conditions are sufficiently uncomplicated
- There is no excavation below the water table
- Comparable local experience indicates that the proposed excavation below the water table will be uncomplicated

If in doubt, consult a geotechnical specialist.

6.1. INSTALLATION OF SMALL PUMPING STATIONS, WITH MAIN SECTION OF 400 MM TO 1000 MM

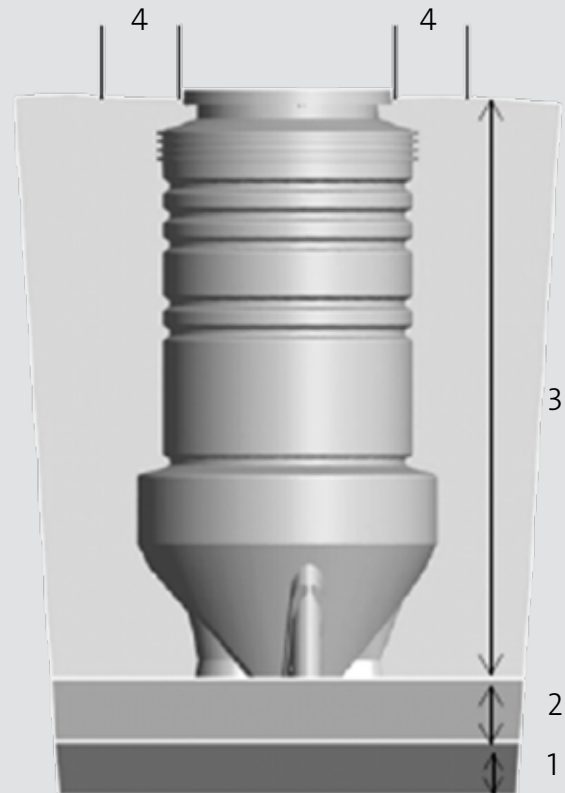


Fig. 10 Schematic installation drawing

Pos.	Description
1	Foundation layer
2	Bedding layer
3	Backfill, compacted in layers of maximum 300 mm
4	Distance of 500 mm from cover where heavy traffic loads must not occur

6.2. BUOYANCY PREVENTION

The pumping station design ensures that the pumping station is protected against buoyancy if installed correctly.

The broad sump shoulders keep the station in the ground without concreting. This ensures the downward forces are larger than the upward forces.

It is important to follow the instructions for installation described in the installation manual for the pumping station. Requirements for buoyancy prevention depend on the geotechnical conditions as determined by the engineer or construction contractor and are outside Grundfos' area of responsibility.

6.3. FOUNDATION LAYER

The bottom of the excavation for a pumping station must have a foundation layer if soil analyses and information about pumping station load shows that the subsoil is not capable of bearing the load. The bedding layer, on which the pumping station is placed, is not regarded as a foundation layer.

Following excavation, laying the foundation requires a stable layer of suitable base gravel or similar material and compacting it in layers of maximum 300 mm (corresponding to approximately 200 mm after compaction). Such a foundation layer is also required if the excavation is mistakenly dug too deep.

6.4. BEDDING LAYER

The material for the bedding layer must be compactible and composed so that neither its properties nor compaction will cause damage to the pumping station.

- Grains larger than 16 mm must not be present
- The content of grains between 8 mm and 16 mm must not exceed 10 %
- The material must not be frozen
- Sharp flint etc. must not be present

- The bedding layer must usually have a thickness of 100 mm

If the foundation layer meets these requirements, a bedding layer is not required.

6.5. BACKFILL

The backfill must provide sufficient support of the lift station on all sides and ensure that the load can be transferred without detrimental point impacts or similar impacts.

- The backfill must meet the same requirements as those for the bedding layer
- The backfilling must be carried out so that the pumping station is not damaged or deformed
- The backfill must be compacted in layers of maximum 300 mm, corresponding to approximately 200 mm after compaction

6.6. DISTANCE FROM COVER

The distance from cover, where heavy traffic loads occur must not be less than 500 mm.

7. Large pumping stations

Pumping stations for sewage and stormwater are available in seven different diameters from 1200 mm to 3000 mm and ranging in depth from 2 to 8 m. The standard execution has a lockable hatch with built-in safety features, such as anti-slip roughing on the cover, an elevated hatch frame to prevent accidental falls, and safety grid. Traffic covers are also available up to class D - 40 Ton.

7.1. TECHNICAL DATA

Diameter: D1200, D1400, D1600, D1800, D2000, D2200 and D3000 mm
Depth: 2 to 8 m (12 m on request)

Outlet pipe size: DN 50 - DN 250

Liquid temperature: max. 40 °C

Made of glass-fibre-reinforced plastic (GRP), pipes and valves made of PE or stainless steel, with or without valve chamber.



Fig. 11 Pumping station in diameter 1800 mm for double installation of submersible SE sewage pumps on auto-coupling system

High quality non-return valves and gate valves are an integrated part of the package for pumping stations without valve chambers.

Optional valve chambers with non-return valves and gate valves are available for all large pumping stations, meaning there is no need to enter the pump pit to service the valves. All valve chambers come with a drainage pipe.



Fig. 12 Valve chamber for a double pump installation

8. Installation of large pumping stations



Fig. 13 Schematic installation drawing

Pos.	Description
1	Foundation layer
2	Concrete slab
3	Backfill compacted in layers of maximum 50 cm
4	Distance of 50 cm from cover where heavy loads must not occur

8.1 FOUNDATION LAYER

The bottom of the hole must have a foundation layer if soil analyses and information about pit load show that the bottom is not capable of bearing the weight.

The foundation layer can be made after the excavation by laying a stable layer of suitable gravel or similar material and compacting it in layers of maximum 50 cm. Such a foundation layer is also required if the excavation is mistakenly dug too deep.

8.2. FOUNDATION SLAB

We recommend that the concrete used meets:

- Strength class C40/50-2
- Exposure class XC4
- Water-to-cement ratio ≤ 0.45
- Maximum chloride content 0.4 %
- Reinforcement B500B
- Maximum angle of inclination 25°

Maximum water absorption by mass 6 %



Fig. 14 Pouring of concrete slab on site

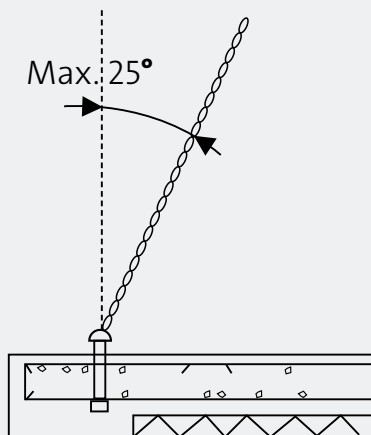


Fig. 15 Maximum inclination angle of lifting chain for lifting prefabricated concrete slab.

Make sure that the foundation slab is in level before installing the pit. Each anchor bolt must be able to withstand 20 kN (2000 kg) in a tensile test.

If the foundation slab is to be cast on site, see the data booklet 98697625 casting dimensions. The document is available in Grundfos Product Center.

If the foundation slab is cast on site, the surface of the slab must be rubbed down to a smooth surface.

8.3. INSTALLING THE PUMPING STATION

Clean the surface of the foundation slab, make sure nothing can get between the foundation slab and the mounting flange of the pumping station.

Lift the pumping station by the lifting lugs and place it in the middle of the circle of anchoring bolts on the foundation slab.

Position the pit correctly so that the flanges are in the right direction for inlet and outlet pipes.



Fig. 16 Lowering the pit

In pits with diameters of 2.0, 2.2 or 3.0 m, with outlet pipes above DN 150 and with 2 holes in the bottom of the pit, fill the hollow space below the bottom of the pit with concrete to avoid vibrations. See Fig. 17.

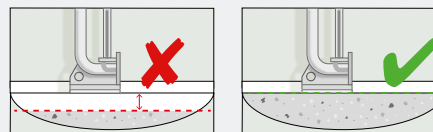
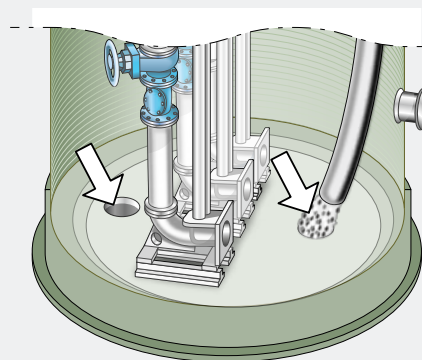


Fig.17 How to fill the hollow space with concrete



Fig. 18 Placing the mounting brackets

8.4. BACKFILL

Do not use plate compactors at a distance of less than 30 cm from the pit wall.

The backfill must provide sufficient support for the pit on all sides and ensure that the load can be transferred without detrimental point impacts or similar impacts.

For the backfill material, use compactable gravel or sand with an even fraction size. Do not exceed a maximum fraction size of 32 mm. Make sure the pit is not damaged or deformed while carrying out the backfilling.

The backfill must be compacted in layers of maximum 50 cm.



Fig. 19 Compacted layers of maximum 50 cm

Compact the backfill under the inlet and outlet pipes properly so that they are not exposed to downward loads when the backfill settles.

8.5. INSTALLING THE VALVE CHAMBER

Follow the same instructions as for the installation of the pumping station.



Fig. 20 Valve chamber

8.6. CONNECTING THE PIPES

Compact the backfill around the valve chamber up to the lower part of a pipe connection, before connecting the pipe.

Before connecting the pipes, the gaskets must be clean and ensure the inlet pipe is properly aligned with the pipe connection.

For more details, see the installation manual and instructions delivered with the pumping station and the valve chamber.

8.7. PUMPING STATION CREATOR

Grundfos has developed a Pumping Station Creator design tool for designing a pumping station in a matter of minutes. The Pumping Station Creator is available from Grundfos Product Center under 'tools'.

The Pumping Station Creator will help you:

- Size a pumping station solution including pumps and controls
- Get full documentation including 3D drawings of the station
- Full CE certification for the solution



How the pumping station creator works

1. Input your requirements > choose your flow
2. Select a solution > Select a basic solution to build on
3. Configure & Customise > Customise the basic solution to your specific requirements
4. Pick your accessories > Fine-tune the design with the perfect accessories
5. Print or e-mail your order > see the final solution with full documentation

[8]

MULTILIFT LIFTING STATIONS

1. General

Multilift lifting stations are all-in-one solutions designed for the collection and pumping of effluent and sewage (black and grey wastewater) from selected sanitary appliances. These appliances may be in a single room, a complete floor or an entire building of any size, from a single-family house up to a huge shopping mall. Multilift lifting stations come in many versions of different size and performance.

Lifting stations are designed for placement inside a building with their discharge pipes connected to the wastewater collecting lines for the building.

The Multilift unit consists of a gas, odour and pressure-tight tank, a wastewater pump dry installed outside the tank, level sensor, controller and non-return valve.

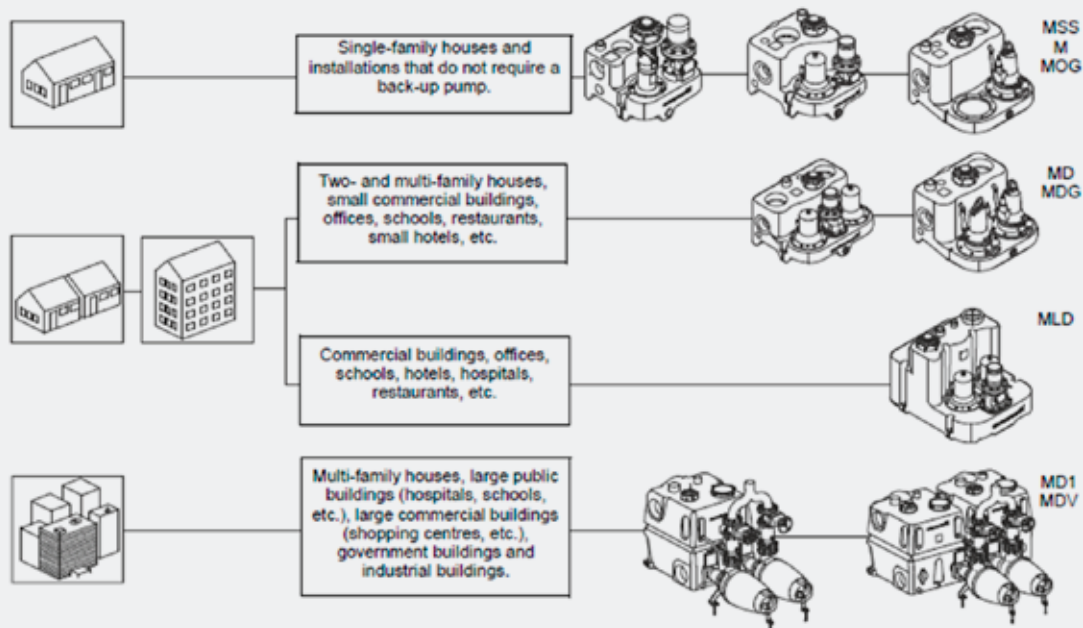
In spite of the compact design and the dry installed pumps, lifting stations are able to handle a large amount of domestic wastewater.

Usually, Multilift lifting stations are installed in basements situated below the municipal sewer system outside the building. This means pumping the wastewater up above the backflow level. Depending on local regulations, this is normally the street level.

Lifting stations are the only safe system to ensure uninterrupted, sustained discharge of wastewater from basements into sewer lines, which can be overloaded for example by heavy rainfall.

The application overview below shows typical installation sites for Multilift lifting stations.

Fig. 1 Application overview



2. Description

Multilift lifting stations collect wastewater in a tank for discharge up to the sewer system. Sensors in the tank measure the liquid level and send signals to the controller. The pumps start and stop according to the liquid level in the tank.

In double-pump lifting stations, the pumps start alternately to achieve even distribution of operating hours. Automatic pump

changeover ensures uninterrupted wastewater transport in case of a fault in one pump. One pump must be able to discharge 100 % of the inflow in commercial buildings. In case the inflow exceeds the performance of one pump, the second pump will start, and the two pumps will operate in parallel to lower the liquid level in the tank.

3. General operating information

The flow of wastewater is uneven when seen over a period, for instance an hour or a day, as shown in Fig. 2.

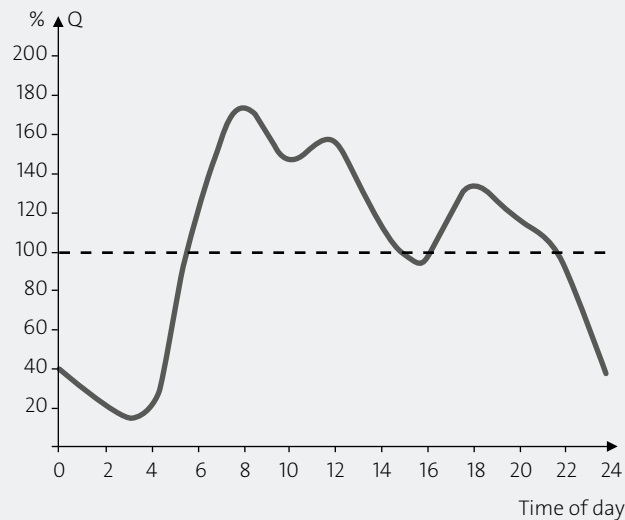


Fig. 2 Uneven wastewater flow from a residential building. This looks different when from a hospital, sports arena, or restaurant

Fig. 2 shows the typical wastewater flow from a residential building over a day, also called the daily profile.

In the morning, around lunchtime and in the evening, the wastewater flow is higher than average. The pump(s) must be able to handle the peak flow for certain, rather short, periods when several sanitary appliances are in use at the same time.

To be able to select the right tank size, it is important to know the wastewater peak flow from all connected sanitary appliances over one hour [l/h].

The motors used for Multilift lifting stations are designed for intermittent duty. This means they can run for a certain period and then need to stop for a certain period to avoid overheating and automatic switch-off by the motor protection.

Most of the Multilift pumps are designed for intermittent duty (S3) with the designation S3 50 % - 1 minute. This means that an operating cycle is 1 minute and within this cycle the pumps can operate 50 % = 30 seconds and then need 30 seconds stop. This can be repeated 60 times per hour, meaning that one pump can empty the lifting station tank up to 60 times per hour.

This, and not the performance of the individual pump, determines the total drain capacity of a lifting station. This is shown in the tables next page.

The tables below illustrate that the maximum drain capacity over one hour depends on the effective tank volume and the selected inlet level.

Lifting station	Peak flow performance***			Max. effective tank volume [l]	Max. drain capacity* [l/h] = Max. inflow	
	DN 40 [l/s]	DN 80 [l/s]	DN 100 [l/s]		1 pump**	with 2 pumps running
Multilift MSS	n/a	3.5 - 8	5.6 - 8	28	1,680	n/a
Multilift M	n/a	3.5 - 16	5.6 - 16	62	3,720	n/a
Multilift MOG	0.5 - 4.5	n/a	n/a	50	3,000	n/a
Multilift MD	n/a	3.5 - 16	5.6 - 16	86	5,160	10,320
Multilift MLD	n/a	3.5 - 16	5.6 - 16	190	11,400	22,800
Multilift MDG	0.5 - 4.5	n/a	n/a	50	3,000	6,000
Multilift MD1/MDV	n/a	3.5 - 18	5.6 - 28	240 - 720	14,400	28,800

* Conditions: Uneven inflow, values are independent of the duty point and valid for the highest starting level

** Recommended values for sizing of double-pump stations to secure 100 % backup

*** Depending on the duty point with one-pump operation

Lifting station	Max. number of pump starts per hour	Effective tank volume [l] depending on inlet pipe level and related pump start level				Max. drain capacity* [l/h] = max. inflow [l/h] depending on inlet pipe level and related pump start level			
		180 mm	250 mm	315 mm	560/750 mm	180 mm	250 mm	315 mm	560/750 mm
Multilift MSS	60	20	28	n/a	n/a	1,200	1,680	n/a	n/a
Multilift M	60	34	49	62	n/a	2,040	2,940	3,720	n/a
Multilift MOG	60	23	37	50	n/a	1,380	2,220	3,000	n/a
Multilift MD	60	49	69	86	n/a	2,940	4,140	5,160	n/a
Multilift MDG	60	23	37	50	n/a	1,380	2,220	3,000	n/a
Multilift MLD	60	n/a	n/a	n/a	190	n/a	n/a	n/a	11,400
Multilift MD1/MDV, 1 tank	60	n/a	n/a	n/a	240	n/a	n/a	n/a	14,400
Multilift MD1/MDV, 2 tanks	60	n/a	n/a	n/a	480	n/a	n/a	n/a	28,800
Multilift MD1/MDV, 3 tanks	60	n/a	n/a	n/a	720	n/a	n/a	n/a	43,200

* Uneven inflow, values are independent of duty point for double-pump stations, only one pump included to secure backup

Note: The values in the tables above always represent the maximum performance of one pump. This also applies to double-pump lifting stations, as pump 2 is 100 % backup in case of malfunction in pump 1.

Do not connect rainwater drainpipes to lifting stations because of the unpredictable volume of water. Only Multilift MD1/MDV with Grundfos SE pumps is designed for continuous operation in dry installation and can handle uncontrollable wastewater inflow.

4. Sizing

Sizing of Multilift lifting stations is done in two steps:

In step 1, the required pump capacity is determined to make sure the pump can handle the peak flow when several sanitary appliances are in use at the same time and drained into the lifting station. The pump capacity enables selection of pump size, as all Multilift lifting stations, except Multilift MSS, come with a range of six or more motor sizes, making it possible to select a Multilift tailored to the specific need in the building.

In step 2, the required tank size is selected. The Multilift range includes different tank sizes to enable the best possible adaptation of the lifting station to the specific need. As shown in the tables above, the tank size with related effective tank volume and the number of starts and stops determines how much wastewater can be handled in one hour or in one day.

For both sizing steps, it is essential to know the type of sanitary appliances and how many of them are connected to the lifting station. If other devices are connected, consider them as well.

The calculation of the inflow parameters must take into consideration the different regulations and standards in each country.

All Grundfos Multilift lifting stations are designed according to The European norm EN 12050-1 and approved by an external institute.

5. Typical applications

Multilift lifting stations are for indoor installation. They are extremely compact units with easy-to-operate controllers for collecting and pumping of domestic wastewater with toilet waste from single-family houses, holiday cottages, restaurants, commercial buildings, offices, schools, hotels, hospitals etc.

Typically, Multilift lifting stations are used for:

- Basement installation below sewer level
- Renovation or modernisation of existing buildings, for example developing basements with fitness room, sauna, bath, washroom, etc.
- Temporary installations such as mobile homes, houseboats, mobile toilets for concerts, etc.

6. Multilift MSS

Multilift type MSS is supplied complete and ready to install, with or without non-return valve if use of an external valve is desired.



Fig. 3 Multilift MSS with and without non-return valve



Fig. 4 Example of installation of Multilift MSS behind a floor-standing toilet with horizontal outlet according to The European norm EN33/EN37

6.1. APPLICATIONS

Multilift MSS is a compact lifting station with a single pump

and with an easy-to-operate controller for collecting and pumping of domestic wastewater with toilet waste from single-family houses or holiday cottages.

Fig.5 shows the sizing guide with maximum length of vertical and horizontal pipes with nominal diameter DN 80 and DN 100. The non-return valve, the isolating valve and four bends are included. The limit of use is due to the self-cleaning velocity of 0.7 m/s. Normal length of pipework in single-family houses or similar buildings is approximately 5-15 m.

7 m	-	-	-	-	-	-	DN100	MSS.12.3.4
	113	-	-	-	-	-	DN80	
	-	-	-	-	-	-	DN100	MSS.12.1.4
	53	-	-	-	-	-	DN80	
6 m	-	-	-	-	-	-	DN100	MSS.12.3.4
	225	135	-	-	-	-	DN80	
	-	-	-	-	-	-	DN100	MSS.12.1.4
	175	95	-	-	-	-	DN80	
5 m	-	-	45	-	-	-	DN100	MSS.12.3.4
	335	115	5	-	-	-	DN80	
	-	-	-	-	-	-	DN100	MSS.12.1.4
	275	80	-	-	-	-	DN80	
4 m	-	-	175	60	-	-	DN100	MSS.12.3.4
	275	185	45	11	-	-	DN80	
	-	-	105	6	-	-	DN100	MSS.12.1.4
	245	145	25	-	-	-	DN80	
3 m	-	-	335	195	32	-	DN100	MSS.12.3.4
	345	255	95	55	4	-	DN80	
	-	-	255	125	-	-	DN100	MSS.12.1.4
	305	215	75	32	-	-	DN80	
2 m	-	-	480	330	125	-	DN100	MSS.12.3.4
	650	320	140	95	33	-	DN80	
	-	-	380	260	70	-	DN100	MSS.12.1.4
	600	280	120	75	18	-	DN80	
1 m	-	-	600	500	210	50	DN100	MSS.12.3.4
	750	390	320	150	60	10	DN80	
	-	-	550	400	150	10	DN100	MSS.12.1.4
	680	350	280	120	45	0	DN80	

Qp [l/s]	4.5	5.5	6	7	8.5
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↑ Required min. flow for v = 0.7 m/s at DN 100
 ↑ Required min. flow for v = 0.7 m/s at DN 80

Fig. 5 Maximum length of vertical and horizontal discharge pipes

6.2. TECHNICAL DATA FOR MULTILIFT MSS

Parameter	Value
Free passage	50 mm
Liquid temperature	Max. 40 °C For short periode up to 60 °C (max. 5 minutes per hour)
Ambient temperature	0 - 40 °C
pH-value	4 - 10
Max. density of pump liquid	1,100 kg/m ³
Flood conditions	Max. 2 m for 7 days
Enclosure class (lifting station and motor)	IP68
Enclosure class (controller)	IP56
Insulation class (motor)	F (155 °C)
Voltage (motor)	1 x 230 V, 3 x 400 V
Frequency (motor)	50 Hz
Potential-free contacts	NO/NC. max. 250 VAC / 2 A
Voltage (sensor)	12 V
Signal output (sensor)	0 - 5 V
Power consumption (controller)	2 W

7. Multilift M

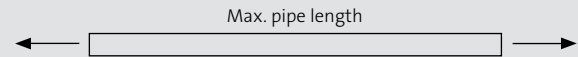
Multilift type M is supplied complete and ready to install with non-return valve.



Fig. 5 Multilift M with non-return valve

7.1. APPLICATIONS

Multilift M is a compact lifting station with a single pump and an easy-to-operate controller for collecting and pumping domestic wastewater with toilet waste from single-family houses, or light commercial applications.



Max. pipe length	85	-	-	-	-	-	-	DN100	M.38
15 m	85	-	-	-	-	-	-	DN100	M.38
	385	200	42	-	-	-	-	DN100	M.38
13 m	115	-	-	-	-	-	-	DN100	M.32
	680	415	180	94	30	-	-	DN100	M.38
11 m	415	210	34	-	-	-	-	DN100	M.32
	980	630	330	209	120	13	-	DN100	M.38
9 m	710	425	178	88	20	-	-	DN100	M.32
	175	60	-	-	-	-	-	DN100	M.24
	1280	850	475	325	215	75	-	DN100	M.38
7 m	1010	640	325	198	115	-	-	DN100	M.32
	475	275	56	-	-	-	-	DN100	M.24
	220	110	49	-	-	-	-	DN100	M.22
5 m	1575	1075	620	440	310	140	40	DN100	M.38
	1310	860	470	320	205	70	-	DN100	M.32
	770	490	208	100	28	-	-	DN100	M.24
	520	330	194	135	90	35	5	DN100	M.22
	265	155	63	30	-	-	-	DN100	M.15
	160	70	-	-	-	-	-	DN100	M.12
3 m	1875	1280	765	495	405	200	92	DN100	M.38
	1605	1075	615	435	300	135	42	DN100	M.32
	1070	705	345	215	122	15	-	DN100	M.24
	815	545	338	250	183	105	57	DN100	M.22
	565	370	208	145	98	30	-	DN100	M.15
	460	285	143	88	51	-	-	DN100	M.12
2 m	2025	1390	837	610	450	235	118	DN100	M.38
	1755	1180	685	490	348	170	68	DN100	M.32
	965	650	410	275	230	140	83	DN100	M.22
	710	480	280	208	145	65	18	DN100	M.15
	605	395	215	145	98	30	-	DN100	M.12

Qp [l/s]	5.5	6.5	8	9	10	12	14
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↑
Required min. flow for v = 0.7 m/s at DN 100

Fig. 6 Maximum length of vertical and horizontal discharge pipes

Fig. 6 shows the sizing guide with maximum length of vertical and horizontal pipes with nominal diameter DN 100. The non-return valve, an isolating valve and four bends are included.

The limit of use is due to the self-cleaning velocity of 0.7 m/s. Normal length of pipework in single-family houses or similar buildings is approximately 5-15 m.

7.2. TECHNICAL DATA FOR MULTILIFT M

Parameter	Value
Free passage	50 mm
Liquid temperature	Max. 40 °C For short periode up to 60 °C (max. 5 minutes per hour)
Ambient temperature	0 - 40 °C
pH-value	4 - 10
Max. density of pump liquid	1,100 kg/m ³
Enclosure class (lifting station and motor)	IP68 (2 m water column for 7 days)
Enclosure class (controller)	IP56
Insulation class (motor)	F (155 °C)
Voltage (motor)	1 x 230 V 3 x 230 V 3 x 400 V
Frequency (motor)	50 Hz
Potential-free contacts	NO/NC. max. 250 VAC / 2 A
Voltage (sensor)	12 V
Signal output (sensor)	0 - 5 V

8. Multilift MOG

Multilift type MOG is supplied complete and ready to install. Multilift MOG is furnished with a grinder pump type SEG, which is necessary if the application is for a relatively small amount of wastewater but requires high discharge head due to the resistance in long pressure pipes through a building or from the building to the recipient.



Fig. 7 Multilift MOG without non-return valve

8.1. APPLICATIONS

Multilift MOG is a compact lifting station with an easy-to-operate controller for collecting and pumping of domestic wastewater with toilet waste from single-family houses, holiday cottages or light commercial applications.

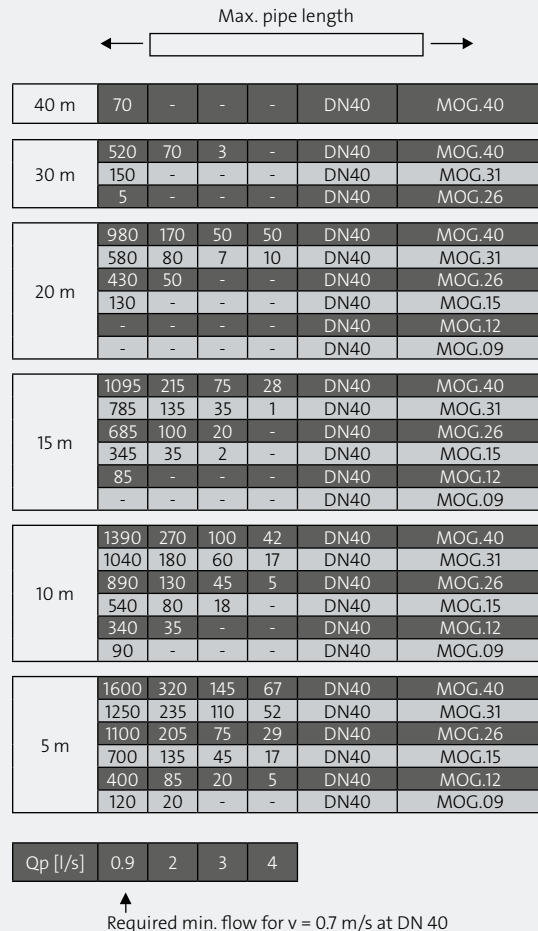


Fig. 8 Maximum length of vertical and horizontal discharge pipes

Fig. 8 shows the sizing guide with maximum length of vertical and horizontal pipes with nominal diameter DN 40. The non-return valve, the isolating valve and four bends are included. The limit of use is due to the self-cleaning velocity of 0.7 m/s.

Normal length of pipework in single-family houses or similar buildings is approximately 5-15 m.

8.2. TECHNICAL DATA FOR MULTILIFT MOG

Parameter	Value
Free passage	Grinder system
Liquid temperature	Max. 40 °C For short periode up to 60 °C (max. 5 minutes per hour)
Ambient temperature	0 - 40 °C
pH-value	4 - 10
Max. density of pump liquid	1,100 kg/m ³
Enclosure class (lifting station and motor)	IP68 (2 m water column for 7 days)
Enclosure class (controller)	IP56
Insulation class (motor)	F (155 °C)
Voltage (motor)	1 x 230 V 3 x 230 V 3 x 400 V
Frequency (motor)	50 Hz
Potential-free contacts	NO/NC. max. 250 VAC / 2 A
Voltage (sensor)	12 V
Signal output (sensor)	0 - 5 V
Power consumption (controller)	2 W
Number of starts per hour	Max. 60

9. Multilift MD

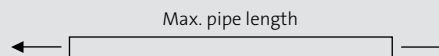
Multilift MD is supplied complete with two pumps, and butterfly non-return valve, ready to install.



Fig. 9 Multilift MD

9.1. APPLICATIONS

Multilift MD is a compact lifting station with an easy-to-operate controller for collecting and pumping of domestic wastewater with toilet waste from multi-family houses as well as in public and commercial buildings, such as offices, schools, hotels and restaurants.



15 m	85	-	-	-	-	-	-	DN100	MD.38
	385	200	42	-	-	-	-	DN100	MD.38
13 m	115	-	-	-	-	-	-	DN100	MD.32
	680	415	180	94	30	-	-	DN100	MD.38
11 m	415	210	34	-	-	-	-	DN100	MD.32
	980	630	330	209	120	13	-	DN100	MD.38
9 m	710	425	178	88	20	-	-	DN100	MD.32
	175	60	-	-	-	-	-	DN100	MD.24
	1280	850	475	325	215	75	-	DN100	MD.38
7 m	1010	640	325	198	115	-	-	DN100	MD.32
	475	275	56	-	-	-	-	DN100	MD.24
	220	110	49	-	-	-	-	DN100	MD.22
	1575	1075	620	440	310	140	40	DN100	MD.38
5 m	1310	860	470	320	205	70	-	DN100	MD.32
	770	490	208	100	28	-	-	DN100	MD.24
	520	330	194	135	90	35	5	DN100	MD.22
	265	155	63	30	-	-	-	DN100	MD.15
	160	70	-	-	-	-	-	DN100	MD.12
	1875	1280	765	495	405	200	92	DN100	MD.38
3 m	1605	1075	615	435	300	135	42	DN100	MD.32
	1070	705	345	215	122	15	-	DN100	MD.24
	815	545	338	250	183	105	57	DN100	MD.22
	565	370	208	145	98	30	-	DN100	MD.15
	460	285	143	88	51	-	-	DN100	MD.12
	2025	1390	837	610	450	235	118	DN100	MD.38
2 m	1755	1180	685	490	348	170	68	DN100	MD.32
	1220	815	418	275	168	50	-	DN100	MD.24
	965	650	410	307	230	140	83	DN100	MD.22
	710	480	280	204	145	65	18	DN100	MD.15
	605	395	215	145	98	30	-	DN100	MD.12

Qp [l/s]	5.5	6.5	8	9	10	12	14
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↑
Required min. flow for $v = 0.7$ m/s at DN 100

Fig. 10 Maximum length of vertical and horizontal discharge pipes

Fig. 10 shows the sizing guide with maximum length of vertical and horizontal pipes with nominal diameter DN 100. The non-return valve, the isolating valve and four bends are included. The limit of use is due to the self-cleaning velocity of 0.7 m/s.

9.2. TECHNICAL DATA FOR MULTILIFT MD

Parameter	Value
Free passage	50 mm
Liquid temperature	Max. 40 °C For short periode up to 60 °C (max. 5 minutes per hour)
Ambient temperature	0 - 40 °C
pH-value	4 - 10
Max. density of pump liquid	1,100 kg/m ³
Enclosure class (lifting station and motor)	IP68 (2 m water column for 7 days)
Enclosure class (controller)	IP56
Insulation class (motor)	F (155 °C)
Voltage (motor)	1 x 230 V 3 x 230 V 3 x 400 V
Frequency (motor)	50 Hz
Potential-free contacts	NO/NC. max. 250 VAC / 2 A
Voltage (sensor)	12 V
Signal output (sensor)	0 - 5 V

10. Multilift MLD

Multilift type MLD is supplied complete with two pumps, and butterfly non-return valve, ready to install.



Fig. 11 Multilift MLD

10.1. APPLICATIONS

Multilift MLD is a compact lifting station with an easy-to-operate controller for collecting and pumping of residential wastewater with toilet waste from multi-family houses as well as from public and commercial buildings, such as offices, schools, hotels and restaurants.

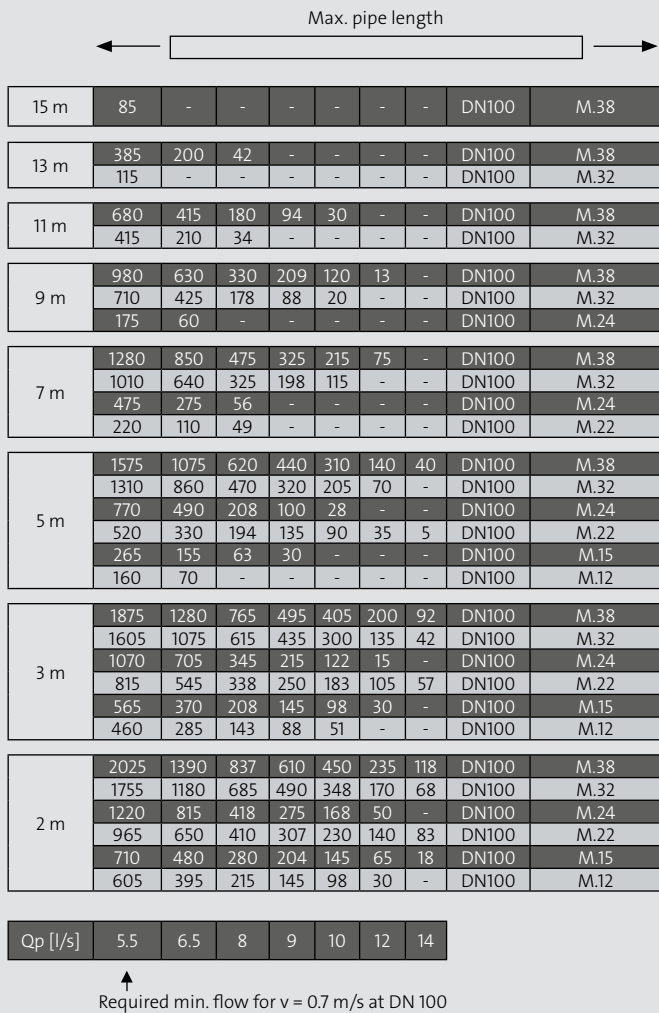


Fig. 12 Maximum length of vertical and horizontal discharge pipes

Fig. 12 shows the sizing guide with maximum length of vertical and horizontal pipes with nominal diameter DN 100. The non-return valve, the isolating valve and four bends are included. The limit of use is due to the self-cleaning velocity of 0.7 m/s.

10.2. TECHNICAL DATA FOR MULTILIFT MLD

Parameter	Value
Free passage	50 mm
Liquid temperature	Max. 40 °C For short periode up to 60 °C (max. 5 minutes per hour)
Ambient temperature	0 - 40 °C
pH-value	4 - 10
Max. density of pump liquid	1,100 kg/m ³
Enclosure class (lifting station and motor)	IP68 (2 m water column for 7 days)
Enclosure class (controller)	IP56
Insulation class (motor)	F (155 °C)
Voltage (motor)	1 x 230 V 3 x 230 V 3 x 400 V
Frequency (motor)	50 Hz
Potential-free contacts	NO/NC. max. 250 VAC / 2 A
Voltage (sensor)	12 V
Signal output (sensor)	0 - 5 V

11. Multilift MDG

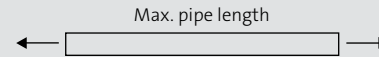
Multilift type MLD is supplied complete with two grinder pumps, type SEG, which are necessary if the application is for a relative small amount of wastewater but requires high discharge head due to the resistance in long pressure pipes through a building or from the building to the recipient.



Fig. 13 Multilift MDG.

11.1. APPLICATIONS

Multilift MDG is a compact lifting station with an easy-to-operate controller for collecting and pumping of domestic wastewater with toilet waste from multi-family houses as well as from public and commercial buildings, such as offices, schools, hotels and restaurants.



40 m	70	-	-	-	DN40	MDG.40
30 m	520	70	3	-	DN40	MDG.40
	150	-	-	-	DN40	MDG.31
	5	-	-	-	DN40	MDG.26
20 m	980	170	50	50	DN40	MDG.40
	580	80	7	10	DN40	MDG.31
	430	50	-	-	DN40	MDG.26
	130	-	-	-	DN40	MDG.15
	-	-	-	-	DN40	MDG.12
	-	-	-	-	DN40	MDG.09
15 m	1095	215	75	28	DN40	MDG.40
	785	135	35	1	DN40	MDG.31
	685	100	20	-	DN40	MDG.26
	345	35	2	-	DN40	MDG.15
	85	-	-	-	DN40	MDG.12
	-	-	-	-	DN40	MDG.09
10 m	1390	270	100	42	DN40	MDG.40
	1040	180	60	17	DN40	MDG.31
	890	130	45	5	DN40	MDG.26
	540	80	18	-	DN40	MDG.15
	340	35	-	-	DN40	MDG.12
	90	-	-	-	DN40	MDG.09
5 m	1600	320	145	67	DN40	MDG.40
	1250	235	110	52	DN40	MDG.31
	1100	205	75	29	DN40	MDG.26
	700	135	45	17	DN40	MDG.15
	400	85	20	5	DN40	MDG.12
	120	20	-	-	DN40	MDG.09

Qp [l/s]	0.9	2	3	4
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↑
Required min. flow for v = 0.7 m/s at DN 40

Fig. 14 Maximum length of vertical and horizontal discharge pipes

Fig. 14 shows the sizing guide with maximum length of vertical and horizontal pipes with nominal diameter DN 40. The non-return valve, the isolating valve and four bends are included.

The limit of use is due to the self-cleaning velocity of 0.7 m/s. Normal length of pipework in single-family houses or similar buildings is approximately 5-15 m.

11.2. TECHNICAL DATA FOR MULTILIFT MDG

Parameter	Value
Free passage	Grinder system
Liquid temperature	Max. 40 °C For short periode up to 60 °C (max. 5 minutes per hour)
Ambient temperature	0 - 40 °C
pH-value	4 - 10
Max. density of pump liquid	1,100 kg/m ³
Enclosure class (lifting station and motor)	IP68
Enclosure class (controller)	IP56
Insulation class (motor)	F (155 °C)
Voltage (motor)	1 x 230 V 3 x 230 V 3 x 400 V
Frequency (motor)	50 Hz
Potential-free contacts	NO/NC. max. 250 VAC / 2 A
Voltage (sensor)	12 V
Signal output (sensor)	0 - 5 V
Power consumption (controller)	2 W
Number of starts per hour	Max. 60

12. Multilift MD1 and MDV

Multilift MD1 and MDV are supplied complete and ready to install with non-return valve.



Fig. 15 Multilift MD1 and MDV.

12.1. APPLICATIONS

Multilift MD1 and MDV are lifting stations with an easy-to-operate controller for collecting and pumping of domestic wastewater with toilet waste from large-scale multi-family houses as well as in public and commercial buildings, such as offices, schools, hotels and restaurants.

Typically, Multilift MD1 and MDV are used for:

- Basement installation below sewer level
- Renovation or modernisation of existing buildings, e.g. developing basements with fitness room, sauna, bath, washroom, etc.

22 m	85	-	-	-	-	-	DN100	MDV.65.80.40
	22	-	-	-	-	-	DN 80	
20 m	385	39	-	-	-	-	DN100	MDV.65.80.40
	116	-	-	-	-	-	DN 80	
16 m	980	415	48	-	-	-	DN100	MDV.65.80.40
	305	125	-	-	-	-	DN 80	
13 m	1425	695	220	-	-	-	DN100	MDV.65.80.40
	445	215	66	-	-	-	DN 80	
	385	48	-	-	-	-	DN100	MDV.65.80.30
	116	-	-	-	-	-	DN 80	
9 m	2025	1070	450	158	19	-	DN100	MDV.65.80.40
	635	335	138	46	-	-	DN 80	
	980	425	71	-	-	-	DN100	MDV.65.80.30
	305	129	19	-	-	-	DN 80	
	415	58	-	-	-	-	DN100	MDV.65.80.22
	125	13	-	-	-	-	DN 80	
6 m	2470	1350	625	275	103	13	DN100	MDV.65.80.40
	780	420	192	83	30	-	DN 80	
	1430	705	245	37	-	-	DN100	MDV.65.80.30
	450	218	73	9	-	-	DN 80	
	860	340	42	-	-	-	DN100	MDV.65.80.22
	270	102	10	-	-	-	DN 80	

Qp [l/s]	5.5	7	9	11	13	15
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Fig. 16

Fig. 16 shows the sizing guide for Multilift MDV.65.80, with maximum length of vertical and horizontal pipes depending on the internal pipe diameter and the duty point. The limit of use is due to the self-cleaning velocity of 0.7 m/s. DN 80 pipework requires a flow of minimum 3.5 l/s and DN 100 pipework requires a flow of minimum 5.5 l/s.

The non-return valve, an isolating valve and four bends are included.

Max. pipe length

22 m	-	-	-	-	-	-	-	-	-	DN100	MD1.80.80.75	
	26	-	-	-	-	-	-	-	-	DN80		
20 m	-	280	20	-	-	-	-	-	-	DN100	MD1.80.80.75	
	120	83	-	-	-	-	-	-	-	DN80		
16 m	-	875	200	50	-	-	-	-	-	DN100	MD1.80.80.75	
	310	270	60	-	-	-	-	-	-	DN80		
13 m	-	1320	340	114	46	18	-	-	-	DN100	MD1.80.80.75	
	450	415	104	33	13	-	-	-	-	DN80		
	-	830	178	44	-	-	-	-	-	DN100	MD1.80.80.55	
	300	255	53	-	-	-	-	-	-	DN80		
	-	220	-	-	-	-	-	-	-	-	DN100	MD1.80.80.40
	97	64	-	-	-	-	-	-	-	DN80		
9 m	-	1920	530	200	94	49	27	15	-	DN100	MD1.80.80.75	
	640	605	163	60	27	14	-	-	-	DN80		
	-	1425	365	129	54	25	10	-	-	DN100	MD1.80.80.55	
	490	445	11	38	15	-	-	-	-	DN80		
	-	815	182	46	10	-	-	-	-	-	DN100	MD1.80.80.40
	285	245	54	12	-	-	-	-	-	DN80		
	-	385	23	-	-	-	-	-	-	-	DN100	MD1.80.80.30
	139	116	16	-	-	-	-	-	-	-	DN80	
	-	295	-	-	-	-	-	-	-	-	DN100	MD1.80.80.20
	120	88	-	-	-	-	-	-	-	-	DN80	
	6 m	-	2365	670	260	130	73	44	27	16	DN100	MD1.80.80.75
		785	745	205	80	39	21	-	-	-	DN80	
-		1875	505	193	90	48	26	13	-	-	DN100	MD1.80.80.55
630		590	155	58	26	13	-	-	-	-	DN80	
-		1260	325	110	46	20	7	-	-	-	DN100	MD1.80.80.40
430		395	98	32	12	-	-	-	-	-	DN80	
-		830	200	65	20	-	-	-	-	-	DN100	MD1.80.80.30
280		260	60	18	-	-	-	-	-	-	DN80	
-		740	164	42	6	-	-	-	-	-	DN100	MD1.80.80.20
260		230	48	11	-	-	-	-	-	-	DN80	
-		190	6	-	-	-	-	-	-	-	DN100	MD1.80.80.15
78		54	-	-	-	-	-	-	-	-	DN80	
3 m		-	2810	810	325	166	96	60	39	25	DN100	MD1.80.80.75
		925	885	250	100	50	28	-	-	-	DN80	
	-	2320	645	255	126	71	43	25	-	-	DN100	MD1.80.80.55
	775	730	200	78	37	21	-	-	-	-	DN80	
	-	1710	465	174	82	43	23	12	-	-	DN100	MD1.80.80.40
	570	535	142	52	24	12	-	-	-	-	DN80	
	-	1275	340	129	56	25	-	-	-	-	DN100	MD1.80.80.30
	425	400	104	38	16	6	-	-	-	-	DN80	
	-	1190	305	106	41	-	-	-	-	-	DN100	MD1.80.80.20
	405	370	92	31	11	-	-	-	-	-	DN80	
	-	635	145	42	-	-	-	-	-	-	DN100	MD1.80.80.15
	220	195	42	11	-	-	-	-	-	-	DN80	

Q [l/s]	3.5	5.5	10	15	20	25	30	35	40
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↑
Required min. flow for v = 0.7 m/s at DN 100

Fig. 17 shows the sizing guide for Multilift MD1.80.80 with maximum length of vertical and horizontal pipes depending on the internal pipe diameter and the duty point. The limit of use is due to the self-cleaning velocity

22 m	22	-	-	-	-	-	-	-	-	-	-	-	-	DN 100	MD1.80.100.75
20 m	310	20	-	-	-	-	-	-	-	-	-	-	-	DN 100	MD1.80.100.75
16 m	-	-	450	120	-	-	-	-	-	-	-	-	-	DN 150	MD1.80.100.75
	900	205	48	-	-	-	-	-	-	-	-	-	-	DN 100	
	-	-	-	-	-	-	-	-	-	-	-	-	-	DN 150	MD1.80.100.55
	380	37	-	-	-	-	-	-	-	-	-	-	-	DN 100	
13 m	-	-	965	420	188	74	15	-	-	-	-	-	-	DN 150	MD1.80.100.75
	1350	345	112	45	18	-	-	-	-	-	-	-	-	DN 100	
	-	-	415	102	-	-	-	-	-	-	-	-	-	DN 150	MD1.80.100.55
	830	178	44	-	-	-	-	-	-	-	-	-	-	DN 100	
	-	-	-	-	-	-	-	-	-	-	-	-	-	DN 150	MD1.80.100.40
	220	-	-	-	-	-	-	-	-	-	-	-	-	DN 100	
9 m	-	-	1655	810	440	250	147	86	42	10	-	-	-	DN 150	MD1.80.100.75
	1950	505	197	94	50	27	15	-	-	-	-	-	-	DN 100	
	-	-	1105	500	240	110	42	-	-	-	-	-	-	DN 150	MD1.80.100.55
	1430	365	129	55	25	10	-	-	-	-	-	-	-	DN 100	
	-	-	435	125	9	-	-	-	-	-	-	-	-	DN 150	MD1.80.100.40
	815	178	46	9	-	-	-	-	-	-	-	-	-	DN 100	
	-	-	22	-	-	-	-	-	-	-	-	-	-	DN 150	MD1.80.100.30
	310	42	-	-	-	-	-	-	-	-	-	-	-	DN 100	
	-	-	-	-	-	-	-	-	-	-	-	-	-	DN 150	MD1.80.100.22
280	18	-	-	-	-	-	-	-	-	-	-	-	DN 100		
6 m	-	-	2175	1110	635	385	245	162	102	59	24	7	-	DN 150	MD1.80.100.75
	2400	675	260	130	73	43	26	17	-	-	-	-	-	DN 100	
	-	-	1620	790	430	245	141	78	34	-	-	-	-	DN 150	MD1.80.100.55
	1875	505	193	91	48	26	14	6	-	-	-	-	-	DN 100	
	-	-	950	420	195	88	22	-	-	-	-	-	-	DN 150	MD1.80.100.40
	1260	320	110	46	19	7	-	-	-	-	-	-	-	DN 100	
	-	-	540	210	54	-	-	-	-	-	-	-	-	DN 150	MD1.80.100.30
	755	182	59	20	-	-	-	-	-	-	-	-	-	DN 100	
	-	-	400	83	-	-	-	-	-	-	-	-	-	DN 150	MD1.80.100.22
	725	160	42	6	-	-	-	-	-	-	-	-	-	DN 100	
	205	9	-	-	-	-	-	-	-	-	-	-	-	DN 100	MD1.80.100.15

4 m	-	-	2515	1305	765	475	315	215	142	91	51	30	DN 150	MD1.80.100.75
	2700	770	300	154	88	54	35	23	-	-	-	-	DN 100	
	-	-	1965	990	560	335	205	131	74	34	-	-	DN 150	MD1.80.100.55
	2170	600	235	115	63	37	22	13	-	-	-	-	DN 100	
	-	-	1295	615	320	177	88	40	8	-	-	-	DN 150	MD1.80.100.40
	1560	410	152	70	35	18	7	-	-	-	-	-	DN 100	
	-	-	880	405	180	88	19	-	-	-	-	-	DN 150	MD1.80.100.30
	1050	275	102	44	18	7	-	-	-	-	-	-	DN 100	
	-	-	725	280	99	16	-	-	-	-	-	-	DN 150	MD1.80.100.22
	1025	250	84	29	8	-	-	-	-	-	-	-	DN 100	
	-	-	210	33	-	-	-	-	-	-	-	-	DN 150	MD1.80.100.15
500	103	19	-	-	-	-	-	-	-	-	-	DN 100		

2 m	-	-	2860	1500	890	565	380	265	183	124	78	52	DN 150	MD1.80.100.75
	3000	860	345	178	104	65	43	29	-	-	-	-	DN 100	
	-	-	2310	1185	685	420	275	180	115	67	-	-	DN 150	MD1.80.100.55
	2460	695	275	140	79	47	30	19	-	-	-	-	DN 100	
	-	-	1640	810	450	265	154	91	48	-	-	-	DN 150	MD1.80.100.40
	1860	505	195	94	50	29	15	8	-	-	-	-	DN 100	
	-	-	1230	605	310	177	85	42	-	-	-	-	DN 150	MD1.80.100.30
	1350	370	144	68	33	18	7	2	-	-	-	-	DN 100	
	-	-	1090	475	225	105	32	-	-	-	-	-	DN 150	MD1.80.100.22
	1325	345	127	53	23	9	-	-	-	-	-	-	DN 100	
	-	-	555	230	80	7	-	-	-	-	-	-	DN 150	MD1.80.100.15
800	196	61	22	5	-	-	-	-	-	-	-	DN 100		

Q_p [l/s]	5.5	10	15	20	25	30	35	40	45	50	55	60
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↑
Required min. flow for v = 0.7 m/s at DN 100

12.2. TECHNICAL DATA FOR MULTILIFT MD1 AND MDV

Parameter	Value
Free passage	65 mm and 80 mm
Liquid temperature	Max. 40 °C. For short periode up to 60 °C (max. 5 minutes per hour)
Ambient temperature	0 - 40 °C
pH-value	4 - 10
Max. density of pump liquid	1,100 kg/m ³
Enclosure class (lifting station and motor)	IP68
Enclosure class (controller)	IP56
Insulation class (motor)	F (155 °C)
Voltage (motor)	3 x 400 V
Frequency (motor)	50 Hz
Potential-free contacts	NO/NC. max. 250 VAC / 2 A
Voltage (sensor)	12 V
Signal output (sensor)	0 - 5 V
Power consumption (controller)	2 W
Number of starts per hour	Max. 60
Sound pressure level	< 70 dB (A)
Dimension (lifting station)	See section Dimensional drawings on page 136
Dimension (controller for ≤ 4 kW)	Height = 390 mm, Width = 262 mm, Depth = 142 mm
Dimension (controller for > 4 kW)	Height = 680 mm, Width = 380 mm, Depth = 350 mm

Fig. 18 shows the sizing guide for Multilift MD1.80.100 with maximum length of vertical and horizontal pipes depending on the internal pipe diameter and the duty point. The limit of use is due to the self-cleaning velocity of 0.7 m/s. DN 100 pipework requires a flow of min. 5.5 l/s and DN 150 pipework requires a flow of min. 10 l/s. The non-return valve, an isolating valve and four bends are included.

13. Accessories in general

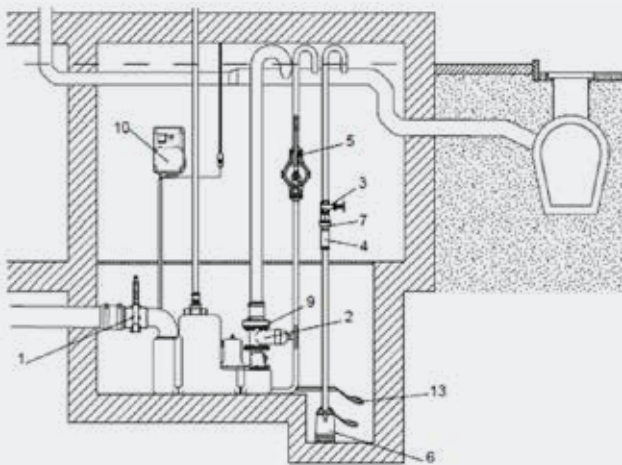


Fig. 19 Examples of accessories

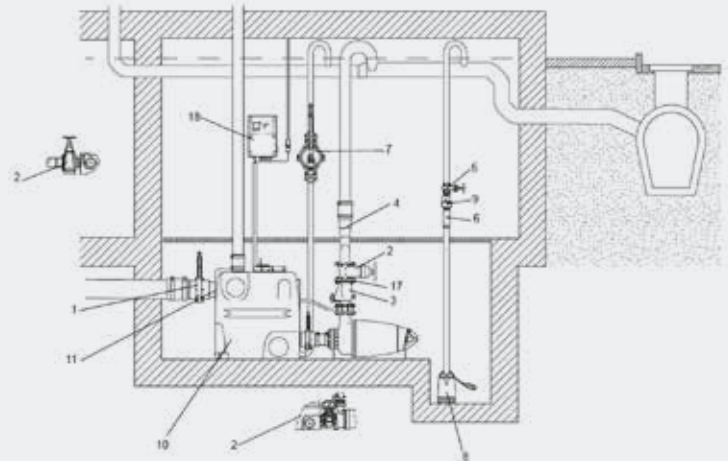


Fig. 20 Examples of accessories for MD1 and MDV

No.	Description of general accessories
1	Isolating valve PVC
2	Isolating valve, cast iron
3	Isolating valve, brass
4	Flexible connection with clamps
5	Manuel diaphragm pump
6	Wastewater pump type Unilift
7	Non-return valve, composite
8	Bolts and nuts, 8 for each flange
9	Battery buffer for alarm
10	Signal lamp for wall mounting
11	Signal horn
12	Level switch type SAS

13.1. ACCESSORIES MD1 AND MDV

No.	Description
1	Isolating valve PVC
2	Isolating valve cast iron
3	Non-return flap valve cast iron
4	Isolating valve PVC
4	Isolating valve PVC
5	Isolating valve cast iron
6	Non-return flap valve cast iron
7	Isolating valve PCC
8	Isolating valve cast iron
9	Non-return flap valve cast iron
10	Breeches pipe with flexible connections and clamps
11	Isolating valve brass
12	Flexible connection with clamps
13	Manual diaphragm pump
14	Wastewater pump type Unilift
15	Non-return flap valve composite
16	Extra PE tank with connections, lids, sealings and anchor bolts
17	Sockets for additional standard inlet DN 150
18	Extra lip seal for lower inlet to the tank
19	Hole-saw Ø 177
20	Centre drill
21	Flange with socket for PVC pipe
22	Flange-hose unit in cast iron with flexible connections
23	Bolts and nuts, 8 for each flange
24	Battery buffer for alarm

14. Installation in general

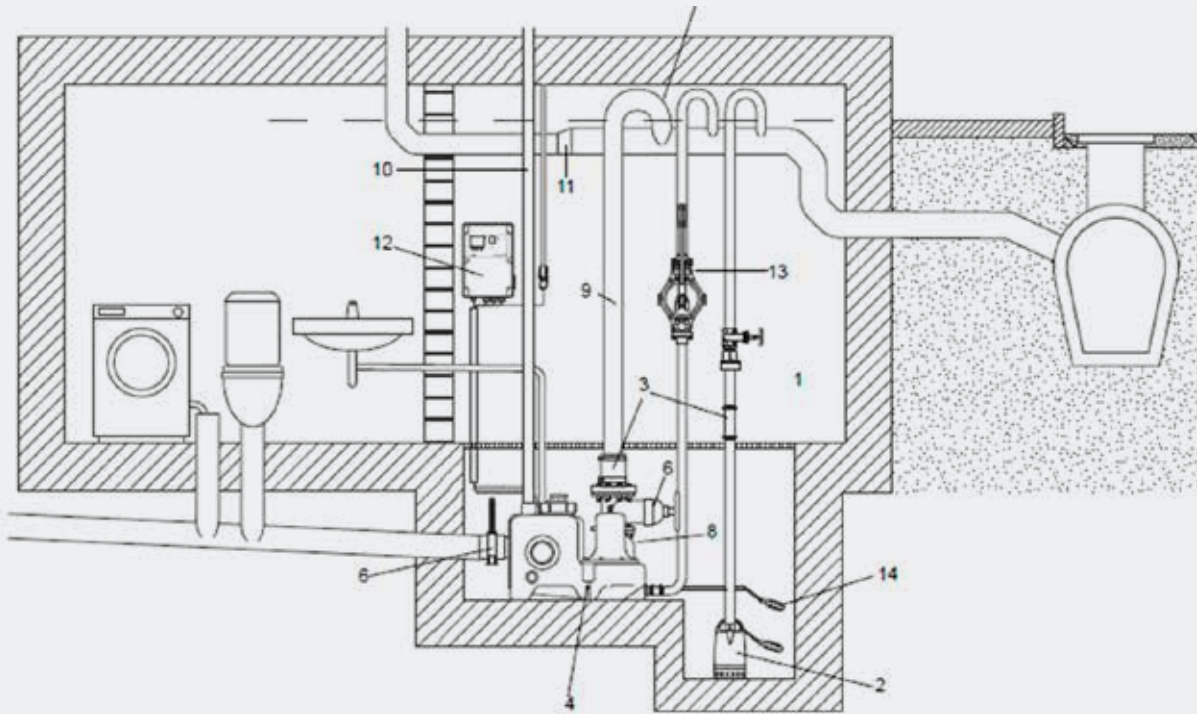


Fig. 21 Installation example of a Multilift station

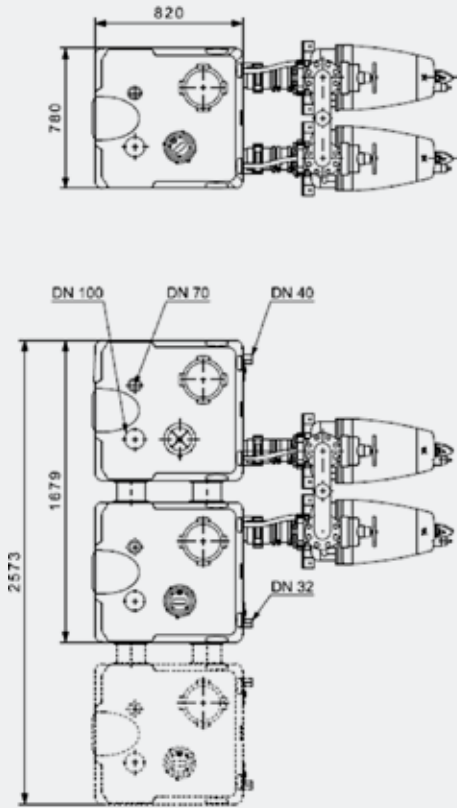


Fig. 22 Installation example for Multilift stations MD1 and MDV with one, two or three collecting tanks

Correct installation of a lifting station according to the European norm EN 12056-4 requires compliance with the following instructions: (See position numbers in Fig. 21).

1. Installation in a properly illuminated and vented room with 60 cm free space for all parts to be serviced and operated.
2. A pump pit must be provided for the drainage of the room. If a lifting station is installed in a basement with the risk of penetrating groundwater, it is advisable (in certain countries required) to install a drainage pump in a separate pump pump below floor level.
3. All pipe connections must be flexible and reduce resonance.
4. Lifting stations must be secured against buoyancy and twist..
5. All discharge pipes (lifting station, diaphragm pump and drainage pump) must have a bend above the local backwater level. The highest point of the goose neck/reversed water seal must be above street level.
6. Discharge pipes, DN 80 and larger requires an isolating valve in the discharge pipe and at the inlet to the tank.
7. Surface water is not allowed to be drained into the lifting station inside the building. It should have its own pumping station outside the building. (Not shown in drawing).
8. Lifting stations must be provided with an approved non-return valve according to the European norm EN 12050-4.
9. The volume of the discharge pipe above the non-return valve up to the backwater level must be less than the effective tank volume.
10. In general, a lifting station for wastewater with toilet waste should be vented above roof level. It is permitted to lead the ventilation, as a secondary ventilation, into the main ventilation. Special venting valves (accessory) should be placed outside the building.
11. If the wastewater is discharged into a collecting sewer line, this collecting line must have a filling ratio of at least $h/d = 0.7$. The collecting line must be at least one nominal diameter bigger after the discharge pipe connection.
12. The controller of the lifting station must be placed in a flood safe place and be equipped with an alarm.
13. Use a diaphragm pump for simple, manual draining of the collecting tank in case of pump failure (not obligatory).

15. Additional float switch

An additional float switch can be connected to the alarm input for extra safety. Please check and follow local and required regulations and standards.

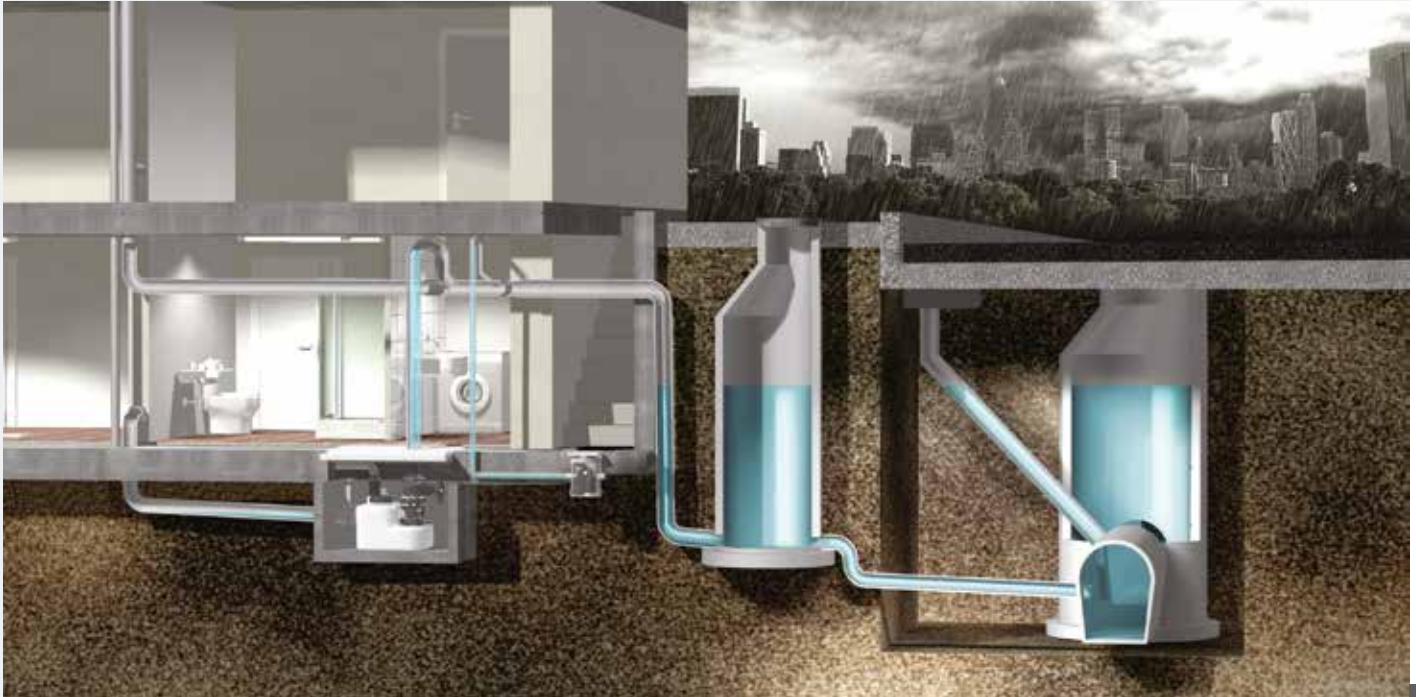


Fig. 23 Water backflow event during a heavy rainfall. Here the water does not enter the building because the lifting station's pressure pipe is looped above the highest backflow level (street level) and it is furthermore supplied with a non-return valve.

[9]

CAVITATION AND NPSH

1. Cavitation

When water flows through a pipeline, the static pressure can be measured anywhere in the pipe with the help of a manometer. If the velocity of water is increased (increased capacity or decreased pipe dimension) the static pressure is reduced, as shown in Fig. 1.

If the velocity of water becomes sufficiently high, the static pressure can become so low that the water starts to boil.



Fig. 1

The phenomenon occurs because the boiling point of water is variable. Water usually boils at 100 °C, but only under conditions of normal pressure i.e. 760 mm quicksilver column or approximately 10 m water column. This is the usual pressure at sea level.

At higher altitudes, for example in mountainous areas, the air pressure is lower, meaning that water can boil at temperatures as low as 90 °C. A good case in point is that eggs cannot boil at the top of Mount Everest. This is because the water boils at such a low temperature that the egg white simply does not stiffen.

In this context, the water in the pipeline behaves as if it was on top of the mountain. When static pressure decreases, the temperature at which boiling occurs is lowered. Fig. 2 illustrates the correlation between the boiling point and the static pressure of water; or to be even more correct – the curve shows the water’s steam pressure as a function of its temperature.

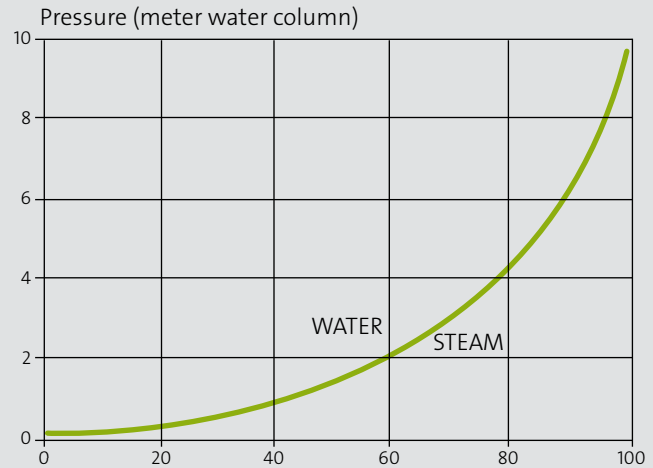


Fig. 2 Shows that water with a temperature of 60 °C is transformed into steam – boils – when the pressure is approximately 2 m water column (absolute). We can also see that water at 30-40 °C or lower is transformed into steam at very low pressures.

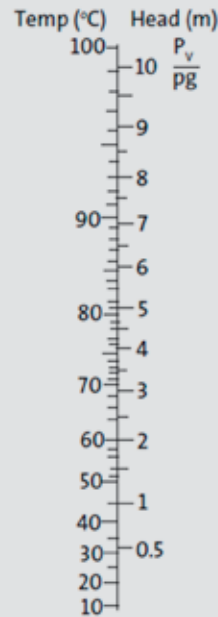


Fig. 3 Temperature in proportion to meter head

1.1. HOW STEAM PRESSURE AFFECTS PUMPING

What influence does the water's steam pressure (boiling) have in a pumping situation?

The relationship is shown in Fig. 4, which in practice corresponds to Fig. 2. Inside the pump, the water has to pass through channels that are normally considerably smaller than the pipelines to which it is connected. This causes the velocity of the water in the channels to become considerably higher than in the pipelines. The narrowest sections are usually at the inlet to the impeller, and so it is here that the static pressure is lowest.

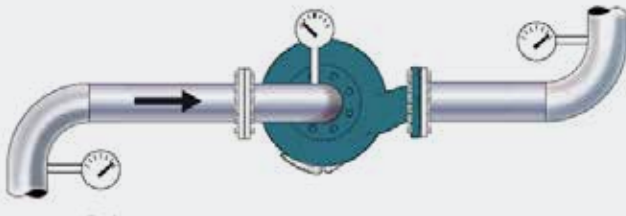


Fig. 4

There is also a risk that water here transforms into steam – a risk that increases as the water temperature rises. If steam forms, the pump is said to be cavitating – i.e. forming hollows in the liquid (cavitate comes from the Latin word *Cavus*, which means hollow).

1.2. NARROWER CHANNELS MEAN GREATER LIQUID VELOCITIES

The steam bubbles formed at the impeller's inlet point follow the water through the pump. After the inlet point, the channel inside the pump becomes wider, which means that the static pressure is increased. The static pressure in the impeller is usually already at a level where the conditions for steam formation are no longer present.

The steam bubbles formed in the inlet are once again transformed into water. The transformation happens very suddenly and takes the form of an implosion, i.e. the opposite of an explosion.

At the implosion, a very distinct banging noise can be heard. The impact from the implosion can cause severe damage, mostly in the impeller. Such damage is called cavitation erosion or pitting.

1.3. CAVITATION CAN SPREAD

Cavitation is not necessarily restricted to the impeller inlet point. If the parameters for static pressure and temperature change in an unfavourable way, the cavitation zone will be expanded. Fig. 5 shows the onset of cavitation in the impeller's inlet, while Fig. 6 is a fully developed case of cavitation.



Fig. 5 Typical cavitation pitting on the backside of the impeller



Fig. 6 Typical cavitation at the inlet to the impeller

1.4. CAVITATION AFFECTS PUMP CAPACITY

Even a relatively low amount of cavitation will have a negative impact on the pump's QH curve. That is because the steam bubbles take up space and disturb the flow through the pump, which in turn leads to a reduction of capacity as well as of the lifting height. See Fig. 7.

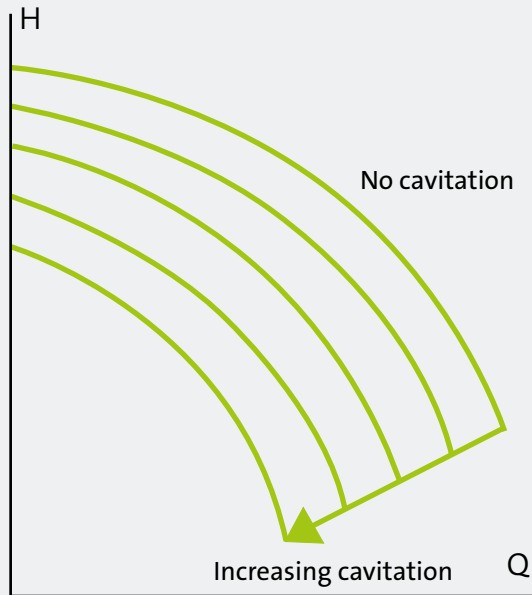


Fig. 7

2. NPSH and cavitation

So at what pressure limit does cavitation begin in a pump? This is shown in the curves from the pump supplier. In addition to the pump performance curve, efficiency curve, and power consumption curve, there is also find a so-called NPSH curve. (NPSH is a US term widely used in pump circles and stands for Net Positive Suction Head). See Fig. 8.

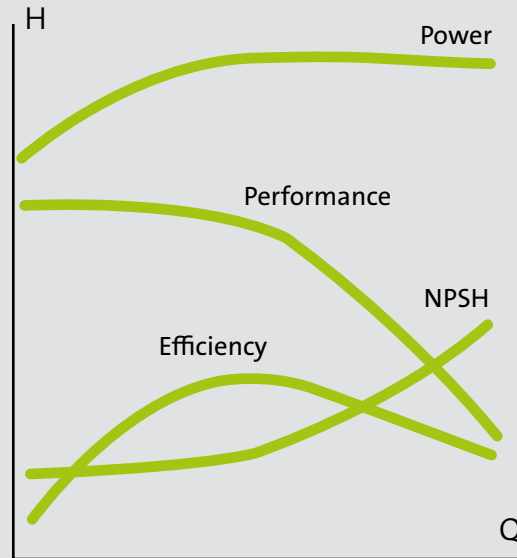


Fig. 8

The NPSH curve describes how high the absolute total pressure – besides the fluid's steam pressure – must be in the pump's inlet during pumping to avoid cavitation.

For water with a temperature of 40 °C or lower, the steam pressure has such a low value that it need not concern us. Here, the NPSH curve gives us the allowed minimum pressures directly. For water of higher temperatures – or for liquids with higher steam pressure (such as petrol) – subtract the steam pressure from the NPSH curve.

As shown in Fig 8, the required NPSH increases as capacity increases.

2.1. WHAT IS THE AVAILABLE NPSH?

Knowing the required NPSH value is not enough, though – we also need to know the available NPSH, meaning the pressure usually found in the inlet pipe stub. The pressure is determined by whether the pump is working with inlet pressure or suction height, pressure loss in the pipe in the suction side, valves, bends, straight pipes and so on.

Overall, the available NPSH must be larger than or equal to the required NPSH to avoid cavitation.

$$(NPSH) \text{ Available} \geq NPSH \text{ (required)}$$

2.2. CALCULATING REQUIRED AND AVAILABLE NPSH

What follows is a full explanation of how (NPSH) available and (NPSH) required are calculated.

A couple of examples will follow at the end. When determining the required as well as the available NPSH, both values must be attributed to the same reference level on the pump.

In pumps for horizontal dry pit installation and thereby horizontal shafts, this level goes through the center of the shaft (see Fig. 9), while the reference level in pumps for vertical dry installation with vertical shaft goes through the lower part of the impeller. See Fig. 10.

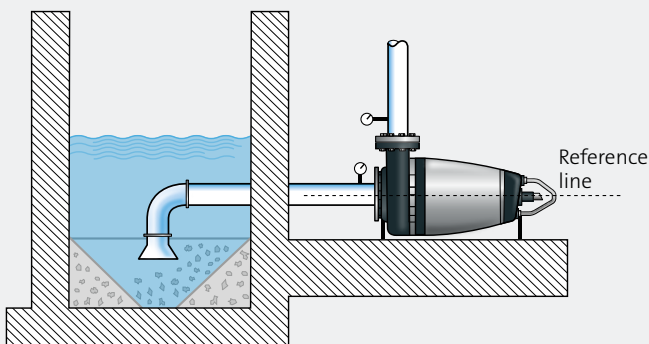


Fig. 9 Horizontal dry pit installed sewage pump with reference line

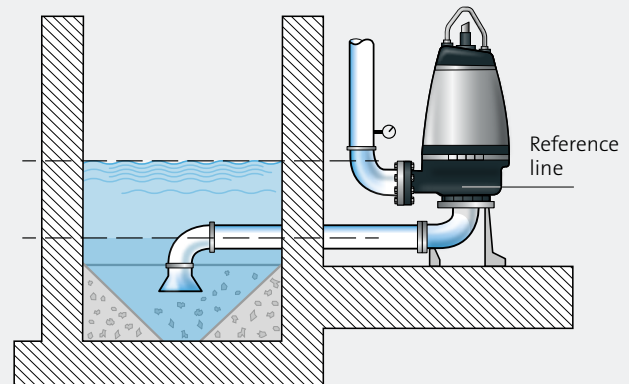


Fig.10 Vertical dry pit installed sewage pump with reference line

2.3. CALCULATING NPSH

Before we start calculating NPSH and cavitation, we need to know about the different types of pressure, such as:

- Atmospheric pressure
- Absolute pressure
- Relative pressure
- Negative pressure
- Static pressure
- Dynamic pressure
- Pump pressure

The atmospheric pressure is everywhere and we cannot feel it. Average atmosphere pressure on the earth is 1013 mbar, or 10.33 m. At sea level the atmospheric pressure is higher than on the top of a mountain, as mentioned above.

Every time we move 1 m up above sea level, the atmospheric pressure will decrease by 1.16 mm/m. The atmospheric pressure can change from day to day depending on the weather.

Absolute pressure is 0 at absolute vacuum. To get below the atmospheric pressure, a vacuum pump is needed in the system.

However, even though we use the best vacuum pump available we will never be able to reach absolute pressure of 0, due to the

fact that there will always be some molecules left in the system and they will create a minor pressure.

Relative pressure starts from 0 relative, equal to atmosphere pressure, and can be read from a manometer.

The negative pressure between 0 on the manometer and 0 absolute can be measured with a vacuum meter.

The lowest relative pressure we can get is minus 10.33 m due to the atmospheric pressure.

In practice a normal pump cannot draw more than 6 to 7 m due to the design of the pump, friction losses and leakage in the system.

Negative pressure can be measured with a vacuum meter, and negative pressure will occur with dry installed pumps, when pumping from a level below the centre of the inlet to the pump. Here, we are talking suction height or negative pressure. All pumps have an NPSH curve showing the maximum suction height or negative pressure from where the pump can move water with a certain capacity.

Static pressure is the pressure we can measure with a manometer in the pipe system of a stand-by pump, where the pipes are filled with water. The static head is the same as geodetic head.

When the same pump in the same system is operating, the pressure at the manometer will increase. The difference between the static pressure and the total pressure when the pump is in operation is pump pressure. This is because we measure directly on the discharge of the pump.

Friction loss is not taken into account in this case.

3. Calculations terms

H_{atm} = pressure on the water surface in m (usually atmospheric pressure)

H_{sf} = friction loss in m in the suction pipe

H_{sgeod} = the geodetic level difference in m between the water surface and the reference point in the pump.
If the water level is below the reference point in the pump, calculate using $-H_{sgeod}$

If the water level is above the reference point in the pump, calculate using $+H_{sgeod}$ See Fig. 11

H_{sman} = actual low pressure in the inlet to the pump (the absolute static head in the inlet is hereafter = $H_{atm} - H_{sman}$)

H_{stot} = total absolute static head in the inlet to the pump in m

H_d = liquid steam pressure (at the actual temperature) in m

V_s = velocity in the inlet to the pump

Z_s = geodetic level difference between the reference point in the pump and the centre of the manometer

NB! measure all pressure in meters (m) water column

4. Identifying the required NPSH

Identifying the required NPSH requires practical measurements in a test bed and is therefore usually carried out by the pump supplier.

Below is a description of how to carry out these measurements. By measuring at points above the pump's area of capacity, it can be determined – for example by gradually lowering the surface of the water – at what pressure cavitation occurs at each of the measuring points.

Cavitation occurs where the absolute static pressure in the inlet of the pump = $H_{atm} - H_{sman}$, and the total static pressure (H_{stot}) is found by adding the friction loss.

$$H_{(stot)} = (\text{NPSH}) \text{ required} = H_{atm} - H_{sman} + (Vs^2 / 2g)$$

Where:

Vs^2 = velocity in the inlet to the pump

$2g$ = acceleration due to gravity

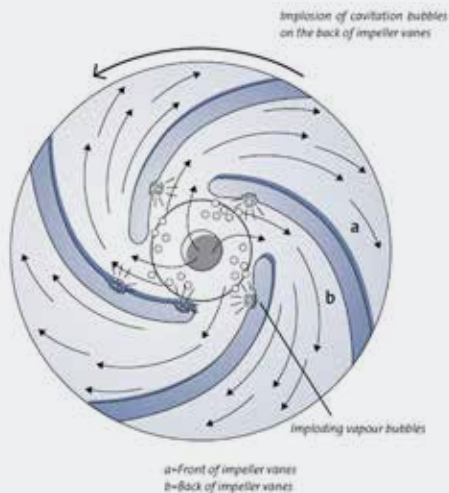


Fig. 13 Four-vane impeller with implosion of cavitation bubbles on the back of impeller vanes

5. Compensate for steam pressure where relevant

The above is valid if the water is cold. If the steam pressure needs to be taken into account, compensate as follows:

$$(\text{NPSH}) \text{ required} = H_{stot} - H_d$$

The measurements up to now refer to the level of the manometer.

NPSH reference level is found by:

$$(\text{NPSH}) \text{ required} = H_{atm} - H_{sman} - H_d - Z_s + (Vs^2 / 2g)$$

When pumping cold water at a normal air pressure, $H_{atm} \sim 10$ m and $H_d \sim 0$.

In this case, the following applies:

$$(\text{NPSH}) \text{ required} \sim 10 - H_{sman} - Z_a + (Vs^2 / 2g)$$

6. Checking the available NPSH

The calculation of available NPSH is dependent on the installation. See Figs. 9 and 10

Total available static pressure in the pump's inlet:

$$H_{stot} = H_{atm} - (H_{sgeod} - Z_s) - h_{sf}$$

Available total absolute pressure in the pump's inlet (cold water):

$$(\text{NPSH}) \text{ available} = H_{atm} - (H_{sgeod} - Z_s) - h_{sf} - H_d + (Vs^2/2g)$$

For pumping of cold water, the following applies:

$$(\text{NPSH}) \text{ available} \sim 10 - (H_{sgeod} - Z_s) - h_{sf} + (Vs^2/2g)$$

As mentioned above, the following must be fulfilled to avoid cavitation:

$$(\text{NPSH}) \text{ available} > (\text{NPSH}) \text{ required}$$

For borderline cases, where the two are found to be identical, for example:

(NPSH) available = (NPSH) required, the following applies:

$$H_{sgeod} \text{ max.} = H_{atm} + Z_s - h_{sf} - H_d + (Vs^2/2g) - (\text{NPSH}) \text{ required}$$

- or with cold water at normal air pressure:

$$H_{sgeod} \text{ max.} \sim 10 + Z_s - H_{sf} + (Vs^2/2g) - (\text{NPSH}) \text{ required}$$

If the result of the equation above is negative, take the inlet height into consideration.

7. Practical examples

Example 1.

Pumping of cold water from open pump sump. Normal air pressure. Pressure loss in the suction pipe is calculated to $h_{sf} = 3$ m. According to the supplier, (NPSH) required = 5.5 m, $Z_s = 0.1$ m and V_s is calculated to 1.5 m/s.

$$H_{sgeod} \text{ max.} = 10 + 0.1 - 3.0 + (1.5^2/2g) - 5.5 = 1.7 \text{ m}$$

The pump can thus work with a geodetic suction height of 1.7 m.

Example 2.

Pumping of water with a temperature of 70 °C. Otherwise as example 1.

$$(H_d = H_{atm}).$$

$$H_{sgeod} \text{ max.} = 10 + 0.1 - 3.0 + (1.5^2/2g) - 3.2 - 5.5 = 1.5 \text{ m}$$

The pump requires a geodetic inlet pressure of 1.5 m, or in other words. The stop level in the sump shall be minimum 1.5 m above the reference point in the pump.

If H_{sgeod} is negative (most relevant for hot liquids), increase the static inlet pressure to avoid cavitation.

8. Safety calculation

When deciding the safety value, estimate the possible variations in H_{sp} , H_d and NPSH, such as increased friction losses caused by deposits in the suction pipe, changes in liquid temperature and variations in pump capacity (Q).

The safety value is usually set at 0.5 m for liquid temperatures up to 60° C. If the temperature is above 60° C, the value is raised to 1 m.

Cavitation may destroy impeller, shaft seal or motor bearings after less than 100 hours operation. Initial cavitation alone will normally only partly reduce the impeller life, but if installed in an abrasive or corrosive liquid, material loss from the impeller may require regular replacement of the impeller.

9. How to avoid cavitation

As demonstrated in the above, the available NPSH must be higher than or equal to the required NPSH.

If this is not the case, cavitation can be avoided by adjusting one of the following values:

- Available NPSH
- Required NPSH
- Action
- Dry-installed pumps

These are explained below.

Available NPSH

- The static pressure in the pump's inlet can be increased by decreasing the geodetic suction height or, alternatively, by increasing the inlet height.
- The friction losses in the suction pipes can be reduced by removing surplus valves and bends. Pipe and fittings dimensions can be increased.
- The pump's temperature can be lowered, but this will in most cases prove rather difficult. Furthermore, the steam pressure curve shows that for water below 40 °C, the temperature reduction has very little impact.

Required NPSH

- Lowering the pump's number of revolutions. This will, however, change the pump's performance curve dramatically, and is therefore rarely used in practice.
- Replacing the pump with a newer version with a lower required NPSH.

This will in most cases involve changing to a considerably larger and more expensive pump.

Action

Wet-installed pumps

Raise the start/stop levels by 0.3 m. Check the actual pump flow in the installation. If it exceeds what is recommended on the data sheet, an impeller with a smaller diameter should be fitted.

Dry-installed pumps

Check the suction pipe system for possible air traps, concentric reducers, etc. Raise the start/stop level by 0.3 m. Check the actual pump flow in the installation.

[10]

**DENSITY, POWER AND
VARIABLE SPEED**

1. Density and viscosity

Both the density and the viscosity of a liquid can have influence on the pump performance in relation to the published pump curve and the power consumption for a given pump.

Normally, a wastewater pump is tested in a liquid with a density of 1000 kg/m³. In case of densities other than 1000 kg/m³, the discharge pressure is proportional to the density. When pumping liquids with a density higher than 1000 kg/m³, motors with correspondingly higher outputs must be used.

The pump curves also apply to pumping of airless water at a temperature of +20 °C and with a kinematic viscosity of 1 mm²/s (1 cSt).

1.2. PUMP PERFORMANCE IN HIGH-DENSITY LIQUID

The density of a mixture of water and sand can be written like this:

$$\rho = 1 + 0.007 \times p_m \text{ [t/m}^3\text{]}$$

where p_m is expressed as a percentage by weight.

If $p_v = 15\%$ by volume, p_m will be $\sim 45\%$ by weight.

$$\rho = 1 + 0.007 \times 45 = 1.32 \text{ t/m}^3.$$

Note: Using a standard sewage/contractor pump (for densities of up to 1.1 t/m³) to handle this mixture will overload the motor and in case of inadequate motor protection, overheating and burnt out windings will result.

Action

1. Fit an impeller with a smaller diameter or use a bigger motor. The motor power increase in percent must at least be equal to the increase in density.

2. Introduce a mixer operation during start-up. This will distribute the solids in the liquid. A mixture with 15 % volume will normally only occur with excavation drainage (contractor pumps) or if the pump flow in vertical discharge pipes is not sufficient to keep the sand suspended.

In this case, it will settle in the pump housing after pump stop, and the life of the motor reduced. In this case, a pump with higher flow and head should be installed.

Operation at a very small flow with effluent pumps and particularly sewage pumps should be avoided for the following reasons:

1. Sand and other solids collecting in the pump housing.
2. Excessive scaling (build-up of deposits on the walls of the discharge pipe).
3. Periods of heavy vibrations due to uneven balance of the impeller when partly blocked by solids of high density.

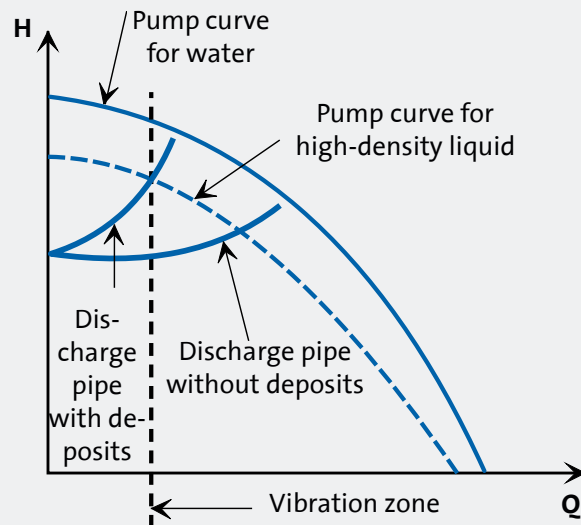


Fig. 1 Effect of high-density liquid

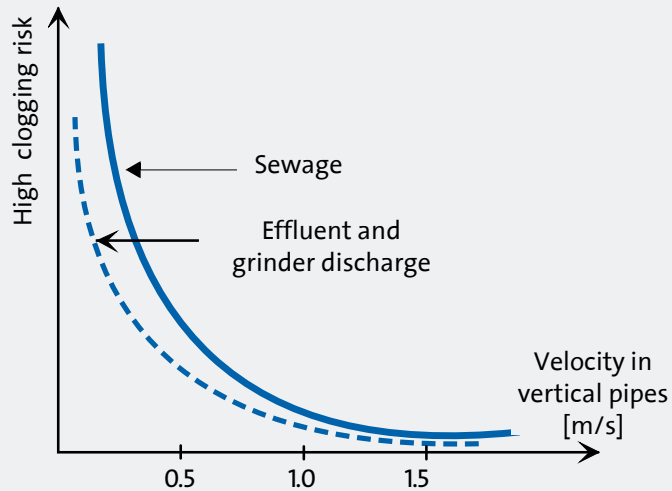


Fig. 2 Scaling and clogging of vertical discharge pipes

2. Minimum velocity

To avoid settlement of sludge and fat inside the walls of pressure pipes and to keep sand suspended, the following minimum velocities are recommended:

Sewage: in vertical pipes = 1 m/s

Sewage: in horizontal pipes = 0.7 m/s

The velocity should not exceed 3 m/s to avoid noise in the pipe system and for energy saving.

3. Pump performance in highly viscous liquids

The apparent viscosity of inhomogeneous mixtures of water, sludge, fat, leaves and gas can be very high. With an increasing content of solids and sludge, the friction loss in the pipe system will increase while the pump performance decreases, in some cases by up to 40 %.

This is partly because the impeller needs more energy for pumping highly viscous liquids. This will reduce the motor speed, which will reduce the capacity considerably.



Duty range for centrifugal pumps with either vortex or channel impeller

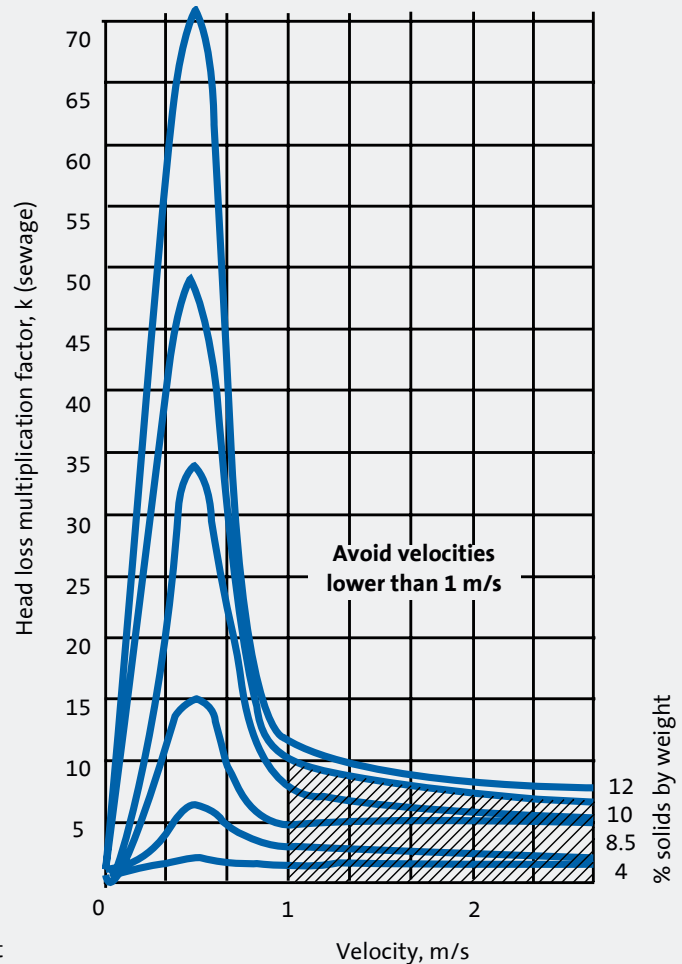
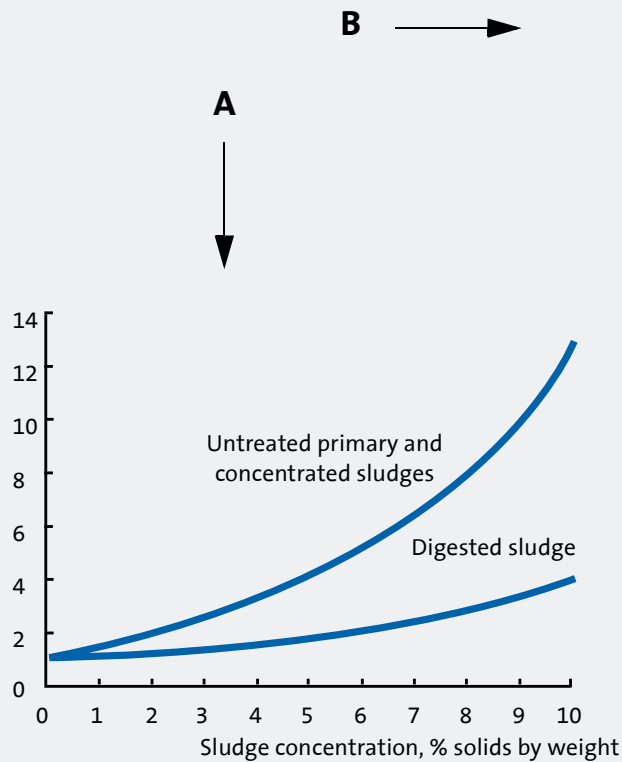


Fig. 3 Head loss multiplication factors. Diagram A is for different sludge types, concentrations, and diagram B is for different pipe velocities and concentrations of solids in sewage

4. Motor service factor (SF)

Grundfos defines service factor as a multiplier, when applied to the rated kW for submersible and dry-pit submersible sewage pumps. The service factor indicates a permissible kW loading, which may be carried under the conditions specified for the service factor at the rated voltage and frequency.

In other words, the service factor is the percentage of overloading the motor can handle for a short periods when operating within the correct voltage tolerances.

The standard service factor for motors in Grundfos submersible and dry-pit submersible sewage pumps is 1.1 (10 %) for 50 Hz pumps and 1.15 (15 %) for 60 Hz pumps.

This means that a 10 kW sewage pump with 50 Hz motor and a 1.1 SF can provide 11 kW when required for short-term use and a 10 hp sewage pump with 60 Hz motor can provide 11.5 hp for short term use.



Fig. 5 Submersible sewage pump with SuperVortex impeller

5. Power supply, under voltage and overvoltage

Power lines are expected to deliver a specific voltage. Near the low voltage transformer, there will often be an overvoltage of 3 % to 5 %. When the power lines are loaded, a voltage drop will occur due to ohmic resistance in periods of peak power consumption.

Most power lines are dimensioned so that undervoltage of more than -10 % will occur less than once a year at the weakest point. However, many consumers still experience periods of considerable voltage drop.

All motors suffer if they do not receive the voltage stamped on the nameplate. In case of voltage drop, the motor torque is reduced and the RPM (rotation per minute) of the loaded motor is consequently reduced, too.

As a result of this, the efficiency and induction resistance of the motor drops. This will make the power consumption increase, resulting in increased generation of heat in the motor.

When a motor fully loaded by a centrifugal pump receives 10 % undervoltage, the power consumption will increase by approximately 5 % and the motor temperature by about 20 %. If this temperature increase exceeds the maximum temperature of the insulation material around the windings, these will be short-circuited and the stator destroyed.

All Grundfos motors are furnished with thermal switches and – or Pt1000 thermal sensors in the stator windings to protect the motor against overheating during operation. It is important to connect the wires from the sensors to a relay in the control panel to avoid damage to the motor.

This will only be the case if the motor is placed in a hot environment and is badly cooled or in case of voltage asymmetry, current asymmetry or voltage transients at the same time.

Usually, increased winding temperature caused by undervoltage will lead to faster aging of the insulation, resulting in reduced life.

In case of overvoltage from the grid, the power consumption and heat generation in the motor windings will increase as well. Continuously running sewage pumps exposed to overvoltage must have ball bearing grease stable up to 10°C above the insulation class temperature. This means that for insulation class F (155°C), the ball bearing grease must be stable up to 165°C . For insulation class H (180°C), the ball bearing grease must be stable up to 190°C .

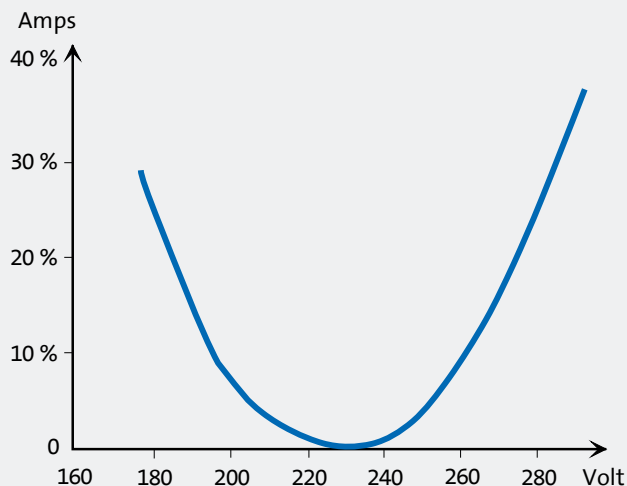


Fig. 6 Additional power consumption at voltage variations

5.1. CONCLUSION

1. For voltage variations of -10 % to +10 % of the rated value, measured at the motor terminals, normal life can be expected when the power consumption is equal to or less than the full-load current stamped on the nameplate and if the motor cooling is sufficient and no transients or asymmetry occur.
2. For short/periodic voltage variations exceeding -10 % to +10 % of the rated value, the reduction in life will be moderate until undervoltage/overvoltage variations are so considerable that the stator windings are short-circuited.
3. With permanent or long lasting voltage variations exceeding -10 % to +10 %, the motor should be de-rated or a bigger motor chosen in order to obtain acceptable life and efficiency. To avoid damage to the motor the thermal switches in the stator windings shall be connected to a relay in the control panel.

It is customary to de-rate a standard motor to ensure long life if overvoltage or undervoltage of more than -10 % to +10 % can be expected at the motor cable entry.

Single-phase motors will often require capacitor adaption when exposed to low voltage supply.

6. Current asymmetry

Low current asymmetry gives the best motor efficiency and longest life. It is therefore important to have all phases loaded equally.

Before measuring takes place, check that the direction of rotation of the pump is correct, i.e. the one giving the highest performance. The direction of rotation can be changed by reversing two phases.

The current asymmetry should not exceed 5 %. This is calculated using the following two formulas:

$$I (\%) = \left\langle \frac{I_{\text{phase max}} - I_{\text{average}}}{I_{\text{average}}} \right\rangle \times 100 [\%]$$

$$I (\%) = \left\langle \frac{I_{\text{average}} - I_{\text{phase min}}}{I_{\text{average}}} \right\rangle \times 100 [\%]$$

The maximum value is used as an expression of the current asymmetry.

The current must be measured on all three phases as illustrated below. The best connection is the one, which gives the lowest current asymmetry.

So as not to have to change the direction of rotation when the connection is changed, always move the phases as illustrated.

Example

See diagram and table below.

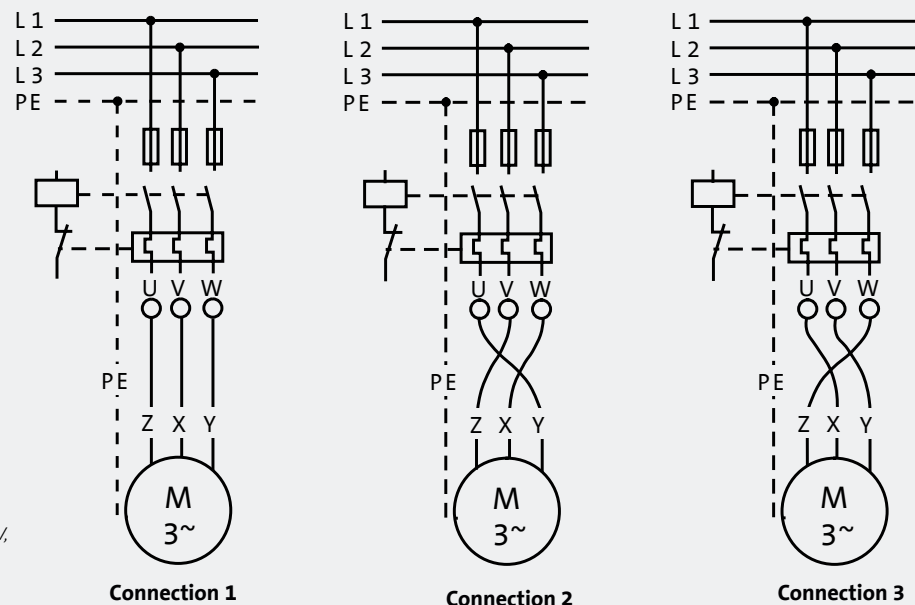


Fig. 7 Correction for current asymmetry for 3 x 400 V, 30 A, 50 Hz submersible motor

Example (continued)

	Connection 1			Connection 2			Connection 3		
Step 1	U	Z	31 A	Z	30 A	Z	29 A		
	V	X	26 A	X	26 A	X	27 A		
	W	Y	28 A	Y	29 A	Y	29 A		
		Total	85 A	Total	85 A	Total	85 A		
Step 2	Average current: $\frac{\text{Total current}}{3 \times 3} = \frac{85 + 85 + 85}{3 \times 3} = 28.3 \text{ A}$								
Step 3	Max. amps. difference from average: Connection 1 = 31 - 28.3 = 2.7 A Connection 2 = 28.3 - 26 = 2.3 A Connection 3 = 28.3 - 27 = 1.3 A								
Step 4	% unbalance: Connection 1 = $\frac{2.7}{28.3} \times 100 = 9.5 \%$ - no good Connection 2 = $\frac{2.3}{28.3} \times 100 = 8.1 \%$ - no good Connection 3 = $\frac{1.3}{28.3} \times 100 = 4.6 \%$ - ok								
Step 5	If the current unbalance is greater than 5 %, the power company should be contacted. As an alternative, a derated or industrial motor protected by a CU 3 should be used. On the remote control, you will be able to read the actual current asymmetry. A current unbalance of 5 % corresponds to a voltage unbalance of 1 to 2 %.								

Even a small voltage imbalance gives a large current imbalance. This imbalance, in turn, causes uneven distribution of heat in the stator windings leading to hot spots and local overheating. The key results are illustrated below.

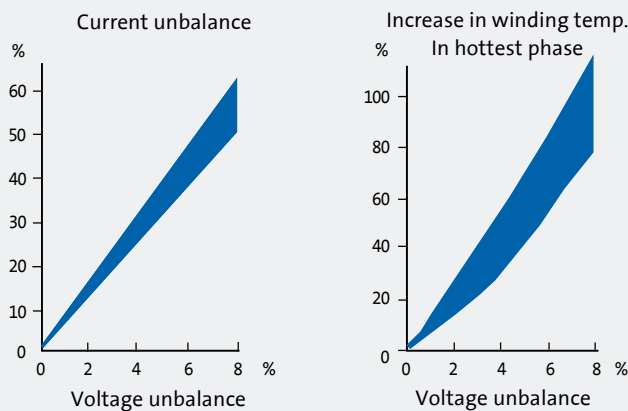


Fig. 8 Relation between voltage and current imbalance and temperature

7. Voltage asymmetry

Power lines are expected to deliver the rated voltage on all three phases. Near the low-voltage transformer, this will often be the case.

When the power lines are loaded, all single-phase appliances should be distributed evenly between all three phases in order to avoid voltage drop on a single phase. As single-phase appliances often operate ON/OFF, they may cause imbalance on the grid. Asymmetrical transformer stations as well as asymmetrical distribution lines or worn or coated contactors can also cause imbalance. In case of imbalance on the grid before the motor is connected, the supply board should be contacted. A motor seldom loads all phases equally; it is therefore often possible to compensate for the imbalance by connection the winding using less current to the phase with the lowest voltage.

8. Frequency

The frequency should always be kept at the nominal value. If the frequency is higher, the pump may overload the motor. If the frequency is lower, the pump performance will drop.

9. Voltage transients

Power lines are supposed to deliver sine shaped waves on all three phases. The sine shaped waves produced at the power station are added to the transients in the distribution system.

Transient sources:

1. Frequency converters without filters
2. Soft starters
3. Contactors for big machines
4. Capacitors for process machines
5. Lightning

10. Frequency converters without filter

Modern frequency converters can be protected with a Sine Wave filter so that they do not produce voltage peaks in connection with long cables between frequency converter and motor. This is fully acceptable and any Grundfos motor with correct rating and cooling will have an acceptable life. Frequency converters without a Sine Wave filter yield an output voltage that differs much from the ideal sinusoidal curve with high transients. These transients will increase with increasing cable length between frequency converter and motor and the result will be a reduction of the motor life.

10.1. FREQUENCY OPERATION

Increasingly, pumps are part of systems controlled by frequency converters. There are several design considerations when selecting a speed-controlled solution.

The two main things to consider are:

- The cable length from the Frequency converter to the pump
- The supply voltage at the installation site

High voltage pulses will arise when connecting a pump to a frequency converter with a long cable (>25 m). This is a physical phenomenon linked to charging capacitance to ground in the output cables. This phenomenon will be the same independent of the manufacturer of the frequency converter.

An output filter can reduce the peak voltages and by that reduce the stress on the motor insulation. The output filter should be of the Sine Wave filter (see Fig. 9, note 1) if the supply voltage is 440 - 500 V and the cable length is more than 25 m or if the supply voltage is 500 V and higher.

The voltage supply at the installation site has high impact on the actual level of the peak voltage. The different supply voltage levels require different solutions for reducing the stress on the motor insulation systems.

Combining cable length issues and the supply voltage gives the following requirements for pumps connected to a frequency converter:

General conditions:

All motors operated by frequency converters must be protected against voltage peaks and dU/dt according to IEC60034-17.

Mains voltage dependent conditions:

200 V - 240 V

No output filters are required for frequency converter operated pumps with mains voltages up to 240 V. These motors are typically rated 200-240 V in delta connection and 380 - 415 V in star connection. The insulation system used in these motors is the same as in 380 - 440 V motors.

380 V - 440 V

No additional protection against peaks voltage is required for frequency converter operated pumps with motor and mains supply up to 440 V. These motors use an insulation system that can withstand the actual pulses.

440 V - 500 V

Sine Wave filters are required for frequency converter operated pumps with motor cable length of more than 25 m, and for mains supply higher than 460 V, Sine Wave filters are also required.

500 V and higher

Sine Wave filters should always be used for motors marked 500 V or higher and a special insulation of motor windings is required.



Fig. 9 Grundfos CUE frequency converters in power range 0.55 to 250 kW

Supply voltage	Cable length < 25 m	Cable length < 25 m
< 240 V	No filter required	No filter required
380 - 440 V	No filter required	No filter required
440 - 500 V	No filter required	Sine Wave filter required
> 500 V	Sine Wave filter required	Sine Wave filter required

Sine Wave filter is also known as LC or RLC filters.

11. Soft starters

A soft starter will absorb a non-sinusoidal current and give rise to a certain grid noise. In connection with very short acceleration/deceleration times, this is of no practical importance and does not conflict with regulations concerning grid noise.

If the start-up time is longer than three seconds, the non-sinusoidal transients will overheat the motor windings and consequently affect the motor life.

12. Contactors for big machines

Big machines starting DOL or in star/delta connection may create sparks and send considerable transients back to the grid when the contactors are opened. These transients are only a threat to submersible motors on very weak grids.

13. Capacitors for process machines

Process plants may contain complicated controls with many large capacitors, which send transients back to the grid. Transients are only a threat to a submersible motor if the grid is very weak.

14. Lightning

A severe lightning strike directly on a pumping station installation, starter or power supply will generally destroy all living organisms and all electrical installations. The transients from such a lightning strike will be at least 20 - 100 kV, and the generation of heat will be enough to melt the insulation materials.

Lightning striking a high-voltage grid will generate transients, which are partly absorbed by the lightning arresters at the transformer station and earthed.

If a low-voltage grid is hit directly by lightning, there is a risk of transients of more than 10 - 20 kV at the pump motor starter.

If starter and motor are not correctly protected by lightning arresters and earthed, the installation may be damaged, as it is installed in electrically conducting groundwater, which earths best.

15. EMC cable

Grundfos standard screened power cables (EMC cables) for variable speed drives in applications with risk for electromagnetic interference are available in the lengths 10 m, 15 m, 25 m, 30 m and 50 m.

[11]



ACCESSORIES FOR WASTEWATER PUMPS

1. General

Detailed planning of pump installation and the right choice of accessories is essential for proper and trouble-free operation. This also applies to accessories for pumps inside and outside the pumping station. The auto-coupling or base stand with pipe system, valves, controls and variable speed drives should be seen as one technical hydraulic unit. The suction and discharge pipes transport the wastewater from the pump sump to the recipient. The mutual connection of all parts can be illustrated as a pump and system characteristic curves.

Grundfos offers high availability of mechanical accessories, controls and frequency converters in high quality for wastewater applications.

2. Accessories for stainless steel drainage, effluent and domestic sewage pumps.

For Unilift KP

- Non-return valve for location in the pump discharge (stainless steel) Rp 1 ¼
- Hose couplings
Screwed couplings (polyamide) G 1 ¼ x Ø25 G 1 ¼ x Ø32, G 1 ¼ x Ø40

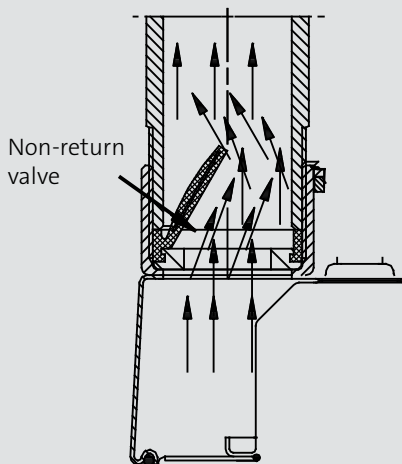


Fig. 1 Functional sketch of non-return valve in Unilift discharge

For Unilift AP

1. Bushing for pipe connection (PVC) Rp 1 ½ / 2, Rp 2 / 2 ½
2. Hose nipple (PVC) Rp 1 ½ / 1 ½, Rp 1 ½ / 2, Rp 2/2, Rp 2 / 2 ½
3. 10 m rubber hose incl. clamps (PVC) 1 ½", 2", 2 ½"
4. Connecting piece for rubber hoses (PVC)
5. Non-return valve (PVC) ball type Rp 1 ½, Rp 2, Rp 2 ½*I
6. Isolating valve (PVC) Rp 1 ½, Rp 2, Rp 2 ½
7. Hexagon nipple (PVC) Rp 1 ½, Rp 2, Rp 2 ½
8. Union (PVC) Rp 1 ½, Rp 2, Rp 2 ½
9. 90° pipe bend (PVC) Rp 1 ½, Rp 2, Rp 2 ½

* Cast iron

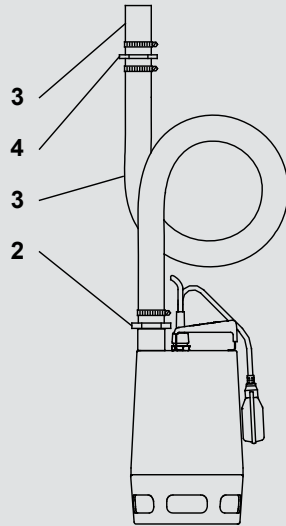


Fig. 2 Unilift with hose connection

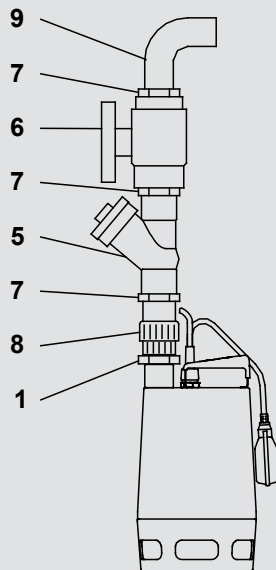


Fig. 3 Unilift with pipe connection, isolating valve and non-return valve

3. Accessories for cast iron drainage, effluent and domestic sewage pumps.

For DP10.50., EF30.50. and DP10, EF30, SE1 and SEV AUTOADAPT

- Complete auto-coupling system, including guide claw, base plate and upper guide rail holder. Cast iron, epoxy-coated. Rp 2



Fig. 4 Cast iron auto-coupling system

- Hook-up auto-coupling system with guide claw and 90o elbow Rp 2 and integrated non-return valve of the ball type.



Fig. 5 Cast iron hook-up auto-coupling system

For DP 10.65., SL1.50.65. and SLV.65.5.

- Complete auto-coupling system, including guide claw, base plate and upper guide rail holder. Cast iron, epoxy-coated. DN65/DN65 and DN80/DN65



Fig. 6 Cast iron auto-coupling system

- Galvanised-steel lifting chain with lifting link, safety, hook and certificates.



Fig. 7 Lifting chain

- Stainless-steel lifting chain with lifting link, safety hook and certificates.

For SEG and SEG AUTOADAPT

- Auto-coupling system complete, i.e. upper guide rail bracket, bolts, nuts, gaskets, guide claw and base elbow. Cast iron. DN40/Rp 1 1/2
- Hookup auto coupling, i.e. base stand, counterpart, bolts, nuts and gaskets. Cast iron. DN40/Rp 1 ½ and DN50 Rp/Rp 2
- Three loose feet for extending the space below the pump. To be fitted to the pump housing of freestanding pumps.



Fig. 8 Stainless steel legs for extending the free space below the SEG grinder pumps

- Intermediate guide rail bracket for guide rails longer than 4 meter.



Fig. 9 Stainless steel intermediate guide rail bracket

- Galvanised-steel lifting chain with lifting link, safety, hook and certificates.
- Stainless-steel lifting chain with lifting link, safety hook and certificates.

4. Other accessories for SEG AUTOADAPT

- Grundfos power line PC Tool Link USB communication unit. All AUTOADAPT pumps.

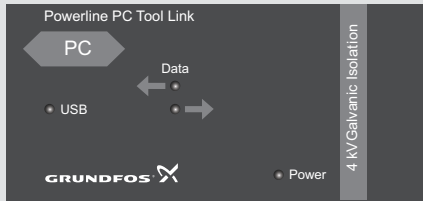


Fig. 10 Grundfos PC Tool

- **For Grundfos GO:**
MI 202 – Dongle for iPhone cpl. with IR and radio communication.
- **For Grundfos GO:**
MI 204 – Dongle for iPhone cpl. with IR and radio communication.
- **For Grundfos GO:**
MI301 – module with built-in IR and radio communication. It must be used in conjunction with an Android or iOS Smartphone with Bluetooth connection.
- GENibus communication* Grundfos GO, CIU 902



Fig. 11 Grundfos GO, CIU 902

- Profibus communication
Profibus DP + Grundfos GO, CIU 152
- Modbus RTU + Grundfos GO, CIU 202
- GSM / GPRS / SMS (e.g. for SCADA)
+ Grundfos GO, CIU 252
- Grundfos Remote Management (GRM)
+ Grundfos GO, CIU 272
- PROFIBUS IO + Grundfos GO /
MODBUS TCP + Grundfos GO /
BACNET IP + Grundfos GO /
GRM IP + Grundfos GO, CIU 902 + CIM 500

4.1. AUTOADAPT FUSE BOXES

- AUTOADAPT fuse box, 1 pump without space for CIU



Fig. 12 Grundfos AUTOADAPT fuse box

- AUTOADAPT fuse box, 1 pump with space for CIU
- AUTOADAPT fuse box, 2 pumps without space for CIU
- AUTOADAPT fuse box, 2 pumps with space for CIU

5. Accessories for middle-duty sewage pumps.

For SL1, SLV, SE1 and SEV pumps

- Complete auto-coupling system, including guide claw, base plate and upper guide rail bracket. Cast iron, epoxy-coated. With bolts, nuts and gaskets.

DN65, DN80, DN80/DN65, DN100, DN100/DN80, DN150, DN150/DN100, DN200, DN250, DN300.

For pump, outlet flanges sized DN 250 and above, the guide claw is fitted to the pump outlet flange. For flanges below DN 250 the guide claw is delivered with the auto-coupling kit.

- Complete guide claw Ductile iron BS EN 1563 EN-GJS-500/7. DN250 and DN300



Fig. 13 Cast iron guide claw with profile sealing

- Upper guide rail brackets of stainless steel (EN/DIN 1.4408) for 1 1/2" and 3" guiderails.
- Intermediate guide rail brackets of stainless steel (EN/DIN 1.4308/AISI 304) for vertical discharge pipes 2 1/2", 3", 4", 6", 8" to 24"
- Ring stand with flanged 90° elbow and hose connection. Cast iron, epoxy-coated. With bolts, nuts, gaskets and anchor bolts. For 2 1/2", 3", 4" and 6" hose connection.

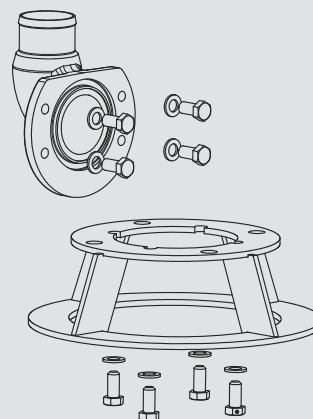


Fig. 14 Ring stand with 90° elbow and hose connection

- Ring stand with flanged 90° elbow and outside thread connection. Cast iron, epoxy-coated. With bolts, nuts, gaskets and anchor bolts. For R 2 1/2", R 3", R 4" 6" and R 8" thread connection.

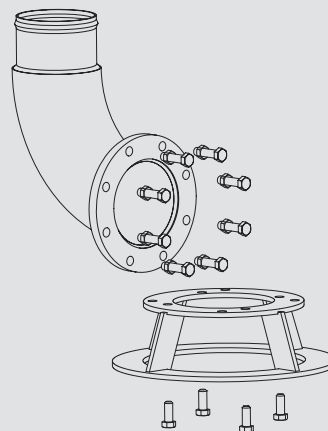


Fig. 15 Ring stand with 90° elbow and outside thread connection

- Galvanised-steel lifting chain with lifting link, safety, hook and certificates.
- Stainless-steel lifting chain with lifting link, safety hook and certificates.
- Base stand for vertical dry installation, without 90° elbow. Galvanised steel. With bolts, gaskets and anchor bolts. DN65, DN80, DN100, DN100/DN80, DN150, DN200

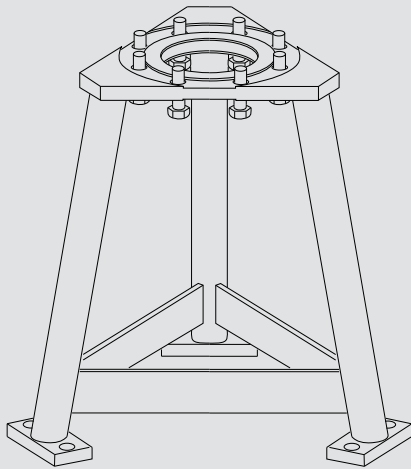


Fig. 16 Base stand for vertical dry installation

- Base plate for DN300, vertical dry installation on concrete foundation, with gaskets and bolts. Steel, epoxy-coated.

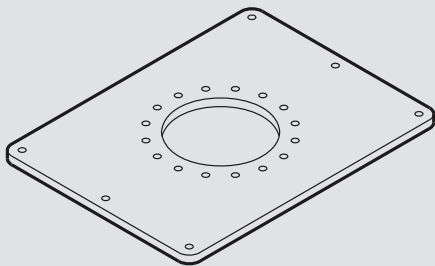


Fig. 17 Base plate for vertical dry installation

- Base stand for horizontal dry installation. Galvanised steel. With bolts, gaskets and anchor bolts. DN100, DN150, DN200 and DN300.

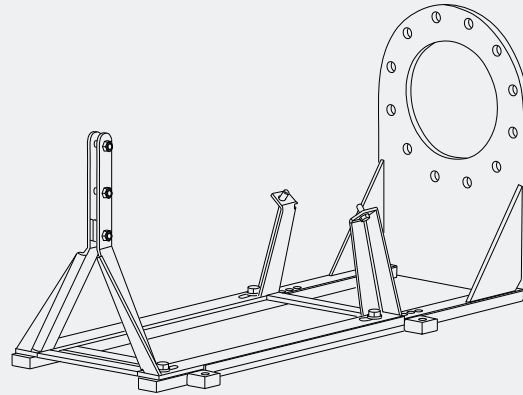


Fig. 18 Base stand for horizontal dry installation

- Galvanised-steel lifting chain with lifting link, safety, hook and certificates. 2 m to 10 m. Maximum load 800 kg
- Stainless-steel lifting chain with lifting link, safety hook and certificates. 2 m to 10 m. Maximum load 800 kg

For further information, see the data booklet or installation and operating instructions for the individual pumps on www.grundfos.com (Grundfos Product Center).

6. LC and LCD level controls



Fig. 19 LCD 110 for two-pump installations

The Grundfos LC and LCD range of level controllers are designed for one or two pump installations. It comprises three series with a total of six variants:

- LC and LCD 107 operated by air bells
- LC and LCD 108 operated by float switches
- LC and LCD 110 operated by electrodes

All controllers are ideally suited for applications requiring up to 11 kW motors for direct-on-line starting.

The LC and LCD can also be supplied with an integrated star-delta starter for applications requiring larger motors up to and including 30 kW.

For further information, see the data booklet or installation and operating instructions for the LC and LCD controller on www.grundfos.com (Grundfos Product Center).

7. Dedicated Controls



Fig. 20 Dedicated Controls CU 361

Grundfos Dedicated Controls is a control system that can control and monitor one to six Grundfos wastewater pumps and a mixer or a flush valve.

Dedicated Controls is used in installations requiring advanced control and data communication.

Main components of the Dedicated Controls system is:

- CU 362 control unit
- IO 351B module (general I/O module)



Fig. 21 IO 351B module for two pumps

Dedicated Controls is available either as separate components or as control cabinets.

The following can operate the control system:

- Float switches
- Pressure transducer
- Ultrasonic sensor

The control cabinet is available for the following pump sizes and starting methods:

- Pumps up to and including 9 kW, direct-on-line starting
- Pumps up to and including 30 kW, star-delta starting
- Pumps up to and including 30 kW, soft starter

The separate control unit and modules can be built for practically any size of system.



Fig. 22 Dedicated Controls control cabinet

7.1. BASIC FEATURES AND BENEFITS

The Grundfos Dedicated Controls system offers these features:

- Pump start/stop
- alternating operation of pumps
- overflow detection
- overflow measurement
- alarms and warnings

- advanced alarm schedules
- start and stop delays
- free language selection

7.2. ADVANCED FEATURES

- User-defined functions
- alternating between groups of pumps
- start level variation (reduced sedimentation)
- combi alarms
- daily emptying
- foam draining
- anti-seizing (limestone)
- safety after-run delay
- mixer or flush valve
- maximum number of started pumps
- pump flow measurement
- system flow measurement
- pump flow calculation
- system flow calculation

7.3. ADDITIONAL FEATURES, IO 113

- Monitoring of:
 - insulation resistance
 - moisture in motor
 - water in oil chamber for pumps up to 7 kW with 4-pole motor and 11 kW (with 2-pole motor).



Fig. 23 IO 113 module

7.4. ADDITIONAL FEATURES, SM 113 SENSOR BOARD

The SM 113 sensor board is used for collecting and transfer of additional sensor data like bearing temperature, water in air and vibration level.

For each pump, an IO 113 module with communication and an SM 113 sensor board are required if the number of sensors in the pumps are more than the IO113 module without communication can cope with.



Fig. 24 SM 113 sensor board

7.5. ADDITIONAL FEATURES, MP 204

- Anti-blocking
- monitoring of:
 - voltage
 - current
 - current asymmetry
 - phase sequence
 - cos ϕ (power factor)
 - power
 - energy
 - insulation resistance
 - temperature, PT100/PT1000
 - temperature, PTC
 - temperature, Tempcon.



Fig. 25 MP204 intelligent electronic motor protection

7.6. ADDITIONAL FEATURES, CUE OR VFD (VARIABLE FREQUENCY DRIVE)

The Grundfos CUE variable frequency converter, or a general variable frequency converter, offers better pump protection and a more steady flow through the pipe system.

In addition, Grundfos CUE offers these features:

- Anti-blocking
- Automatic energy optimisation
- Specific-energy test
- Output frequency
- Monitoring of:
 - voltage*
 - current*
 - phase sequence*
 - power*
 - energy*
 - torque*

- Reverse start
- Run flushing
- Stop flushing
- PID control

* These functions are only available with a Grundfos CUE.



Fig. 26 CUE frequency converter for variable speed drive

7.7 COMMUNICATION FEATURES

- Complete overview of the pump installation
- Set-point change, resetting of system and start/stop of pumps
- Access to complete alarm/warning log
- Automatic redirection of alarms and warnings to the on-duty staff
- Optimisation of your maintenance and service programme
- Reduction in energy consumption
- Modbus RTU communication via cable
- Modbus TCP communication via GSM/GPRS
- SMS commands (send/receive)
- SMS schedule
- VNC connection for migration of user interface to a web browser

For further information, see the data booklet or installation and operating instructions for Dedicated Controls on www.grundfos.com (Grundfos Product Center).

8. Frequency converters for variable speed drive

Grundfos CUE is a series of frequency converters designed for speed control of a wide range of Grundfos pumps.

The CUE is a multi-purpose frequency converter suitable for a variety of applications in both new and existing installations, demanding reliable and cost-efficient pump operation.

8.1. USER INTERFACE

The user interface offers these possibilities:

- Local operation via a control panel with graphic display where the menu structure is based on the well-known system from Grundfos E-pumps.
- Remote operation via external signals, for instance via digital inputs or GENIbus.
- Monitoring of operating status via indicator lights and signal relays.
- Display of alarm or warning and logging of the last five alarms and warnings.

8.2. FUNCTIONS FOR CENTRIFUGAL PUMPS

The CUE has a wide range of pump-specific functions:

- Open loop
- Proportional differential pressure
- Constant differential pressure
- Constant pressure
- Constant level
- Constant flow rate
- Constant temperature
- Constant other value

The CUE cabinet sizes are characterised by their enclosures. Fig. 27 shows the relation between power size (P2), mains supply (V) and enclosure class (IP). It shows the complete range of the CUE.

For further information, see the data booklet or installation and operating instructions for CUE on www.grundfos.com (Grundfos Product Center).



Fig. 27 CUE User interface

Product range overview

Typical shaft power P2		Mains supply and enclosure class													
		1 x 200-240 V			3 x 200-240 V		3 x 380-500 V				3 x 525-600 V		3 x 525-690 V		
[kW]	[hp]	IP20	IP21	IP55	IP20	IP55	IP20	IP21	IP54	IP55	IP20	IP55	IP21	IP54	IP55
0.55	0.75						*			*					
0.75	1				*	*	*			*	*	*			
1.1	1.5	*		*	*	*	*			*	*	*			
1.5	2		*	*	*	*	*			*	*	*			
2.2	3		*	*	*	*	*			*	*	*			
3	4		*	*	*	*	*			*	*	*			
3.7	5		*	*	*	*									
4	5						*			*	*	*			
5.5	7.5		*	*	*	*	*			*	*	*			
7.5	10		*	*	*	*	*			*	*	*			
11	15				*	*	*			*	*	*	*		*
15	20				*	*	*			*	*	*	*		*
18.5	25				*	*	*			*	*	*	*		*
22	30				*	*	*			*	*	*	*		*
30	40				*	*	*			*	*	*	*		*
37	50				*	*	*			*	*	*	*		*
45	60				*	*	*			*	*	*	*		*
55	75						*			*	*	*	*		*
75	100						*			*	*	*	*		*
90	125						*			*	*	*	*		*
110	150							*	*				*	*	
132	200							*	*				*	*	
160	250							*	*				*	*	
200	300							*	*				*	*	
250	350							*	*				*	*	

Fig. 28 CUE Range overview



[12]

PRACTICAL EXAMPLES

CASE 1. CALCULATION OF WASTEWATER FLOW RATE Q_{TOT}

A small hospital's sewage system will have to be connected to an outside building sewage main.

Bedrooms and the cafeteria are located above street level, causing wastewater from these facilities to gravitate to the sewer main in the nearby street. Wastewater from all other facilities will have to be pumped to the sewer main, as they are located in the building's basement.

In this building, there are no sanitary installations supplying a continuous flow rate Q_c and there are other pumping stations. Hence, Q_p is not relevant. In this building the design flow rate Q_{tot} will be equal to Q_{ww} .

ANSWER TO CASE 1

$$Q_{ww} = K \sqrt{\Sigma DU} = 0.7 \sqrt{55.9} = 5.2 \text{ l/s}$$

$$Q_{tot} = Q_{ww} + Q_c + Q_p = 5.2 + 0 + 0 = 5.2 \text{ l/s}$$

The required pump must be able to handle a flow rate of at least 5.2 l/s during operation.

Discharge unit (DU), System II	Amount pcs.	Water flow-rate, l/s	Total water flow-rate, l/s
Kitchen & staff facilities			
Dishwasher, large	2	0.6	1.2
Kitchen sinks	2	0.6	1.2
Floor gullies, DN 100	8	1.2	9.6
Floor gullies, DN 70	2	0.9	1.8
WC with 6.0 l cistern	4	1.8	7.2
Urinal with flushing valve	1	0.3	0.3
Shower with plug	8	0.5	4.0
Wash basin, bidet	8	0.3	2.4
Laundry area			
Washing machine up to 12 kg	10	1.2	12.0
Floor gullies, DN 100	10	1.2	12.0
Wash basins, bidet	2	0.3	0.6
WC with 6.0 l cistern	2	1.8	3.6
Sum, DU			55.9 l/s

Usage of appliances	K
Intermittent use eg. in dwelling, guesthouse, office	0.5
Frequent use eg. in hospital, school, restaurant, hotel	0.7
Congested use eg. in toilets and/or showers open to public	1.0
Special use eg. laboratory	1.2

CASE 2. RAINWATER RUN-OFF FLOW RATE

A rainwater system for a shopping mall has to be designed. The building's roof is 830 m² and the facade area 2,560 m². The catchment is determined by reviewing the building(s) surface run-off areas and the site on which the property stands. Run-off coefficients are used to reduce the quantity, depending on the likely surface absorption:

Note:

Since rainfall events around the world may vary in intensity, duration and occurrence, rainwater systems should always be sized in accordance with national guidelines and legislation.

Run-off coefficient, c

The amount of run-off is dependent on the surface permeability and describes the amount of rainwater that appears as run-off in relation to the total rainwater amount.

$$c = \frac{\text{run-off amount}}{\text{rainfall amount}}$$

Examples of run-off coefficients, c according to surface type:

Unimproved areas	0.10 - 0.30
Residential areas	0.30 - 0.75
Lawns	0.05 - 0.35
Asphalt streets	0.70 - 0.95
Concrete streets	0.80 - 0.95
Brick streets	0.70 - 0.85
Playgrounds	0.20 - 0.35
Drives and walks	0.75 - 0.85
Roofs and facades	0.75 - 0.95

Application	n	Rainwater intensity i l/sm ² (l/sha)
Separate systems: Where there is only a risk of inconvenience, e.g. flooding outside building	1	0.011 (110)
Common systems: Where there is only a risk of inconvenience, e.g. smell. Flooding is not acceptable	1	0.011 (110)
Where there is a risk of minor damage to buildings, furniture, machines or equipment. Resumption of normal service should be possible with ordinary cleaning and short-term drying.	1/2	0.014 (140)
Where there is a risk of severe damage to buildings, machines or equipment	1/10	0.023 (230)
Where there is a risk of accidents or health hazards to animals or human beings	~ 1	Max. exp. rainwater intensity

The total rainwater flow rate Q_r is calculated from:

$$Q_r = A \cdot i \cdot c \quad \text{where}$$

Q_r	=	Design flow rate (l/s)
A	=	Run-off area (m ²)
i	=	Rainfall intensity (l/sm ²)
c	=	Run-off coefficient (-)

Catchment areas

Horizontal area (roof(s)):	830 m ²
Vertical area (facade on one side):	2,560 m ²
1/3 =	855 m ²
Sidewalk:	250 m ²
Playground, gravel:	400 m ²
Parking area, asphalt:	2,350 m ²
Lawn:	400 m ²

Rainwater intensity of 140 l/s/ha is used to prevent risk of minor building damage.

Total flow, $Q_r = A \times I \times c$

ANSWER TO CASE 2

Roof	$830 \text{ m}^2 \times 0.014 \text{ lsm}^2 \times 0.95 = 11.0 \text{ l/s}$
Facade	$855 \text{ m}^2 \times 0.014 \text{ lsm}^2 \times 0.95 = 11.4 \text{ l/s}$
Walks	$250 \text{ m}^2 \times 0.014 \text{ lsm}^2 \times 0.85 = 3.0 \text{ l/s}$
Playground	$400 \text{ m}^2 \times 0.014 \text{ lsm}^2 \times 0.35 = 2.0 \text{ l/s}$
Parking	$2,350 \text{ m}^2 \times 0.014 \text{ lsm}^2 \times 0.85 = 28.0 \text{ l/s}$
Lawn	$400 \text{ m}^2 \times 0.014 \text{ lsm}^2 \times 0.35 = 2.0 \text{ l/s}$

Rainwater flow rate, $Q_r = 57.4 \text{ l/s}$



CASE 3. DRAIN WATER FLOW RATE

Classification of soil and groundwater conditions

In order to determine whether a building or structure should be drained or not, and in order to calculate drainage water flows, groundwater and soil conditions should be categorised.

Note:

This chapter's drainage procedures are based on Danish standard DS436. Drainage of buildings and structures should always be based on local legislation and guidelines.

Class 1:

Sandy or other permeable soils with groundwater table below drainage level.

Class 2:

Impermeable soil with groundwater level below drainage level.

Class 3:

Low-permeability soil with groundwater level above drainage level.

Class 4:

High-permeability soil with groundwater level above drainage level.

Drain water flow rate

The drain water flow rate should be estimated before the design of drainage system and sizing of pumps. Compared to rainwater flow rates, drain water flow rates are usually modest.

WALLS:

Class 1:

Typically not drained

Class 2:

Water flow rate per m² wall:
 $q = 0.01 - 0.03 \text{ l/sm}^2$

Class 3:

Water flow rate per m² wall:
 $q = 0.03 - 0.1 \text{ l/sm}^2$

Class 4:

Typically not drained

FLOORS:

Class 3: Water flow rate per m² floor:
 $q = 0.001 - 0.005 \text{ l/sm}^2$

Class 4: Typically not drained

Note:

Water flow rates per m² wall or floor are estimated on the basis of climate conditions with moderate precipitation intensities, frequencies and duration. Drain water flow rates should always be based on national guidelines and legislation.

The drain water flow rate, Q_d is calculated from:

$$Q_d = A \cdot q \quad \text{where}$$

Q_d = Drain water flow rate (l/s)

A = Wall or floor area (m²)

q = Water flow rate per m², wall or floor

A building for a shopping center is in the design phase. Groundwater and soil conditions have been investigated and the building will need a drainage system around its perimeter and under the basement floor.

Building dimensions:

Basement height: 3 m

Basement length: 65 m

Basement width: 30 m

The building soil is impermeable and the groundwater table is higher than the drainage level, making this a class 3 building.

Drain water flow rate, $Q_d = A \times q$

Answer to case 3:

Walls:

$$2 \times (65 \text{ m} + 30 \text{ m}) \times 3 \text{ m} \times 0.06 \text{ l/sm}^2 = 34.2 \text{ l/s}$$

$$\text{Floor: } 65 \text{ m} \times 30 \text{ m} \times 0.003 \text{ l/sm}^2 = 5.85 \text{ l/s}$$

Drain water flow rate, $Q_d = 40 \text{ l/s}$

CASE 4. WASTEWATER PUMP SIZING

Wastewater from an 80-room hotel building must be pumped to the sewer main in a nearby street. It has been decided to install two identical pumps and they shall operate in alternating operation. Meaning there will be 100 % spare pump capacity. Meaning there will be 100 % spare pump capacity. The wastewater flow rate has already been calculated:

$$Q_{\text{tot}} = Q_{\text{ww}} + Q_c + Q_p = 3.76 + 0 + 0 = 3.76 \text{ l/s}$$

Other data:

Street level	0.0 m
Discharge pipe inlet to sewer main	1.0 m below street level
Highest backflow level	2.0 m below street level
Wastewater inlet level	5.5 m below street level
Pump stop level	6.5 m below street level

Discharge pipe length: 75 m

1. Static head:

$H_{\text{geo}} =$ Discharge pipe outlet level - pump stop level

$$H_{\text{geo}} = 6.5 \text{ m} - 1.0 \text{ m} = 5.5 \text{ m}$$

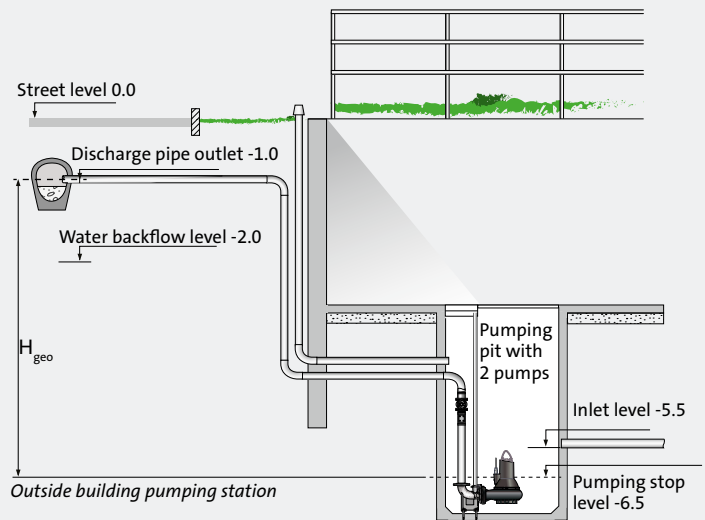
2. Losses in valves and fittings H_{vA} :

The pipe velocity is calculated from: $v = \frac{Q}{A}$

$v =$ Pipe velocity (m/s). Horizontal pipes: 0.7 - 3.0 m/s, vertical pipes: min. 1.0 m/s

$Q =$ Wastewater flow rate (m^3/s)

$A =$ Internal pipe area (m^2)



A DN80 discharge pipe with an internal diameter of 70 mm is chosen. The water velocity turns out to be within the acceptable range of 0.7 m/s to 3.0 m/s.

$$v = \frac{Q}{A} = \frac{Q}{\frac{\pi}{4} \cdot d_i^2} = \frac{3.76 \cdot 10^{-3}}{\frac{\pi}{4} \cdot 0.07^2} = 0.98 \text{ m/s}$$

Resistance factors (Zeta) (-) for valves and fittings on discharge pipe are calculated:

Gate valve 1 x 0.5	= 0.5
Non-return valve 1 x 2.2	= 2.2
Bend 90° 5 x 0.5	= 2.5
T-piece 1 x 1.5	= 1.5
Total (Zeta) value	= 6.7

Head losses in valves and fittings are calculated:

$$H_{V,A} = \sum_i \zeta_i \frac{V_i^2}{2g}$$

$$H_{V,A} = 6.7 \frac{0.98^2}{2 \cdot 9.81} = 0.33 \text{ m}$$

3. Linear friction losses in discharge pipe, $H_{V,R}$

The total pressure loss in the discharge pipe is determined:

$$H_{V,R} = H_{V,j} \times L_{V,i} = 0.020 \times 75 \text{ m} = 1.50 \text{ m}$$

Head, $H_{V,j}$ is found in the nomogram as a function of flow rate and internal pipe diameter.

4. Discharge head, H_p

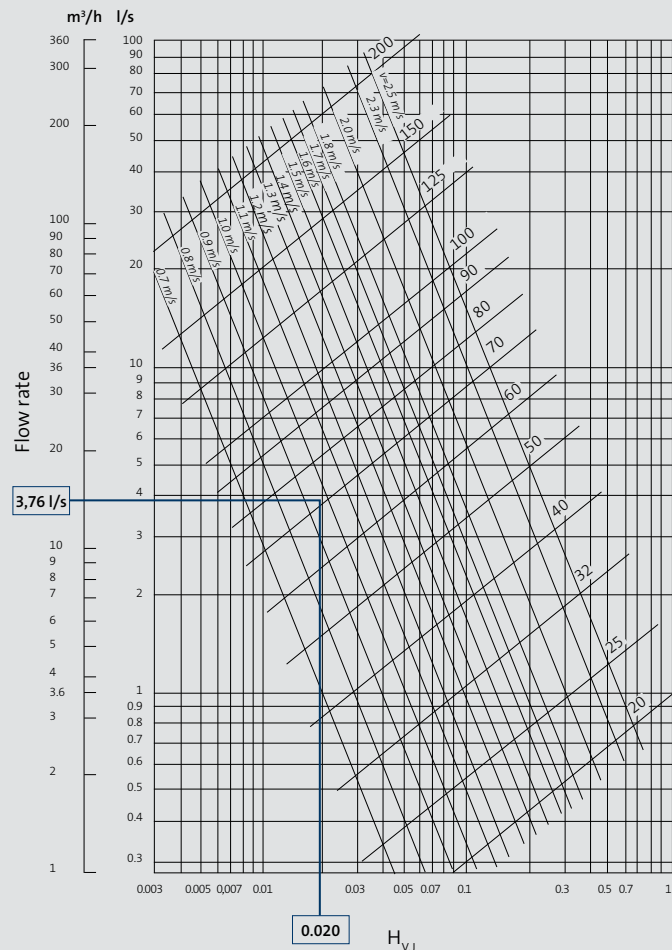
The pump's discharge head, H_p should be equal to or greater than the total head in the system, H_{tot} .

The total head is calculated below:

$$H_{\text{tot}} = H_{\text{geo}} + H_V \text{ where } H_V = H_{V,A} + H_{V,R}$$

$$H_{\text{tot}} = H_{\text{geo}} + H_{V,A} + H_{V,R}$$

$$H_{\text{tot}} = 5.5 \text{ m} + 0.33 \text{ m} + 1.50 \text{ m} = 7.33 \text{ m}$$



The pumps are sized in Grundfos Product Center.

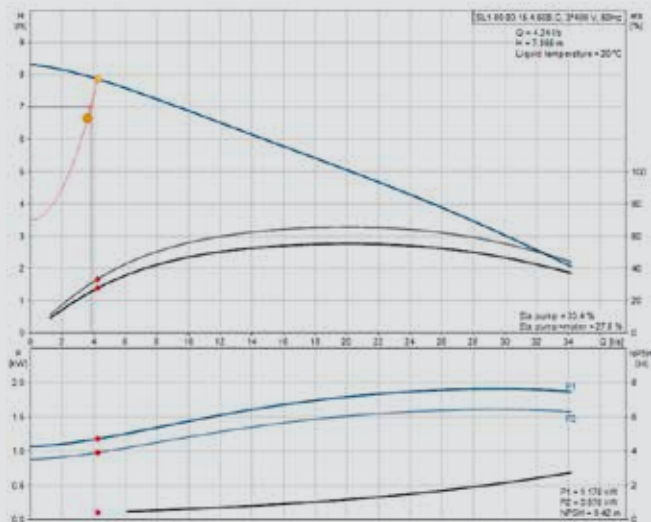
Flow, static head (geometric head) and friction losses are used as input in the sizing tool:

$$\begin{aligned} \text{Flow, } Q_{\text{tot}} &= 3.76 \text{ l/s} \\ \text{Static head, } H_{\text{geo}} &= 5.5 \text{ m} \\ \text{Friction losses: } H_{V,A} + H_{V,R} &= 1.83 \text{ m} \end{aligned}$$

The selection from Grundfos Product Center is pump type SL1.80.80.15.4.50D.B. The pumps have free passages of 80 mm and 80 mm outlets.

The pumps are slightly oversized for the duty point with a:

$$\begin{aligned} \text{Flow of } 4.24 \text{ l/s} \\ \text{Head of } 7.8 \text{ m} \\ \text{Velocity in the discharge pipe is approximately } 1.3 \text{ m/s} \end{aligned}$$



CASE 5. RAINWATER AND SEWAGE PUMP SIZING

Wastewater from a village is drained of in a combined system, meaning sewage, effluent and rainwater is running to the pumping station from where it must be pumped to the sewer main.

It has been decided to install three identical pumps. Two of the pumps shall operate in parallel in the heavy rain period, and the third pump is a standby pump. In dry weather and periods with moderate rainfall two pumps will operate in alternating operation. The peak flow rate has already been calculated:

$$\begin{aligned} \text{Peak inflow to the pit: } 22 \text{ l/s} \\ \text{Required pump capacity with two pumps in parallel operation:} \\ 22 \text{ l/s} \times 1.05 = 23 \text{ l/s} \end{aligned}$$

$$Q_{\text{tot}} = 23 \text{ l/s}$$

Other data:

$$\begin{aligned} \text{Street level:} & 0.0 \text{ m} \\ \text{Discharge pipe inlet} \\ \text{to sewer main:} & 1.0 \text{ m below street level} \\ \text{Highest backflow level:} & 1.5 \text{ m below street level} \\ \text{Wastewater inlet level:} & 4.5 \text{ m below street level} \\ \text{Pump stop level:} & 6.8 \text{ m below street level} \end{aligned}$$

Vertical discharge pipes and manifold in the pump pit:
 Length including valves is 5.5 m
 Horizontal discharge pipe outside pit: Length 135 m

1. Static head:

H_{geo} = Discharge pipe outlet level - pump stop level

$$H_{\text{geo}} = 6.8 \text{ m} - 1.0 \text{ m} = 5.8 \text{ m}$$

2. Losses in valves and fittings $H_{V,A}$:

The pipe velocity is calculated from: $v = \frac{Q}{A}$

v = Pipe velocity (m/s). Horizontal pipes: 0.7 - 3.0 m/s,
vertical pipes: min. 1.0 m/s

Q = Wastewater flow rate (m³/s)

A = Internal pipe area (m²)

Two pumps in parallel operation

DN100 vertical discharge pipes and manifold in the pit with an internal diameter of 92 mm is chosen. The water velocity turns out to be within the acceptable range of 0.7 m/s to 3.0 m/s.

$$v = \frac{Q}{A} = \frac{Q}{\frac{\pi}{4} \cdot d_i^2} = \frac{11.5 \cdot 10^{-3}}{\frac{\pi}{4} \cdot 0.092^2} = 1.7 \text{ m/s}$$

Velocity in the vertical discharge pipe is 1.7 m/s when two pumps are operating in parallel

DN150 horizontal discharge pipe outside the pit with an internal diameter of 140 mm is chosen. The water velocity turns out to be within the acceptable range of 0.7 m/s to 3.0 m/s.

$$v = \frac{Q}{A} = \frac{Q}{\frac{\pi}{4} \cdot d_i^2} = \frac{23 \cdot 10^{-3}}{\frac{\pi}{4} \cdot 0.140^2} = 1.5 \text{ m/s}$$

Velocity in the horizontal discharge pipe is 1.5 m/s when two pumps are operating in parallel.

Resistance factors (Zeta) (-) for valves and fittings on discharge pipe inside the pit are calculated:

Gate valve $1 \times 0.5 = 0.5$

Non-return valve $1 \times 2.2 = 2.2$

Bend 90° $2 \times 0.5 = 1.0$

T-piece $1 \times 1.5 = 1.5$

Total (Zeta) value inside the pit = 5.2

Head losses in valves and fittings are calculated:

$$H_{V,A} = \sum_i \zeta_i \frac{V_i^2}{2g}$$

$$H_{V,A} = 5.2 \frac{1.7^2}{2 \cdot 9.81} = 0.45 \text{ m}$$

Resistance factors (Zeta) (-) for valves and fittings on discharge pipe outside the pit are calculated:

Widening 10° $1 \times 0.5 = 0.5$

Bend 90° $3 \times 0.5 = 1.5$

Outlet $1 \times 1.0 = 1.0$

Total (Zeta) value outside the pit = 3.0

Head losses in valves and fittings are calculated:

$$H_{V,A} = 3.0 \frac{1.5^2}{2 \cdot 9.81} = 0.23 \text{ m}$$

3. Linear friction losses in discharge pipe, $H_{V,R}$

The total pressure loss in the discharge pipe inside the pit is determined:

$$H_{V,R} = H_{V,j} \times L_{V,i} = 0.04 \times 5.5 \text{ m} = 0.22 \text{ m}$$

The total pressure loss in the discharge pipe outside the pit is determined:

$$H_{V,R} = H_{V,j} \times L_{V,i} = 0.02 \times 135 \text{ m} = 2.7 \text{ m}$$

$$H_{R,R} \text{ total} = (0.22 \text{ m} + 2.7 \text{ m}) 2.9 \text{ m}$$

Head, $H_{V,j}$ is found in the nomogram above.

4. Discharge head, H_p

The pump's discharge head, H_p should be equal to or greater than the total head in the system, H_{tot} . The total head is calculated below:

$$H_{tot} = H_{geo} + H_v \quad \text{where} \quad H_v = H_{V,A} + H_{V,R}$$

$$H_{tot} = H_{geo} + H_{V,A} + H_{V,R}$$

$$H_{tot} = 5.8 \text{ m} + 0.68 \text{ m} + 2.9 \text{ m} = 9.4 \text{ m}$$

The pumps are sized in Grundfos Product Center. Required pump capacity with two pumps in parallel operation is:

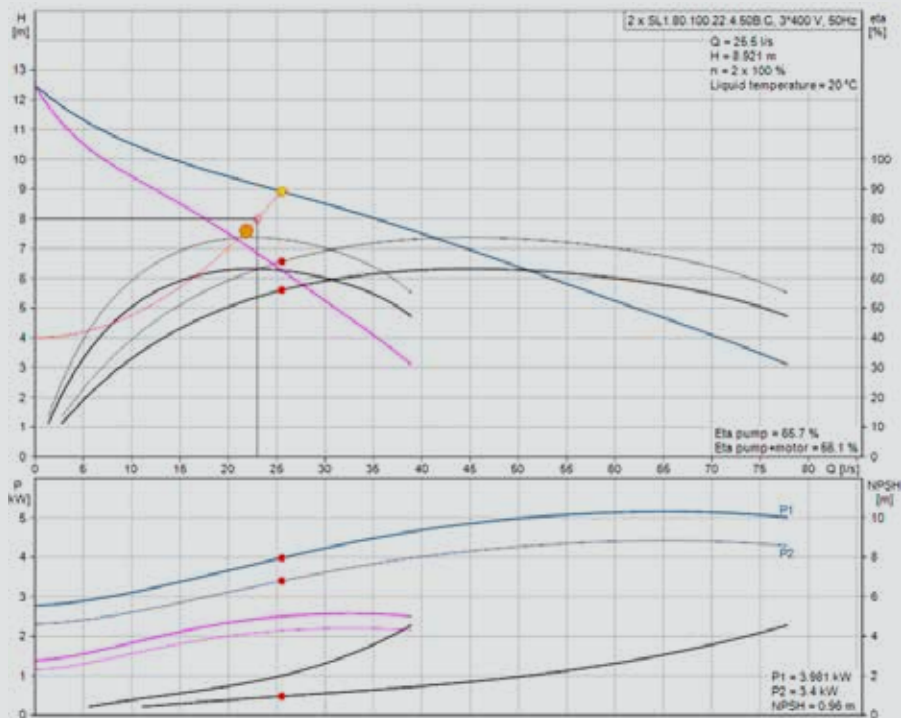
Flow: 23 l/s

Head: 9.3 m

The selection from Grundfos Product Center is pump type SLV.80.100.22.4.50. The pumps have free passages of 80 mm and DN 100 outlets..

Flow: 22.7 l/s

Head: 9.3 m



ALTERNATING OPERATION

1. Static head:

H_{geo} = Discharge pipe outlet level - pump stop level

$$H_{\text{geo}} = 6.8 \text{ m} - 1.0 \text{ m} = 5.8 \text{ m}$$

2. Losses in valves and fittings $H_{V,A}$:

The pipe velocity is calculated from: $v = \frac{Q}{A}$

With only one pump in operation the flow is set to the half of the flow in parallel operation well knowing that it will be slightly higher due to less friction loss:

$$0.5 \times 23 \text{ l/s} = 11.5 \text{ l/s}$$

DN100 vertical discharge pipes and manifold in the pit with an internal diameter of 92 mm

$$V = \frac{Q}{A} = \frac{Q}{\frac{\pi \cdot d^2}{4}} = \frac{11.5 \cdot 10^{-3}}{\frac{\pi \cdot 0.092^2}{4}} = 1.7 \text{ m/s}$$

Velocity in the vertical discharge pipe is 1.7 m/s when only one pump is operating.

DN150 horizontal discharge pipe outside the pit with an internal diameter of 140 mm

$$V = \frac{Q}{A} = \frac{Q}{\frac{\pi \cdot d^2}{4}} = \frac{11.5 \cdot 10^{-3}}{\frac{\pi \cdot 0.140^2}{4}} = 0.75 \text{ m/s}$$

Velocity in the horizontal discharge pipe is 0.75 m/s when only one pump is operating.

Resistance factors (Zeta) (-) for valves and fittings on discharge pipe inside the pit are calculated:

Total (Zeta) value inside the pit = 5.2

Head losses in valves and fittings are calculated:

$$H_{V,A} = 5.2 \frac{1.7}{2 \cdot 9.81} = 0.45 \text{ m}$$

Total (Zeta) value outside the pit = 3.0

Head losses in valves and fittings are calculated:

$$H_{V,A} = 3.0 \frac{0.75}{2 \cdot 9.81} = 0.11 \text{ m}$$

3. Linear friction losses in discharge pipe, $H_{V,R}$

The total pressure loss in the discharge pipe inside the pit is determined:

$$H_{V,R} = H_{Vj} \times L_{Vj} = 0.041 \times 5.5 \text{ m} = 0.23 \text{ m}$$

The total pressure loss in the discharge pipe outside the pit is determined:

$$H_{V,R} = H_{Vj} \times L_{Vj} = 0.005 \times 135 \text{ m} = 0.68 \text{ m}$$

$$H_{R,R} \text{ total} = (0.23 \text{ m} + 0.68 \text{ m}) 0.9 \text{ m}$$

Head, H_{Vj} is found in the nomogram below

4. Discharge head, H_p

The pump's discharge head, H_p should be equal to or greater than the total head in the system, H_{tot} . The total head is calculated below:

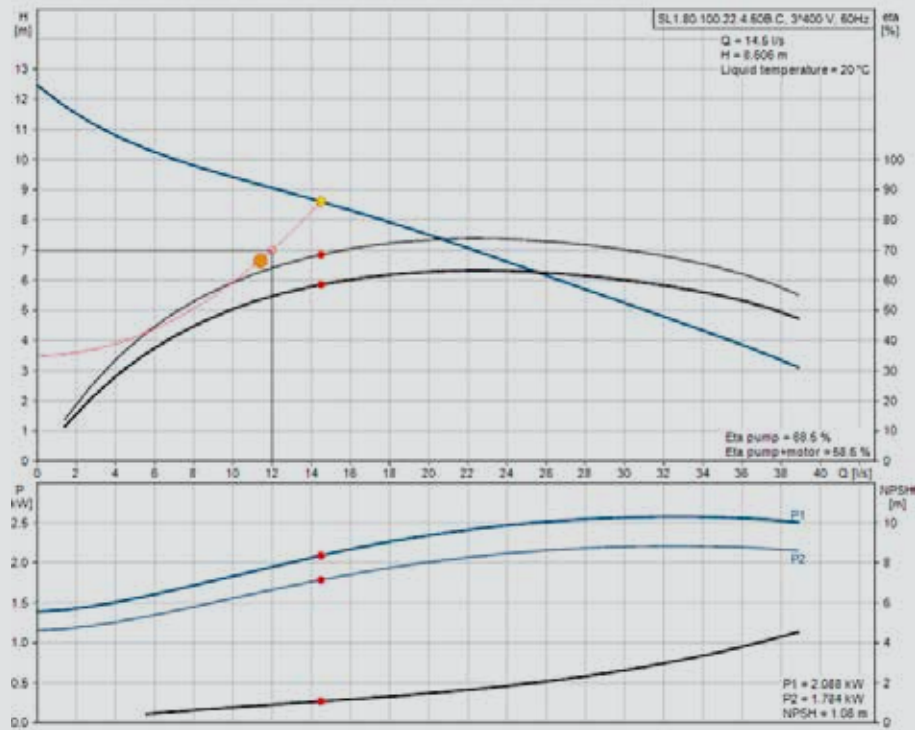
$$H_{\text{tot}} = H_{\text{geo}} + H_v \quad \text{where} \quad H_v = H_{V,A} + H_{V,R}$$

$$H_{\text{tot}} = H_{\text{geo}} + H_{V,A} + H_{V,R}$$

$$H_{\text{tot}} = 5.8 \text{ m} + 0.56 \text{ m} + 0.9 \text{ m} = 7.3 \text{ m}$$

The duty point for only one pump in operation.
 Pump type **SLV.80.100.22.4.50**, is sized in Grundfos
 Product Center.

The result is:
 Flow: 13.8 l/s
 Head: 7.9 m



CASE 6. SIZING OF MULTILIFT STATION

Wastewater from an apartment building has to be pumped to the sewer main.

This time, we will use a lifting station for the job.

1. Maximum hourly inflow volume, $V_{\max, h}$

The wastewater appearance from domestic sanitary appliances varies greatly over the course of a day, with studies showing that morning is generally the peak period. To determine the required tank size, the hourly maximum expected wastewater volume $V_{\max, h}$ has to be calculated for the hour of the day (or week) where flow is at its highest. For an apartment building, this is typically in the morning hours when residents are taking showers and doing their morning toilette. In this example, the apartments are on average occupied by two persons. The total wastewater volume, $V_{\max, h}$ is calculated below.

Average apartment with 2 persons	Flow, l/min	Volume, l	Duration, min.	Usage, h-1	Total flow, l/h
Wash basin	10		4	2	80
Shower	10		5	2	100
Kitchen zink		15		1	15
Dishwasher		20		1	20
Washing machine, 6 kg		60		1	60
WC, 4 l flush		4		2	8
WC, 6 l flush		5		2	12
Total water volume within an hour					295

Table for determining the maximum wastewater volume within a single hour, $V_{\max, h}$

There are 45 apartments in the building, making the total wastewater volume:

$$\sum V_{\max, h} = 45 \cdot 295 \text{ l/h} = 13,275 \text{ l/h}$$

2. First selection of lifting station

Lifting stations are typically made for intermittent operation whereby they run a certain number of pump and pause cycles every hour. The maximum start/stops of a lifting station pump is 60 per hour.

Using this simple rule, the lifting station's total drainage capacity Q_{\max} is calculated by multiplying the number of hourly start/stops with the effective tank volume. $Q_{\max, h}$ should exceed $\sum V_{\max, h}$

$$Q_{\max, h} = \text{Eff. tank vol.} \cdot 60$$

In this case, a Multilift type MD1/V is preferred. With one tank, it has an effective tank volume of 240 l. Making 60 start/stops per hour, the total drainage capacity of this Multilift MD1/V is:

$$Q_{\max, h} = 240 \text{ l} \cdot 60 \text{ h}^{-1} = 14,400 \text{ l/h which exceeds}$$

$$V_{\max, h} = 13,000 \text{ l/h}$$

Multilift type	Number of tanks	Eff. tank vol.
Multilift MSS	1	28
Multilift M	1	62
Multilift MOG	1	50
Multilift MD	1	86
Multilift MLD	1	190
Multilift MDG	1	50
Multilift MD1/V+SL	1	240
Multilift MD1/V+SL	2	480
Multilift MD1/V+SL	3	720

Effective tank volumes for Multilift

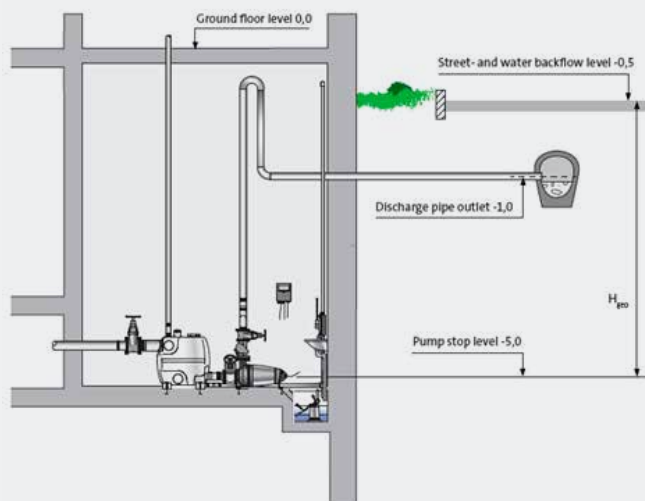
3. Determination of the wastewater flow, Q_{ww} :

To determine losses in valves and fittings and check water velocity in the discharge pipe, the wastewater flow rate according to EN 12056-2 must be calculated.

According to EN12050-2 System 2	DU l/s	Amount	Total l/s
Wash basin	0.3	2	0.6
Shower	0.4	2	0.8
Kitchen sink	0.6	1	0.6
Dishwasher	0.6	1	0.6
Washing machine, 6 kg	0.6	1	0.6
WC	1.8	2	3.6
Total flow			6.8

Each lifting station will service 50 apartments (each with DU of 6.8 l/s), which makes for a Q_{ww} of:

$$Q_{ww} = K\sqrt{\sum DU} = 0.5\sqrt{6.8 \cdot 50} = 9.22 \text{ l/s}$$



Frequency factor of 0.5 is chosen according to table below for usage of appliances.

Usage of appliances	K
Intermittent use eg. in dwelling, guesthouse, office	0.5
Frequent use eg. in hospital, school, restaurant, hotel	0.7
Congested use eg. in toilets and/or showers open to public	1.0
Special use eg. laboratory	1.2

Pump stop level:

5.0 m below ground floor level

Discharge pipe inlet to sewer main:

1.0 m below ground floor level

Highest backflow Level:

0.5 m below ground floor level

Street level

0.5 m below ground floor level

Discharge pipe length: 139 m

4. Losses in valves and fittings, $H_{V,A}$:

The pipe velocity is calculated from: $v = \frac{Q}{A}$

The water velocity turns out to be within the acceptable range of 0.7 m/s to 3.0 m/s. A pipe with an internal diameter of 90 mm is chosen.

$$Q = 9.22 \cdot 10^{-3} \text{ m}^3/\text{s}$$

$$v = \frac{Q}{A} = \frac{Q}{\frac{\pi \cdot d_i^2}{4}} = \frac{9.22 \cdot 10^{-3}}{\frac{\pi \cdot 0.09^2}{4}} = 1.45 \text{ m/s}$$

Resistance factors (Zeta) (-) for valves and fittings on the discharge pipe are calculated:

Shut-off valve	$1 \times 0.5 = 0.5$
Non-return valve	$1 \times 2.2 = 2.2$
Bend 90	$5 \times 0.5 = 2.5$
T-piece	$1 \times 1.0 = 1.0$
Total (Zeta) value	$= 6.2$

Head losses in valves and fittings are calculated:

$$H_{V,A} = \sum_i \zeta_i \frac{v_i^2}{2g}$$

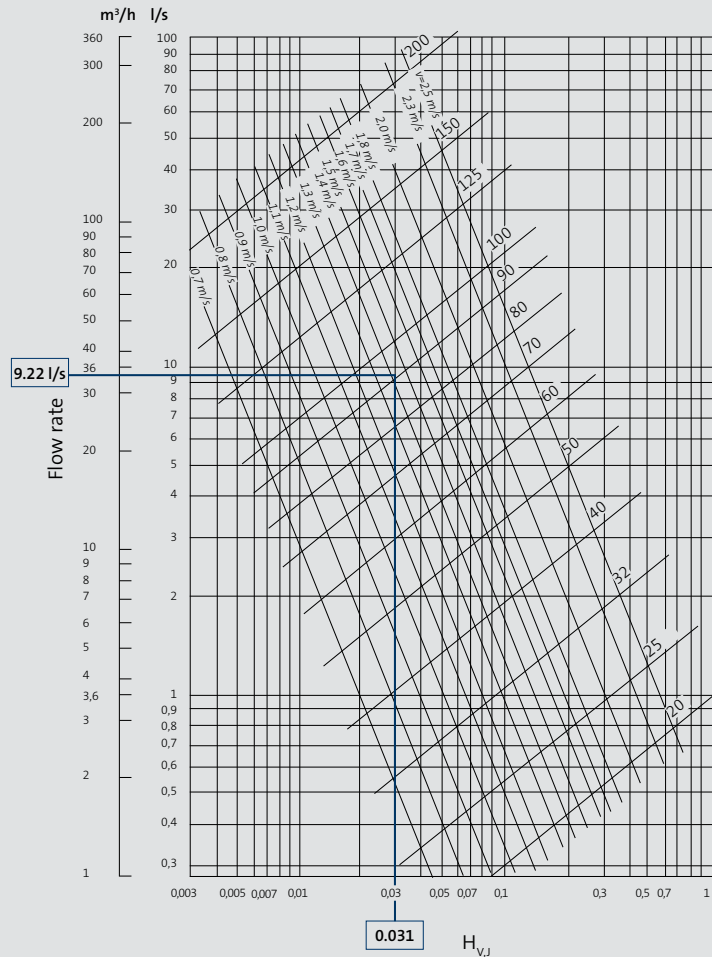
$$H_{V,A} = 6.2 \frac{1.45^2}{2 \cdot 9.81} = 0.7 \text{ m}$$

5. Linear friction losses in discharge pipe, $H_{V,R}$

The total pressure loss in the discharge pipe is determined:

$$H_{V,R} = H_{V,J} L_{V,i} = 0.031 \cdot 139 \text{ m} = 4.3 \text{ m}$$

Head, $H_{V,J}$ is found in the diagram.



6. Discharge head, H_p

The pump discharge head, H_p should be equal to or greater than the total head in the system, H_{tot} .

The total head is calculated as shown below.

$$H_{tot} = H_{geo} + H_v \quad \text{where} \quad H_v = H_{v,A} + H_{v,R}$$

$$H_{tot} = H_{geo} + H_{v,A} + H_{v,R} =$$

$$4.5 \text{ m} + 0.7 \text{ m} + 4.3 \text{ m} = 9.5 \text{ m}$$

7. Final selection of lifting station

Since 100 % spare pump capacity is required in this installation, a two-pump solution is selected where both pumps are sized for full capacity and set for alternating operation with only one pump running at a time.

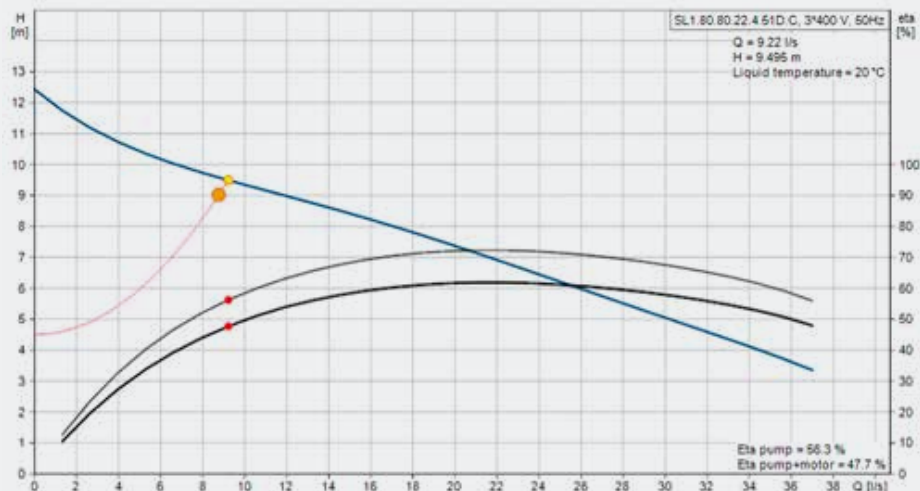
The lifting station solution is sized in Grundfos Product Center.

The pump selection from Grundfos Product Center is pump type SL1.80.80.22.4.51.C

The pumps have free passages of 80 mm and DN 80 outlets.

A one-tank lifting station MD1.80.80.22.4 with two SL 2.2 kW pumps is selected. This system is selected because of the high efficiency of the SL pumps.

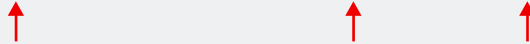
Selecting the Multilift MD1.80.80.22.4 with the use of the sizing guide in section 10 where Multilift lifting stations are described in details.



Selection criteria for MD1.80.80.22.4

Total water volume within one hour: 260 l $H_{geo} = 4.5$ m
 Q_{max} h for one pump shall exceed: 13,275 l / h $H_{geo} = 4.5$ m
 Required pump capacity: 9.22 l/s Internal diameter of discharge pipe: 90 mm
 Dimension of discharge pipe: DN 80 Discharge pipe length: 139 m

Lifting station	Peak flow performance***			Max. effective tank volume [l]	Max. drain capacity* [l/h] = Max. inflow	
	DN 40 [l/s]	DN 80 [l/s]	DN 100 [l/s]		1 pump**	with 2 pumps running
Multilift MSS	n/a	3.5 - 8	5.6 - 8	28	1,680	n/a
Multilift M	n/a	3.5 - 16	5.6 - 16	62	3,720	n/a
Multilift MOG	0.5 - 4.5	n/a	n/a	50	3,000	n/a
Multilift MD	n/a	3.5 - 16	5.6 - 16	86	5,160	10,320
Multilift MLD	n/a	3.5 - 16	5.6 - 16	190	11,400	22,800
Multilift MDG	0.5 - 4.5	n/a	n/a	50	3,000	6,000
Multilift MD1/MDV	n/a	3.5 - 18	5.6 - 28	240 - 720	14,400	28,800



6 m	-	2365	670	260	130	73	44	27	16	DN 100	MD1.80.80.75
	785	745	205	80	39	21	-	-	-	DN 80	
	-	1875	505	193	90	48	26	13	-	DN 100	MD1.80.80.55
	630	590	155	58	26	13	-	-	-	DN 80	
	-	1260	325	110	46	20	7	-	-	DN 100	MD1.80.80.40
	430	395	98	32	12	-	-	-	-	DN 80	
	-	830	200	65	20	-	-	-	-	DN 100	MD1.80.80.30
	280	260	60	18	-	-	-	-	-	DN 80	
	-	740	164	42	6	-	-	-	-	DN 100	MD1.80.80.22
	260	230	48	11	-	-	-	-	-	DN 80	
-	190	6	-	-	-	-	-	-	DN 100	MD1.80.80.15	
78	54	-	-	-	-	-	-	-	DN 80		

3 m	-	2810	810	325	166	96	60	39	25	DN 100	MD1.80.80.75
	925	885	250	100	50	28	-	-	-	DN 80	
	-	2320	645	255	126	71	43	25	-	DN 100	MD1.80.80.55
	775	730	200	78	37	21	-	-	-	DN 80	
	-	1710	465	174	82	43	23	12	-	DN 100	MD1.80.80.40
	570	535	142	52	24	12	-	-	-	DN 80	
	-	1275	340	129	56	25	-	-	-	DN 100	MD1.80.80.30
	425	400	104	38	16	6	-	-	-	DN 80	
	-	1190	305	106	41	-	-	-	-	DN 100	MD1.80.80.22
	405	370	92	31	11	-	-	-	-	DN 80	
-	635	145	42	-	-	-	-	-	DN 100	MD1.80.80.15	
220	195	42	11	-	-	-	-	-	DN 80		

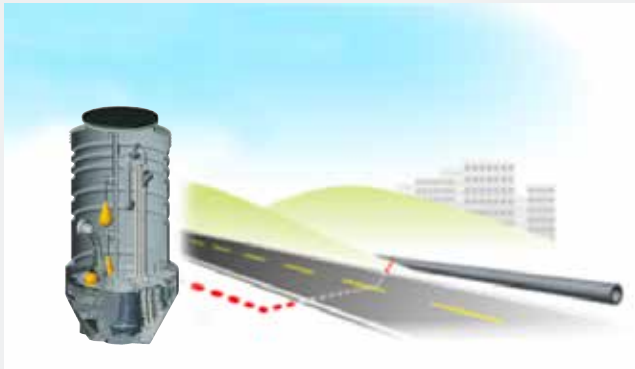
Q [l/s]	3.5	5.5	10	15	20	25	30	35	40
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From the selection guide we can see that the MD1.80.80.22.4 can pump 10 l/s in a DN 100 discharge pipe when the geodetic head is 4 m. Geodetic head is slightly below the actual 4.5 m but flow is more than required and the discharge pipe is longer than required.

CASE 7. Grinder pump sizing

A picnic area along the highway has four toilets. The wastewater from the toilets must be pumped to the sewer main on the other side of the highway. The pumping station outside the building with the toilets has only one pump installed, meaning there will be no spare pump capacity.



1. Determination of the wastewater flow, Q_{ww} :

To determine losses in valves and fittings and check water velocity in the discharge pipe, the wastewater flow rate according to EN 12056-2 must be calculated.

According to EN12050-2 System 2	DU l/s	Amount	Total l/s
Wash basin	0.3	4	1.2
WC with 6,0 l cistern	1.8	4	7.2
Sum, DU			8.4

EN 12056-2 provides the following formula for the calculation of real or expected flow rates in whole and partial sewage system where only domestic sanitary appliances are connected.

$$Q_{ww} = K \sqrt{\sum DU} \quad \text{where}$$

Q_{ww} = Wastewater flow rate (l/s)

K = Frequency factor

DU = Sum of water flow rate discharge units (l/s)

The frequency factor K is determined by consulting the table below. In this case we have toilets open to public and therefore the K frequency factor is 1.0.

Usage of appliances	K
Intermittent use eg. in dwelling, guesthouse, office	0.5
Frequent use eg. in hospital, school, restaurant, hotel	0.7
Congested use eg. in toilets and/or showers open to public	1.0
Special use eg. laboratory	1.2

The total flow rate Q_{tot} , i.e. the design flow rate, is calculated from:

$$Q_{tot} = Q_{ww} + Q_c + Q_p \quad \text{where}$$

Q_{tot} = Design flow rate (l/s)

Q_{ww} = Wastewater flow rate (l/s)

Q_c = Continuous flow rate (l/s)

Q_p = Pumped water flow rate (l/s)

In this picnic area, there are no sanitary installations supplying a continuous flow rate Q_c and there are no other pumping stations. Hence, Q_c and Q_p is not relevant. Therefore the design flow rate Q_{tot} will be equal to Q_{ww} .

$$Q_{ww} = K \sqrt{\sum DU} = 1.0 \sqrt{8.4} = 2.9 \text{ l/s}$$

Other data:

Ground level for

pumping station 0.0 m

Discharge pipe inlet

to sewer main 5.0 m above ground level

Highest backflow level 5.0 m above ground level

Wastewater inlet level 1.5 m below ground level

Pump stop level 3.0 m below ground level

Discharge pipe length: 315 m

2 Static head:

H_{geo} = Discharge pipe inlet level - pump stop level

$$H_{\text{geo}} = 5.0 \text{ m} + 3.0 \text{ m} = 8 \text{ m}$$

3. Losses in valves and fittings H_{VA} :

The pipe velocity is calculated from: $v = \frac{Q}{A}$

A 2" pipe with an internal diameter of 50 mm is chosen.
The water velocity turns out to be within the acceptable range of 0.7 m/s to 3.0 m/s.

$$V = \frac{Q}{A} = \frac{Q}{\frac{\pi}{4} \cdot d^2} = \frac{2.9 \cdot 10^{-3}}{\frac{\pi}{4} \cdot 0.05^2} = 1.45 \text{ m/s}$$

Resistance factors (Zeta) (-) for valves and fittings on discharge pipe are calculated:

Gate valve	$1 \times 0.5 = 0.5$
Non-return valve	$1 \times 2.2 = 2.2$
Widening	$1 \times 1.0 = 1.0$
Bend 90°	$2 \times 0.5 = 1.0$
Bend 45°	$4 \times 0.3 = 1.2$
Outlet	$1 \times 1.0 = 1.0$
Total (Zeta) value	$= 6.9$

Head losses in valves and fittings are calculated:

$$H_{\text{VA}} = \sum_i \zeta_i \frac{V_i^2}{2g}$$

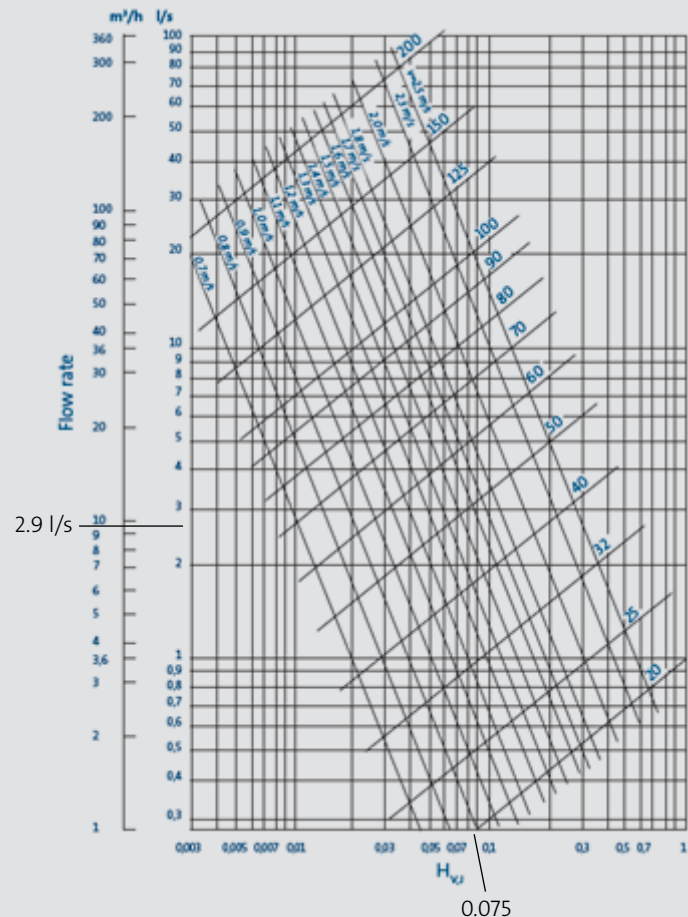
$$H_{\text{VA}} = 6.9 \frac{1.45^2}{2 \cdot 9.81} = 0.51 \text{ m}$$

4. Linear friction losses in discharge pipe, $H_{\text{V,R}}$

The total pressure loss in the discharge pipe is determined:

$$H_{\text{V,R}} = H_{\text{Vj}} \times L_{\text{V,i}} = 0.075 \times 315 \text{ m} = 23.6 \text{ m}$$

Head, H_{Vj} is found in the nomogram as a function of flow rate and pipe diameter.



5. Discharge head, H_p

The pump's discharge head, H_p should be equal to or greater than the total head in the system, H_{tot} .

The total head is calculated below:

$$H_{tot} = H_{geo} + H_v \text{ where } H_v = H_{VA} + H_{VR}$$

$$H_{tot} = H_{geo} + H_{VA} + H_{VR}$$

$$H_{tot} = 8.0 \text{ m} + 0.51 \text{ m} + 23.5 \text{ m} = 32 \text{ m}$$

The right pump is found in the Grundfos Product Center in the sizing part.

Flow, static head (geometric head) and friction losses are used as input in sizing tool:

$$\text{Flow, } Q_{tot} = 2.9 \text{ l/s}$$

$$\text{Static head, } H_{geo} = 8.0 \text{ m}$$

$$\text{Friction losses: } H_{VA} + H_{VR} = 24.0 \text{ m}$$

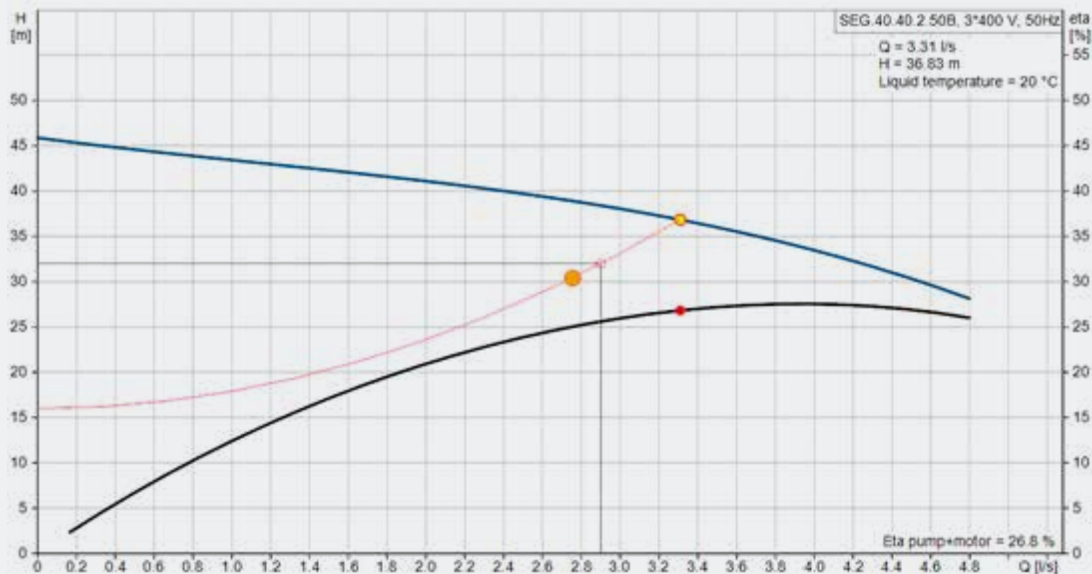
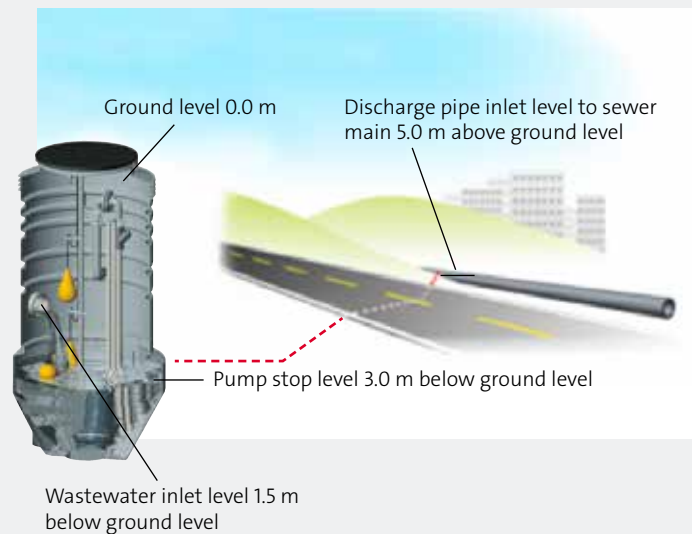
The selection sized in Grundfos Product Center is pump type SEG.40.40.2.50B. The pump is a grinder pump with 4 kW, 50 Hz motor and 40 mm outlets.

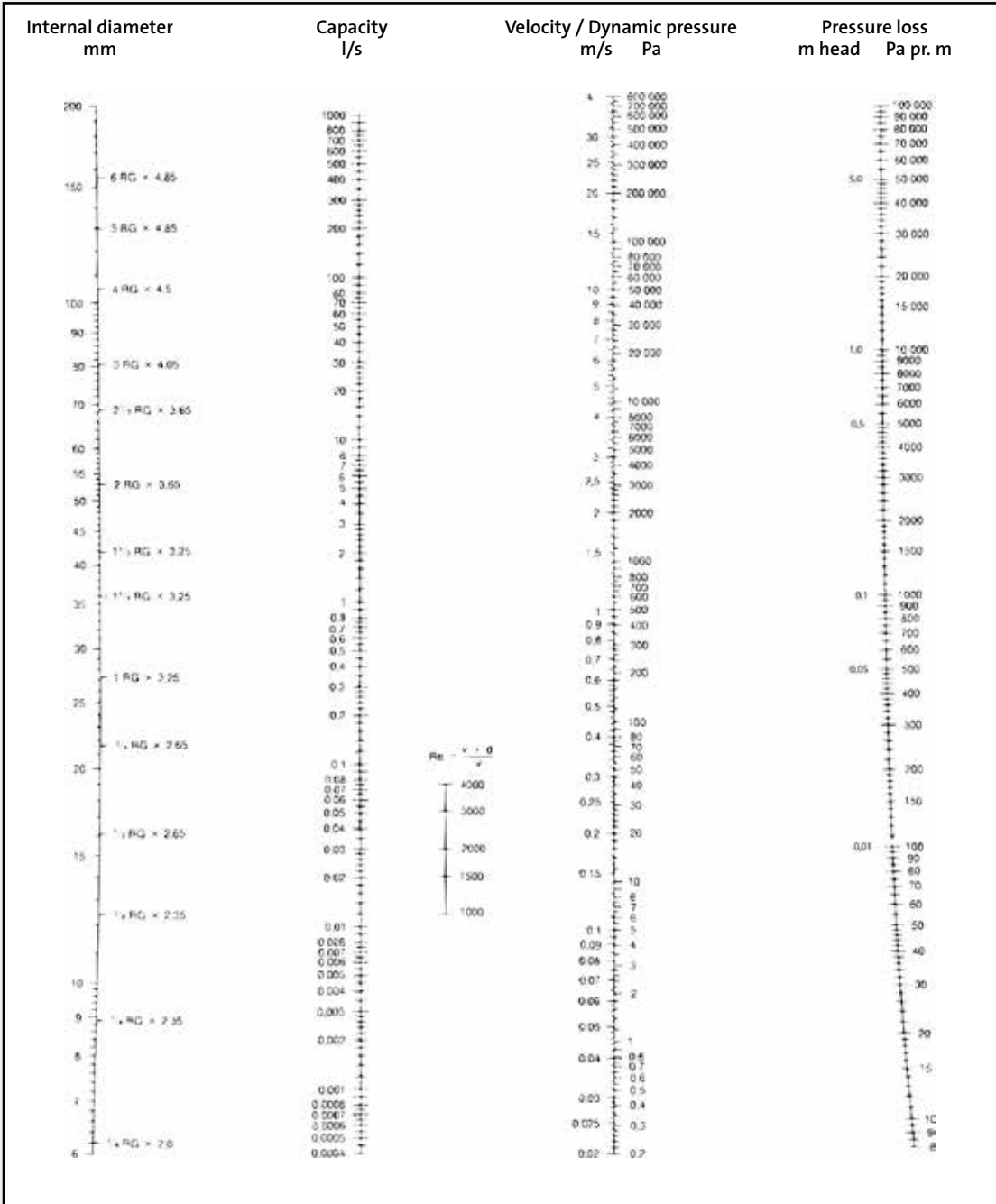
The pump is slightly oversized for the duty point with a:

Flow of 3.3 l/s

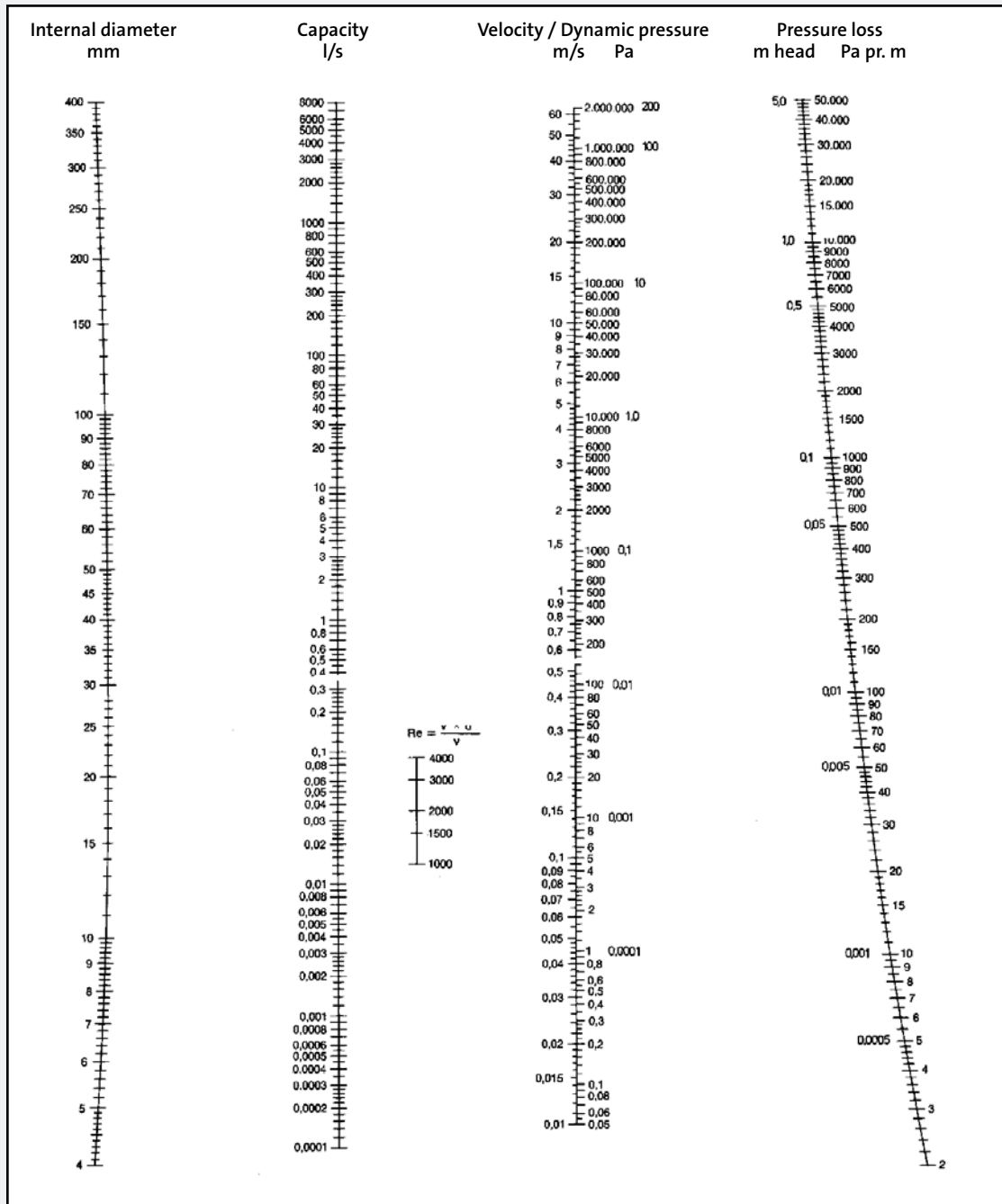
Head of 36.8 m

Velocity in the discharge pipe approximately 1.6 m/s





Nomogram showing friction loss in straight galvanized steel pipes with deposits



Nomogram showing friction loss in PVC ground sewage pipes with deposits



be think innovate



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