Sewage technology for water management

Planning guide – Basic hydraulic and electrical engineering principles

2008

CONTENTS

Introduction

Drainage and sewage – a millennium topic

It is a very old topic that people have always had to deal with since living together in large settlements – what to do with the drainage and sewage? That is the essential topic of urban development, whether in ancient times or in the modern day and age.

Functions, which we take for granted today, were dealt with by engineers in ancient times using sophisticated systems based on gravity and mechanical principles. Instead of high-tech materials and computer calculations, they used craftsmanship and an astonishing inventiveness.

The problem of "drainage and sewage" seems always to have been of great significance, ever since the beginning of civilisation. There is evidence of the first sewage channels in the third millennium before Christ. During the Minoan culture, the palace of Knossos was equipped with a stone-walled sewer system and pipes made of terracotta to get rid of the sewage.

The Romans' bath culture could not do without drainage and sewage systems either. Not only the city of Rome was drained into the river Tiber by means of the Cloaca Maxima, which still exists today. In Cologne too, sections of underground sewage channels from Roman times can still be walked on.

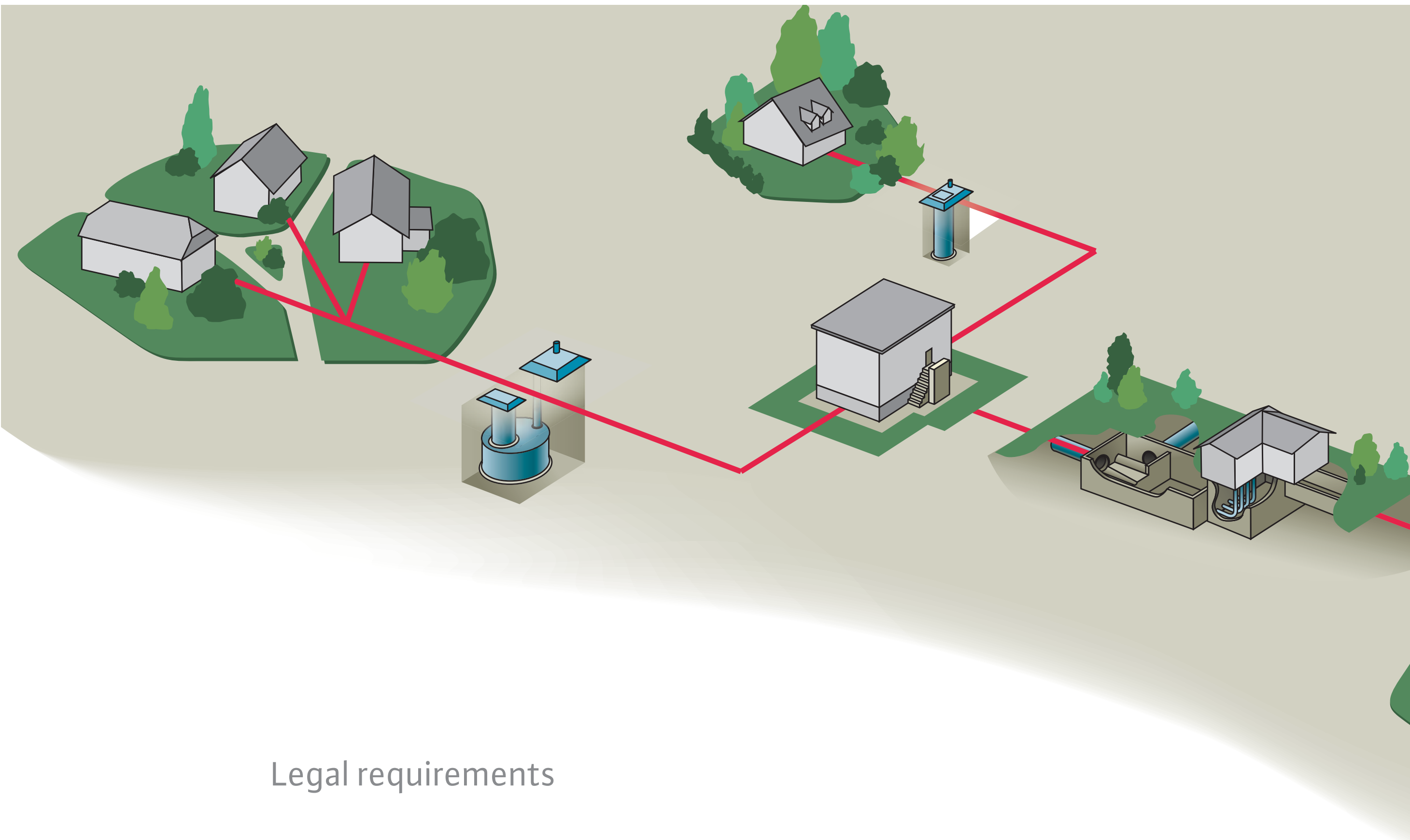
The higher the number of people living closely together, the more urgent became the question of removing human excrements. However, from the middle age up to modern times, conditions prevailed that are unimaginable for us today. For the large part, drainage took place along open gutters into the nearest river.

Those living in Berlin in the Middle Ages had to use a pit latrine, like most of the more than six thousand inhabitants. A closed sewer system did not exist yet, so rainwater, sewage and slurry mixed in the gutter to flow in untreated form into the nearby river Spree.

By 1870, Berlin was already a large city with a population of almost one million. Since hardly any of the flats in buildings had their own toilets, men and women needed to use "public conveniences" of which there were a large number in streets and public places, some of which were even heated. These toilets were connected to an sewage system. However, the sewage still flowed into the river Spree without any water treatment system.

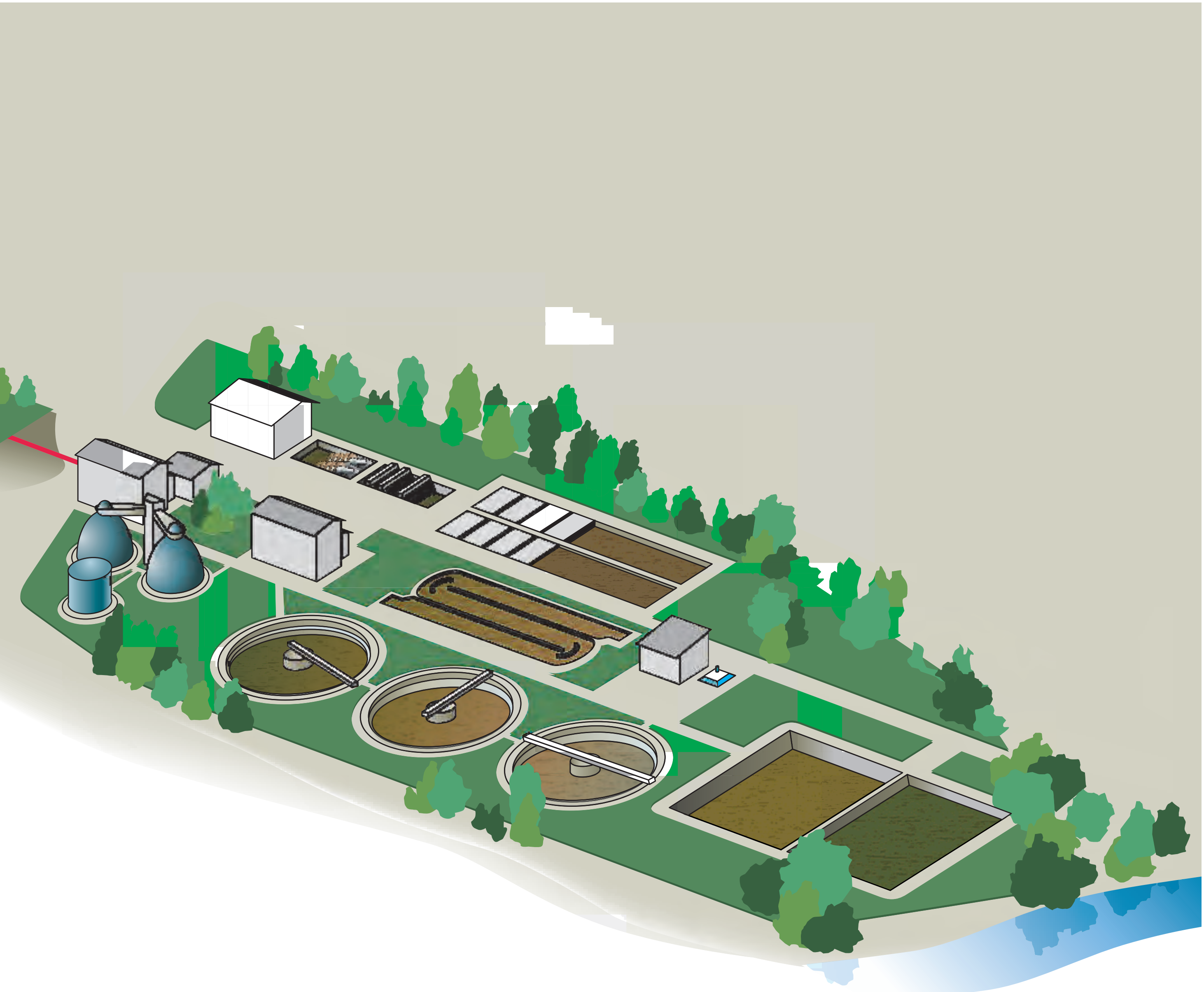
With the beginning of industrialisation and fast-growing urban populations, a controlled sewage disposal system became inevitable. In this context, Hamburg was among the forerunners.
The first German central sewage and water treatment system was developed there in 1856.

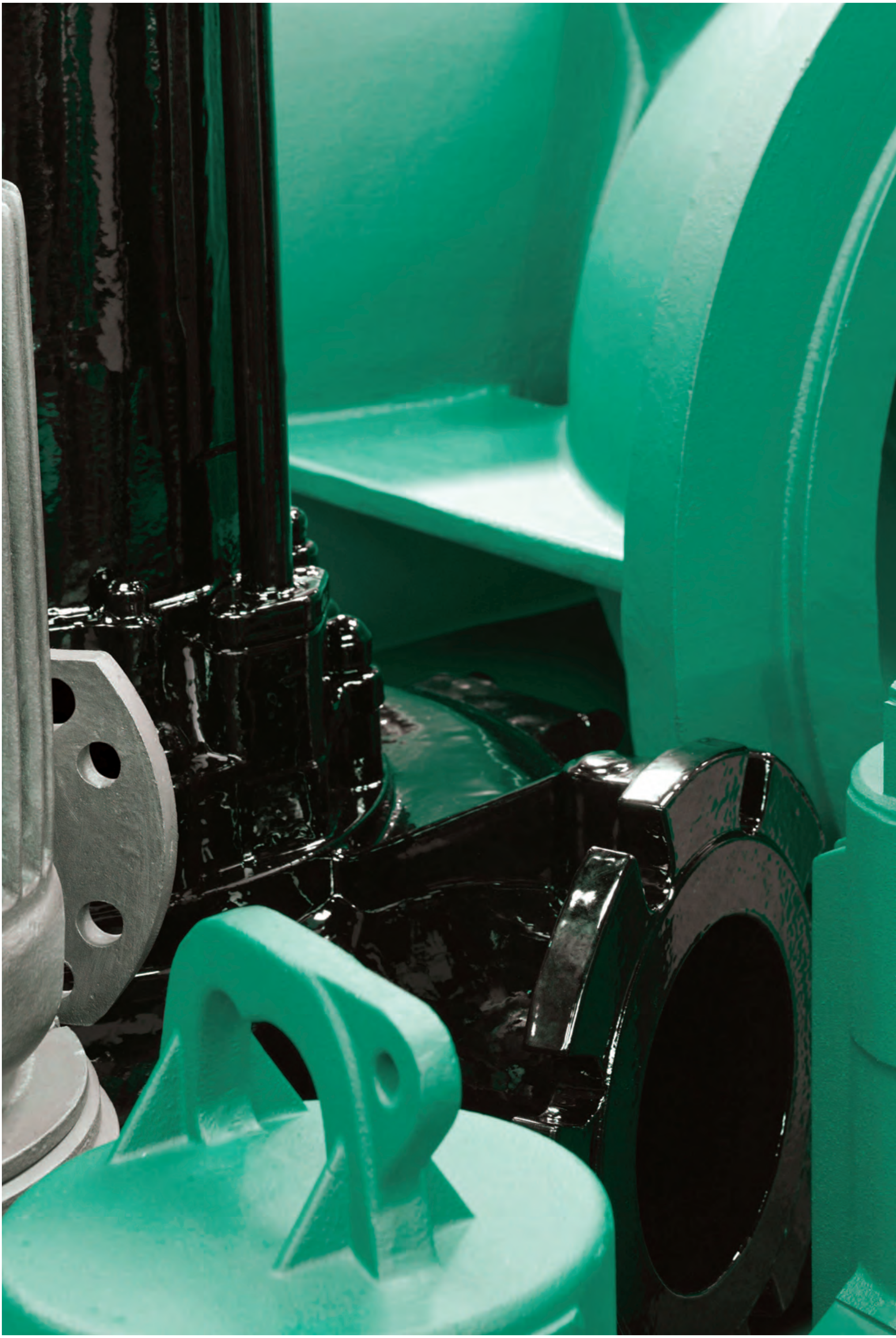
However, this groundbreaking urban development remained a privilege of large cities for another century. In rural areas, sewage and faeces were still collected in sumps and cesspools. It wasn't until the turn of the millennium that legal requirements ensured that domestic households almost everywhere were connected to a sewage system and the drainage and sewage flowed back to the natural water cycle in purified condition via water treatment systems.



Legal requirements

Notes on standards, guidelines and worksheets (excerpt)	
DIN 4045	Sewage technology – Basic terminology
DIN EN 752, Parts 1–7	Drainage systems outside buildings
DIN EN 1671	Pressure drainage systems outside buildings
DIN EN 1299	Mechanical vibrations and blows, vibration insulation of machines
DIN 24260, Part 1	Centrifugal pumps and centrifugal pump systems; terminology, formula symbols, units
DIN 24293	Centrifugal pumps – Technical documents – Terminology, scope of delivery, version
VDE 0100	Specifications for installing heavy-current units with a nominal voltage up to 1000 V
VDE 0105	Operation of heavy-current units
VDE 0160	Equipment of heavy-current units with electronic equipment
and including: DIN EN 61800, Part 3	Electrical drives with variable speed
VDE 0165	Installing electrical systems in potentially explosive areas
VDE 0170/0171	Electrical equipment for potentially explosive areas
DIN EN 50018	Electrical equipment for potentially explosive area, pressure-resistant enclosure
VDE 0660	Low-voltage switchgears
and including: DIN EN 60439 T 1–5	Low-voltage switchgear combinations
DIN EN 60947 T 1–7	Low-voltage switchgears





Basic hydraulic principles

Function of centrifugal pumps

Pumps are necessary to convey fluids and to overcome the resulting flow resistance in pipe systems. In pump systems with different fluid levels, the static height difference also needs to be overcome.

According to their design and type of energy conversion, centrifugal pumps are hydraulic fluid flow machines. Although there is a wide range of designs, in all centrifugal pumps, the fluid enters an impeller in axial direction.

An electric motor drives the pump shaft, on which the impeller is fitted. The water, which flows to the impeller through the suction port and the suction throat, is deflected by the impeller blades in the form of a radial motion (exception: propeller pumps and multistage pumps). The centrifugal forces, which take effect on each fluid particle, result in an increase of the pressure as well as the speed while the fluid flows through the impeller area.

After leaving the impeller, the fluid is collected in the spiral housing. The flow rate is reduced slightly by the housing structure. Due to the conversion of the energy, the pressure is increased even more. A pump consists of the following main components:

- Pump housing
- Motor
- Impeller

Installation types

Very different types of installations are used in submersible systems in municipal applications. The type of installation depends mainly on the application purpose and the investment volume.

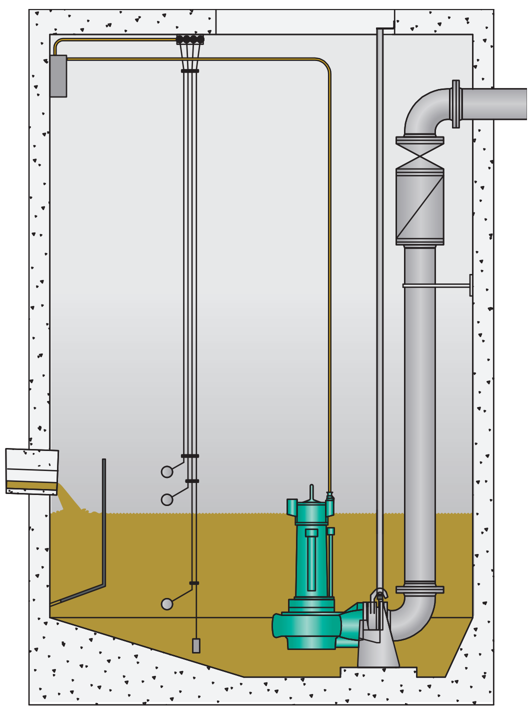
Basically, three main installation types are distinguished:

- Wet well installation, stationary
- Wet well installation, portable
- Dry well installation, stationary

The pipe sump installations are also required. The type of installation depends mainly on the requirements of the planning engineer and the operator. Different viewpoints arise, which each are justified in terms of the individual field of application.

Wet well installation or stationary tank installation

With wet well installation, the pump is installed in the fluid to be pumped. The motor is cooled by the circulating sewage. The advantage of this type of installation is low investment costs compared to the more sophisticated pumping station designs for dry-installed sewage pumps. In such a case, a construction above ground or an intermediate base in the sump for the pumps is not required. In greater depths, an intermediate ceiling is necessary.



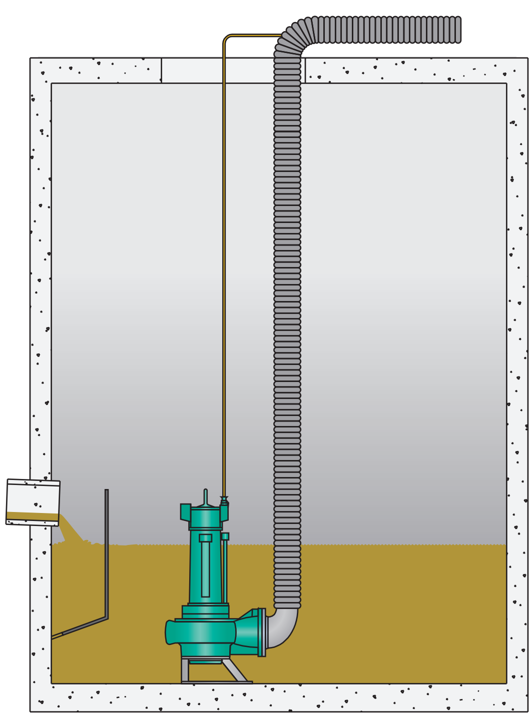
The pump is fastened by means of a suspension unit with lowering mechanism. That allows the pump to be "pulled" at all times, e.g. for maintenance work.

The coupling base and the elbow are usually cast in one piece. The guide consists of two pipes, thus preventing any twisting. The Wilo coupling connection is made is such a way that a lip prevents the seal ring from falling out.

The pressure pipe made of a galvanised steel pipe, or ideally of a stainless steel pipe, is fitted directly on the suspension unit via flanges and leads out of the pump sump. The sump can be made at low costs from ready-made concrete sumps equipped with elastomer seals in accordance with EN 1917 (national addition: DIN 4034 T1). However, one-piece PEHD sumps without joints are a better solution, since these prevent any infiltration of external water.

As shown on the diagram, this installation type gives the operator the option of special pump sump geometries adjusted to individual requirements, the use of additional flushing valves or the installation of vortex impellers with special mixer head technology.

The disadvantage of a wet well installation is the lack of ease of maintenance. In addition, with a wet-installed submersible sewage pump, the water level can only be lowered to a certain level, since optimum cooling of the motor is only possible in submerged condition.



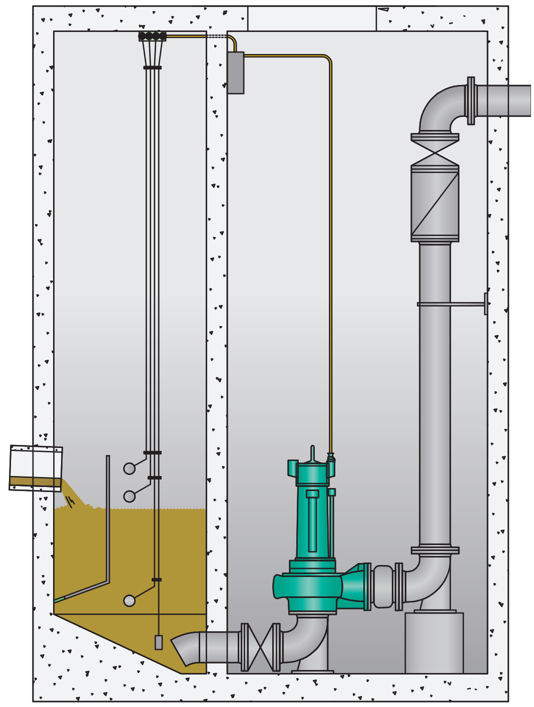
Portable wet well installation

With this type of installation, the motor is cooled in the same way as for stationary wet well installation, However, the pump is not fastened firmly in the pump by means of a suspension unit.
The pump can thus be installed in any sump via a base component on the pump housing. With the right couplings, hoses of appropriate length can be installed on the pressure port. When selecting the pump, hydraulic conditions, such as volume flow and delivery head as well as the pump's NPSH, must also be taken into account.

Portable pumps are frequently used for municipal applications as emergency drainage or residual drainage pumps.

Stationary dry well installation

The dry well installation variant, in particular the dry-installed submersible pump, provides a number of advantages compared to dry-installed pumps, and also compared to wet-installed submersible pumps.



Installation principle of a dry-installed submersible pump

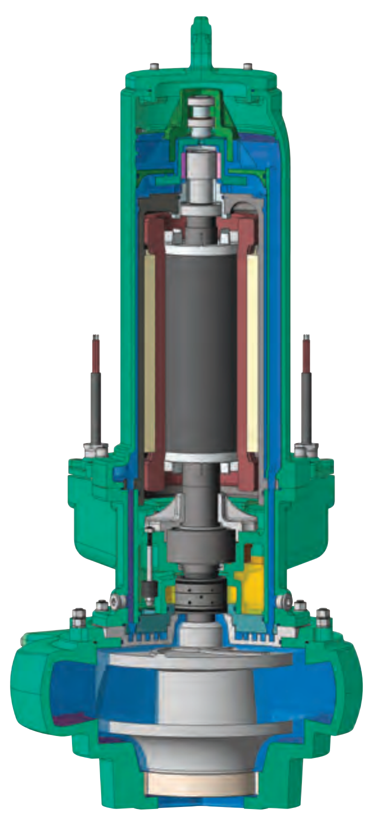
The main difference to a wet-installed submersible pump is the design of the motor. It is a fully encapsulated motor with internal closed-circuit cooling. A distinction is made between an open cooling system and a closed cooling system. With an open cooling system, the fluid to be pumped is used as the coolant. With a closed system (single-chamber or two-chamber system), cooling is performed by an external fluid, such as e.g. water-glycol or medical white oil, in a closed circuit.

Another main difference to the wet-installed submersible pump is that the dry-installed submersible pump is not installed in the fluid to be pumped. In terms of the technical construction, an intermediate base is required directly in the pumping station. The major advantages are the combination. On the one hand, this submersible pump offers all benefits of a dry-installed pump and, on the other hand, all benefits of a submersible pump, such as being overflow-proof.

As already mentioned, the pump is installed in a separate pump room. The pump is fastened to the inflow pipe unspectacularly via a pipe elbow.

Advantages compared to dry-installed pumps (not submersible pumps)

- Overflow-proof and thus more operational reliability
- Low-maintenance carbide mechanical or seal cartridges
- No couplings or V-belts, thus fewer wearing parts and less maintenance required
- Explosion protection is possible at all times
- Clean and hygienic working conditions
- Ease of maintenance



Internal closed-circuit cooling:

Internal cooling circuit prevents any interruption of cooling.

The motor heat is dissipated via heat exchanger to the fluid. Operating temperature and thermal load on the components remain low.

Pumped fluids/impeller shapes

Pumped fluid (untreated sewage, sludge)

Solids concentration
Depending on the concentration of solids, the following pump types can normally be used (rough guideline):

Up to 8 % dry matter:
• Non-clog impeller and vortex impeller
• Mixed flow non-clog impeller pumps

Up to 12 % dry matter:
• Mixed-flow pumps

Above 12 % dry matter:
• Piston pumps, progressive cavity pumps

The smaller value applies to hydrophilic solids, the larger value to non-hydrophilic solids. The prerequisite for perfect pumping in all cases is that the pump's fluid still flows on its own.

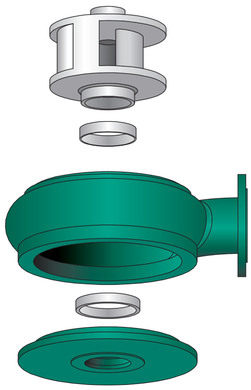
Viscosity
The pump curves and the given motor power values in the type sheets apply to the pumping of water = 1.0×10^{-6} m^2/sec. The diagram for friction losses also applies to water only. If the viscosity of the fluid is greater than $v = 1.5 \times 10^{-6}$ m^2/sec., the following aspects need to be observed in particular:

• Increased friction losses in the pipe (when determining the delivery head)
• Increased power requirement of the pump (when determining the drive power)

Specific weight
The motor power values given in the type sheets apply to water as the fluid (= 1 kg/dm^3).

With a higher specific weight of the fluid than that of water, an increased power requirement of the pump needs to be taken into account.

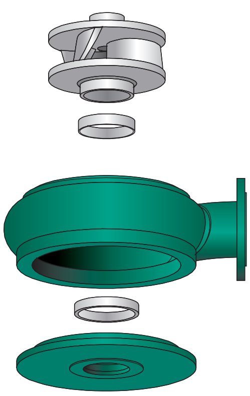
Closed single-blade impeller (single-channel impeller)



Properties:
- Largely insensitive to clogging
- Larger ball passage
- Low susceptibility to wear
- Gentle pumping
- Power correction possible by trimming the impeller
- High degree of efficiency
- For solid matter concentrations up to 8 % dry matter, depending on the type of sludge
- In the event of wear, only the stationary wear ring and the counter ring need to be replaced
- Hydraulic compensation of the axial thrust due to back vanes, thus reduced load on the bearings

Fields of application:
- Untreated sewage
- Circulation and heating sludge
- Mixed water
- Raw and digested sludge
- Activated sludge

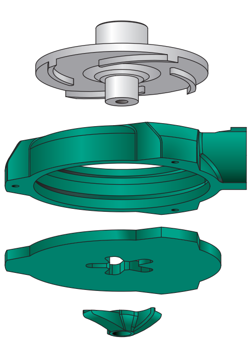
Closed multi-blade impeller (multi-channel impeller)



Properties:
- Smooth running
- Largely insensitive to clogging
- Larger ball passage
- Low susceptibility to wear
- Gentle pumping
- Power correction possible by trimming the impeller
- High degree of efficiency
- For solid matter concentrations up to 5 % dry matter, depending on the type of sludge
- In the event of wear, only the stationary wear ring and the counter ring need to be replaced
- Hydraulic compensation of the axial thrust due to back vanes, thus reduced bearing load

Fields of application:
- Rake-cleaned sewage
- Mechanically treated sewage
- Industrial wastewater
- Landfill water
- Activated sludge
- Industrial sewage

Open multi-blade impeller with cutting unit



The upstream macerator system cuts up the admixtures in the sewage to the required size. The macerator system consists of an Abrasite macerator unit and a cutting plate made of the material 1.4034.

The macerator system has easy-to-use adjustment options for various gap clearances.

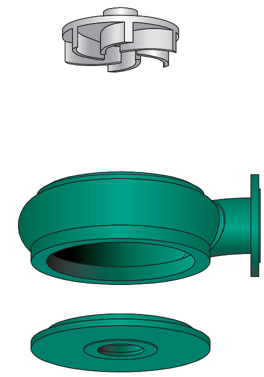
Properties:
- Largely insensitive to clogging
- Small ball passage
- Sensitive to wearing fluids e.g. containing sand

Fields of application:
- Domestic sewage
- Wastewater
- Faeces
- Suitable for low-pressure draining

Vortex impeller

Properties:
- Hardly any clogging
- No gap sealing
- Optimum ball passage
- Suitable for some bubble-forming fluids
- Power correction possible by trimming the impeller
- Lower degree of efficiency compared to the non-clog impeller
- For solid matter concentrations up to 8 % dry matter, depending on the type of sludge
- Insensitive to fibrous sewage
- Hydraulic compensation of the axial thrust due to back vanes, thus reduced bearing load
- Low-wear
- Also suitable for bubble-forming fluids

Fields of application:
- Untreated sewage
- Activated sludge
- Raw and digested sludge
- Mixed water
- Fluids with problematic constituents
- Fluids with wearing constituents



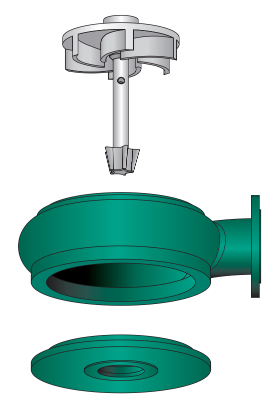
Vortex impeller with mixer head

The mixer head is a mechanical stirring apparatus, which forms a unit with the vortex impeller. The sand is thus only stirred up in the area of the pump inlet. Solid deposits are loosened up and pumped. Due to the narrowly limited flow zone, the depositing of sand is not disturbed.

The mixer head is made of the highly wear-resistant special material, Abrasite.

Properties:
- See vortex impeller
- Loosening up of solidified sand deposits
- High wear-resistance
- Self-cleaning mixer head

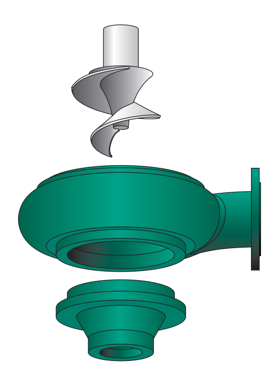
Fields of application:
- In the grit chamber
- Sand and gravel systems
- Sludge settling ponds
- Sedimentation tanks
- Wherever deposits are possible



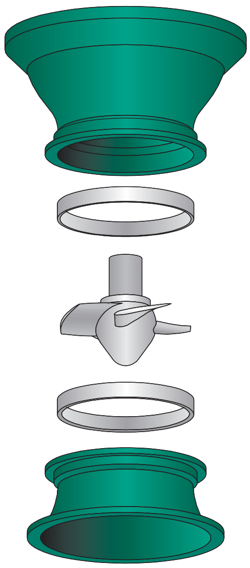
Helical impeller

Properties:
- For highly viscous fluids
- Small ball passage
- Sensitive to wearing fluids (e.g. containing sand)
- Very gentle pumping
- Power correction possible only to a limited extent
- For solid matter concentrations up to 12 % dry matter, depending on the type of sludge
- Power consumption remains constant with increasing volume flow

Fields of application:
- Circulation and heating sludge
- Raw and digested sludge
- Viscous fluids
- Fluids with up to 12 % dry matter



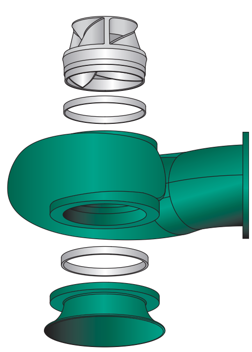
Propeller impeller (axial impeller)



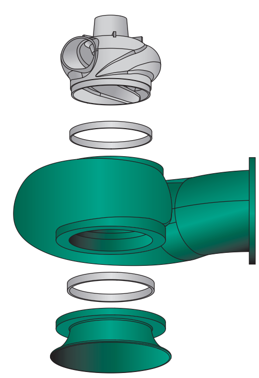
Properties:
- For very high volume flow and very low delivery head
- High degree of efficiency
- Power consumption falls with increasing volume flow
- May not be operated against closed slide valve

Fields of application:
- Fluids with small amounts of dirt
- Rainwater
- Return activated sludge
- Circulation of activated sludge
- Water drawing units etc.

Other impeller shapes are the semi-axial impeller and the impeller in pot design:



Semi-axial impeller



Impeller in pot design

Impeller selection

The precise selection of the right impeller depends on the following:
• Application conditions
• System conditions
• The duty point of the pump
• and several other factors.

These factors need to be checked carefully from case to case.

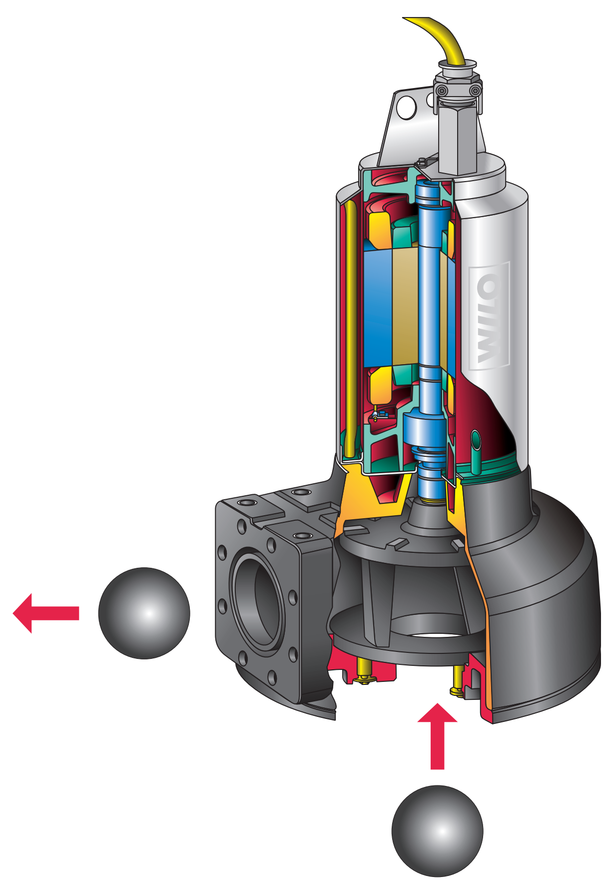
Properties of impellers

	Resistance to clogging	Pump curve progression ++ = very steep – = very flat	Pumping of fluids containing gas	Pumping sludge	Efficiency	Smooth operation	Wear-resistance (*with counter ring & stationary wear ring)
Vortex impeller	+++	–/+	+	+	0	+++	+++
Closed single-blade impeller	++	+	–	+	++	+	++*
Closed multi-blade impeller	+	+	0	+	++	++	++*
Helical impeller	+	++	++	+++	++	+	0
Semi-axial impeller	+	+	0	0	+++	++	+*
Axial impeller	–	++	0	–	+++	++	0
Impeller in pot design	+++	++	+	+	++	+++	++*

+++ = ideal; ++ = very good; + = good, o = limited; – = unfavourable

Free (ball) passage

Sewage pumps and their hydraulic components are adapted to the different conditions and the corresponding constituents of the pumped fluids. However, one needs to take into account which design shape of the impeller is best suited for the corresponding fluid and its composition. An increase of the free ball passage means a reduction of the hydraulic efficiency. That results in a higher motor power with the same hydraulic result, which in turn has an effect on the operating and acquisition costs. Dimensioning is important:
• Economic aspects
• Trouble-free operation of the sewage pumps
• Operational reliability

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Hydraulic power

Volume flow (Q)

The volume flow Q is the hydraulic volume flow achieved by the pump (pumped fluid quantity) within a specific time unit, such as e.g. l/s or m³/h. The circulation or leakage losses required for internal cooling are power losses that are not attributed to the volume flow.

When specifying the volume flow, one distinguishes between the following:
- Best point of the pump (Q_{opt})
- Maximum volume flow (Q_{max})
- Minimum volume flow (Q_{min})

Delivery head (H)

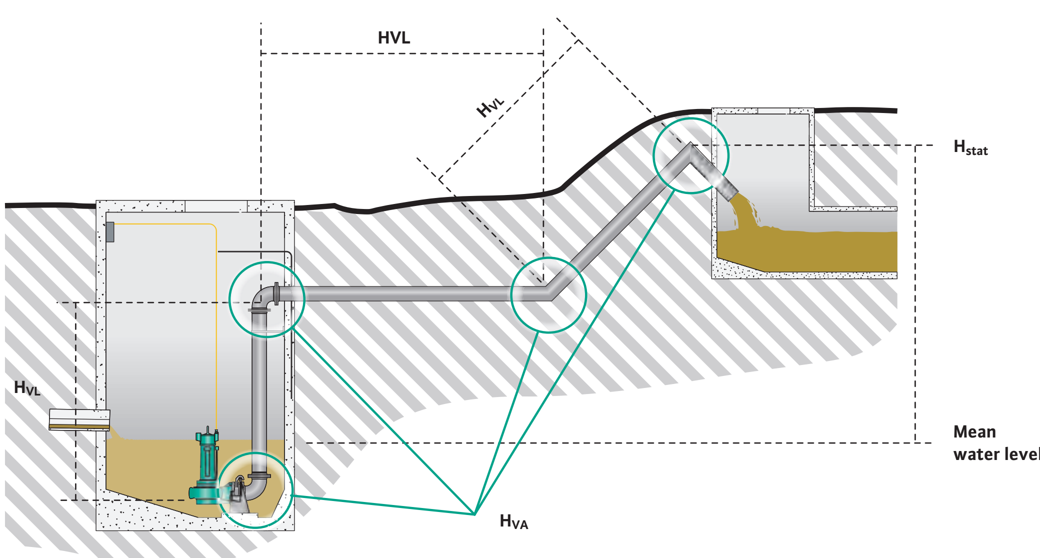
The delivery head H of a pump is the energy difference of the fluid between pump inlet and outlet. The unit of the delivery head is m or bar (10 m ~ 1 bar). The energy proportions are expressed as kinetic head (= delivery head). The pressure is a component of the kinetic head, however, colloquially, the energy difference is used as a synonym (energy difference = pressure).

The delivery head to be achieved by the pump (energy difference) is the sum of the static height difference and the pressure loss (= head loss) in pipes and valves.

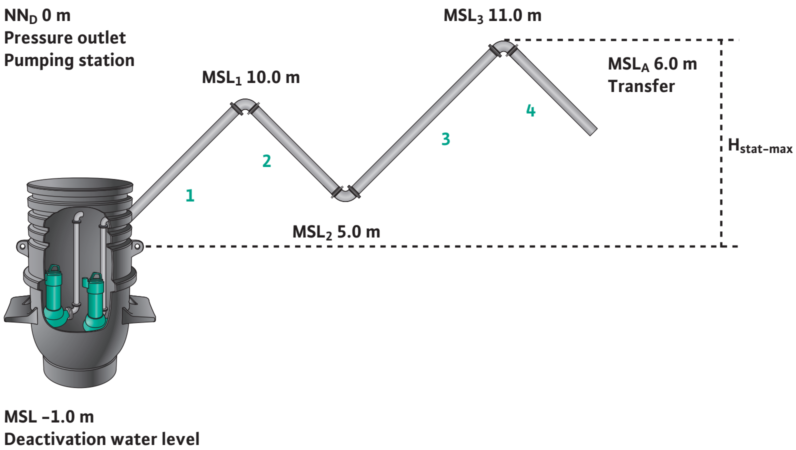
$H_{max} = H_{stat} + H_{VL} + H_{VA}$

When specifying the delivery head, the exact designation of the pressure must be observed. There is a basic difference between the pressure in the optimum duty point, the pressure with the best pump efficiency (H_{opt}) and the maximum pressure of the pump (H_{max}). Damage can be done to the installation and to the unit due to ambiguous specifications which result in overdimensioning or pumps being selected which are too small, which cause the installation/unit to fail temporarily. Potential maximum points are to be taken into account accordingly, i. e. the max. highest point of the pipe is ($H_{stat-max}$).

With pressure pipelines without ventilation that are not laid continuously, the individual values are to be added according to the changes in height. That is due to the fact that, due to the individual height differences, partial fillings of the pipes are most probable, meaning that several mixing water columns need to be added.



H_{VL} = Pressure losses in pipes
H_{VA} = Pressure losses in valves and bends
H_{stat} = Pressure loss due to height difference



In the event of partial fillings, the ascending sub-sections are added:

$$H_{stat-max} = (MSL_1 - MSL) + (MSL_3 - MSL_2)$$
$$= [10\ m - (-1\ m)] + (11\ m - 5\ m)$$
$$= 17\ m$$

If one were to assume the complete filling of the pipe system, only the static height difference between the mean water level of the tank and the highest point would need to be calculated.

For complete filling:

$$H_{stat} = MSL_3 - MSL = 11.0\ m - (-1\ m)$$
$$= 12\ m$$

Flow rate

Solid matter and settling sediments in the sewage may be deposited in pipes resulting, in the clogging of the drainage system. To prevent any clogging of pipes, it is advisable to maintain the following minimum flow rates:

		Recommendation according to DWA A 116-2
Pressure pipe	Horizontal pipes	V_{min} = 0.7–1.1 m/s*
	Vertical pipes	V_{min} = 1.0–1.5 m/s
	Sewer pipes	V_{min} = 2.0–3.0 m/s
Pipes flushed with compressed air	EN 1671	$0.7 \leq V_{min}$
Non-flushed pipes	DWA-DVWK A 134	$0.7 \leq V_{min} \leq 2.5$

** up to DN 100 0.70 m/s*
up to DN 150 0.80 m/s
up to DN 200 0.90 m/s
up to DN 250 0.95 m/s
up to DN 300 1.00 m/s
up to DN 400 1.10 m/s

Depending on the composition of the fluid (e.g. high sand content, pumping sludge), the above-mentioned values may be higher. However, the corresponding regional and national standards and guidelines need to be observed. The flow rate is determined by the full volume flow (m^3/s) per area (m^2) and should generally lie between 0.7 m/s and 2.5 m/s. The following should be taken into account for the selection of the pipe diameter: The higher the flow rate is:

- The less deposits
- The higher the pipe losses
- The less economic
- The higher the risk of wear

Pump curves

The pressure increase in the pump is called delivery head.

Definition of the delivery head

The delivery head of a pump H is the useable mechanical work transferred from the pump to the fluid, in relation to the weight force of the pumped fluid during local gravitational acceleration.

$$H = \frac{E}{G} [m]$$

E = useable mechanical energy [N • m]
G = weight force [N]

The pressure increase generated in the pump and the volume flow through the pump are mutually dependent. This dependency is displayed in a diagram in the form of a pump curve.

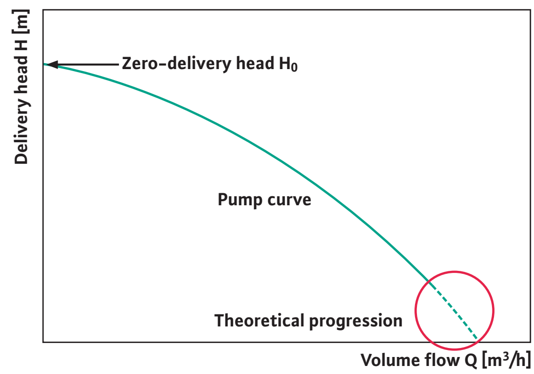
The delivery head H of the pump is entered in metres [m] on the vertical axis, the axis of ordinates. Other axis scales are possible. The following conversion values apply:

10 m ≈ 1 bar = 100 000 Pa = 100 kPa

The scale for the volume flow Q of the pump in cubic metres per hour [m³/h] is indicated on the horizontal axis, the abscissa. A different axis scale is possible here too, e.g. (l/s).

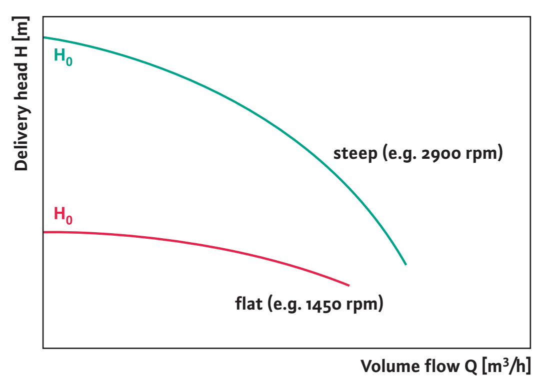
The progression of the pump curve shows the following relationships: The electrical drive energy (taking the overall efficiency into account) in the pump is converted to the hydraulic energy forms, pressure increase and motion. If the pump runs against a closed valve, that results in the maximum pump pressure. That is referred to as the pump's zero-delivery head H_0. If the valve is opened slowly, the fluid begins to flow. Part of the drive energy is thus converted into kinetic energy. The original pressure can then not be maintained any more. The pump curve falls. Theoretically, the intersection point between the pump curve and the volume flow axis is reached when the water only contains kinetic energy and no pressure is built up any more. However, since a pipe system always has an inner resistance, the actual pump curves end before the pumping flow axis is reached.

Pump curve



Pump curve shape

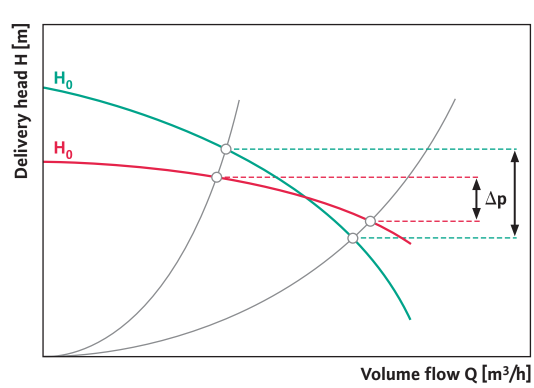
The following diagram shows the different steepness of pump curves, according to e.g. the motor speed.



Depending on the steepness and the change of the duty point, different volume flow and pressure changes are the result:

- Flat pump curve progression – higher volume flow change, but small pressure change
- Steep pump curve progression – smaller volume flow change, but large pressure change

For permanent operation, pumps should never be selected with a duty point in the extreme left or right range of the pump curve.



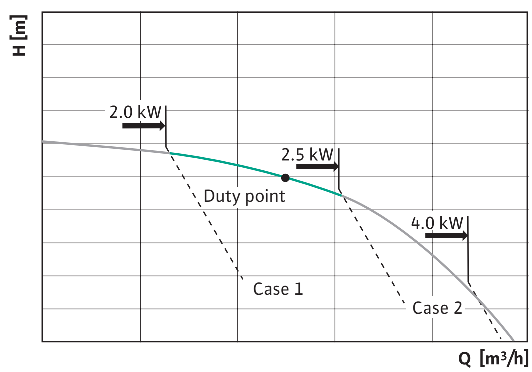
Various volume flow and pressure changes

Selection of the submersible motor

Case 1
The pump runs at one duty point only. Therefore the delivery head is constant. As a rule, the submersible motor with the next higher drive power is selected (in the example: 2.5 kW).

Case 2
The performance of the pump fluctuates within a certain performance range or the pump is operated within the entire range of the pump curve. In this case, the motor with the maximum drive power is used (in the example: 4.0 kW).

Drive power



The motor power values specified by Wilo already include a power reserve of 10 to 15 %. This power reserve takes into account that normal sewage contains solids that cause higher power requirements (as with operation in pure water), due to their bulkiness, fibrousness or friction. Under special conditions, e.g. high solids content, high viscosity, high specific weight, special constituents in the fluid etc., the drive power must be determined separately according to experience. Such conditions nor-mally prevail in the event of thickened sludge.

System curve

H_{VL} = Pressure losses in pipes
H_{VA} = Pressure losses in valves
H_{stat} = Static height difference (static head to be overcome)
H_{tot} = Total height losses

The system curve shows the delivery head H_{tot} required by the system. It consists of the components H_{stat}, H_{VL} and H_{VA}. Whereas H_{stat} (static) remains constant regardless of the volume flow, H_{VL} and H_{VA} (dynamic) increase due to the different types of losses in pipes, valves, fittings and friction increases caused by the temperature etc.

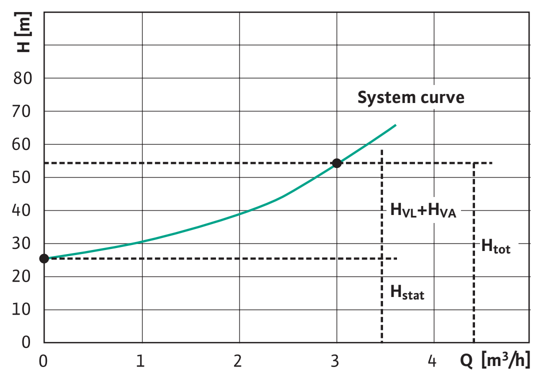
Duty point

The duty point is the point of intersection between the system curve and the pump curve. The duty point is set automatically with pumps with fixed speed.

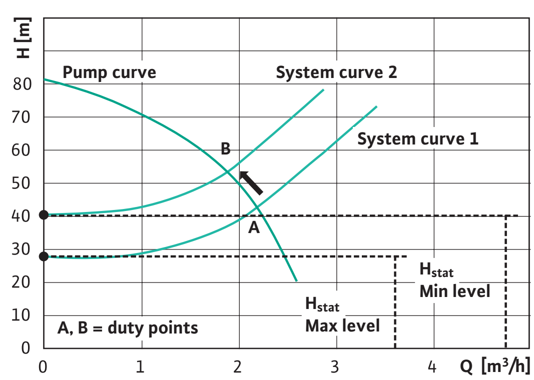
The duty point is only changed if e.g. in the case of a stationary sewage pumping station, the static delivery head fluctuates between a maximum and a minimum value. That changes the volume flow delivered by the pump, since it can only implement duty points on the pump curve.

Reasons for any fluctuation of the duty point could include different water levels in the sump or tank, since the inflow pressure to the pump is changed by varying levels. On the discharge side, this change may also be caused by the clogging of the pipes (incrustation) or by throttling due to valves or consumers.

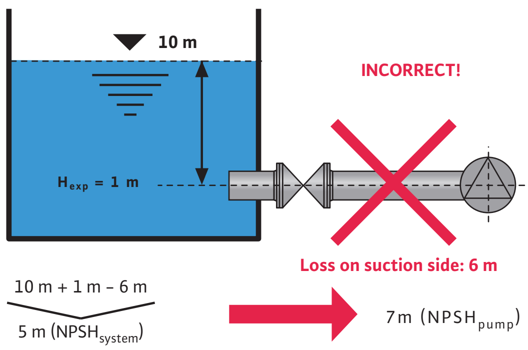
System curve (pipe curve)



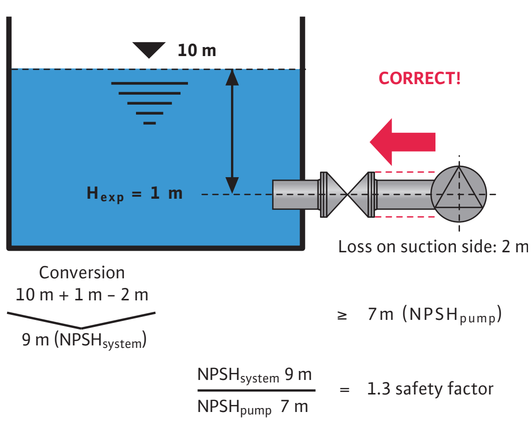
Example:
Fluctuating water level in the tank



Economic dimensioning
$NPSH_{system} \geq NPSH_{pipe}$



Economic dimensioning
$NPSH_{system} \geq NPSH_{pipe}$



NPSH value

The NPSH (Net Positive Suction Head) is an important parameter for a centrifugal pump It specifies the minimum pressure at the pump inlet required by this pump design to be able to operate without cavitation, i.e. the additional pressure that is required to prevent the evaporation of the fluid and maintain its liquid state. The NPSH of the pump is affected by the impeller shape, the pump speed and the NPSH of the surroundings by the fluid temperature, submersion in water and atmospheric pressure.

A distinction is made between two NPSH values:

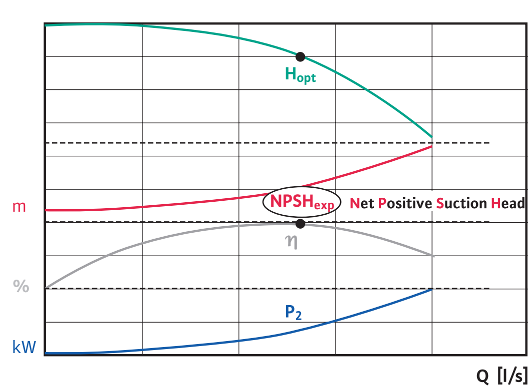
1) $NPSH_{pump}$ = NPSH required
Specifies the inflow pressure required to avoid cavitation. The inflow pressure is also the submersion in water (height difference between pump inflow and water level in the sump).

2) $NPSH_{system}$ = NPSH present
Specifies the pressure at the pump inlet.

$NPSH_{system} > NPSH_{pump}$ or $NPSH_{pres.} > NPSH_{req.}$

For pumps in wet well installation, the $NPSH_{system}$ value is calculated by the addition of the atmospheric pressure and pump submersion in the fluid minus the evaporation pressure. In dry-well installation, the pressure losses on the inlet side are also deducted. The $NPSH_{pump}$ value is specified by the manufacturer with the definition of a cavitation criterion.

NPSH curve



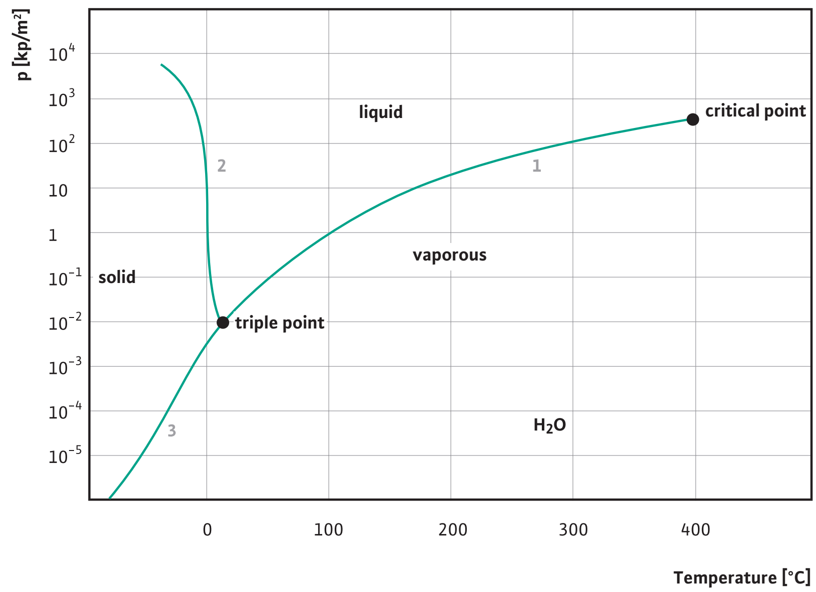
Cavitation

Cavitation refers to the implosion of the vapour bubbles formed (cavities) as the result of the local formation of underpressure under the evaporation pressure of the fluid to be pumped at the impeller inlet. This results in a decline in output (delivery head), non-smooth running properties, a reduction of the efficiency, noise and the destruction of material (in the pump interior). Microscopically small explosions cause, due to the expansion and implosion of small air bubbles in the ranges of higher pressure (e.g. in the advanced stage at the impeller outlet), pressure hammers that damage or destroy the hydraulic system. First signs of this are noise or damage to the impeller inlet.

The damage to the material depends on its structure. For example, cast stainless steel of 1.4408 (AISI 316) quality is roughly 20 times more resistant than the standard material used by the pump industry, grey cast iron (GG 25). Bronze, at least, doubles the service life.

The exploitation of the flow rate, the pressure and the corresponding evaporation temperature helps to prevent cavitation. A high flow rate means a smaller pressure, which in turn results in a lower boiling point of the fluid. For example, the formation of vapour bubbles can be reduced/avoided by an increase of the inflow pressure (e.g. by increased submersion in water/a higher water level in the sump).

Vapour pressure curve of water

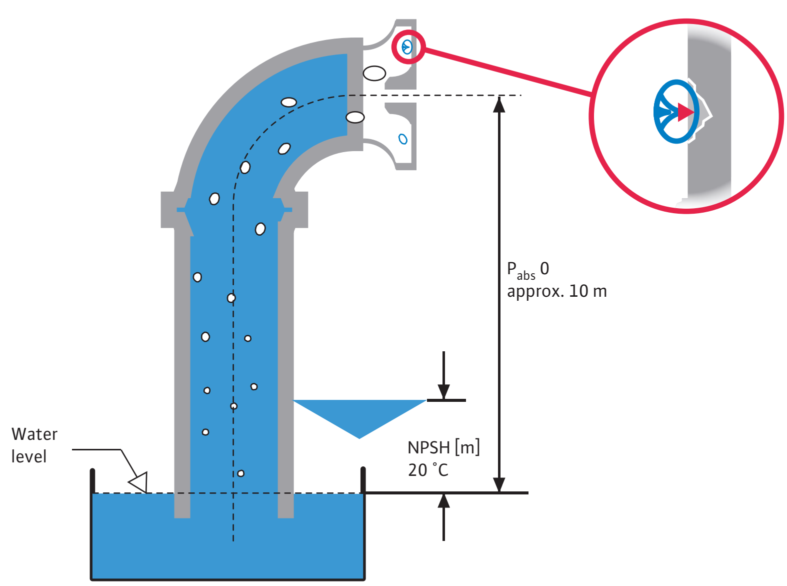


Calculation of the minimum suction head H_{req}

$$H_{req} = H_H + 0.5 + \frac{10^5 \cdot P_D}{\rho \cdot g} - P_b \text{ [m]}$$

Abbreviation	Description
H_{req} [m]	Minimum suction head at suction port
H_H o. NPSH [m]	Required net positive suction head for operating volume flow of the pump, from duty chart
0.5	Margin of safety
P_D [bar]	Vapour pressure of the fluid as absolute pressure for the corresponding fluid temperature, from vapour pressure table
ρ [kg/m³]	Density of the fluid
g [m/s²]	Local gravitational acceleration
P_b [m]	Local air pressure

Vapour bubbles are carried along by the flow, collapsing suddenly if the static pressure increases above the vapour pressure again. Adjacent material surfaces are destroyed by erosion (cavity formation).



Power

In terms of the power of a pump, a distinction can be made between electrical power and hydraulic power. The hydraulic power is described with Q (m^3/h or l/s) and H (m or bar). In terms of the electrical power, several parameters are distinguished. The power consumption is referred to as P_1 and specified in kilowatts (kW). P_2 refers to the shaft power of the motor, i.e. the power transferred from the motor to the hydraulic unit. P_3 describes the hydraulic power output by the motor.

Absorbed effective electrical power P_1

$P_1 = \sqrt{3}U \cdot I \cdot \cos\varphi$ (three-phase current)

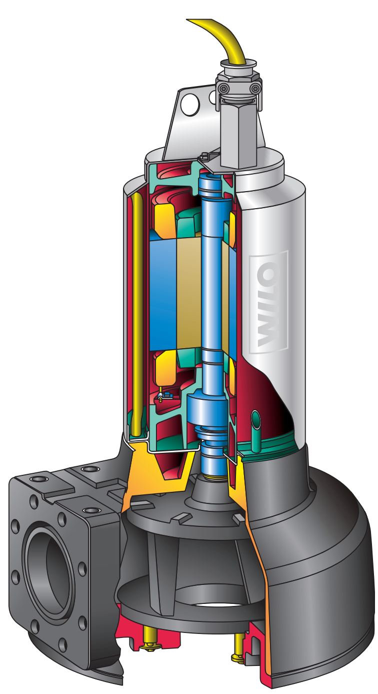
Shaft power P_2 (nominal power)

$P_2 = M \cdot 2n \cdot \pi$

Effective hydraulic power P_3

$P_3 = \rho \cdot g \cdot Q \cdot H$

Abbreviation	Description
U	Voltage [V]
I	Current intensity [A]
cos φ	Motor dependency
M	Nominal torque [Nm]
n	Nominal speed [rpm]
p	Fluid density [kg/dm³]
g	9.81 m/s²
Q	Volume flow [m³/h]
H	Delivery head [m]

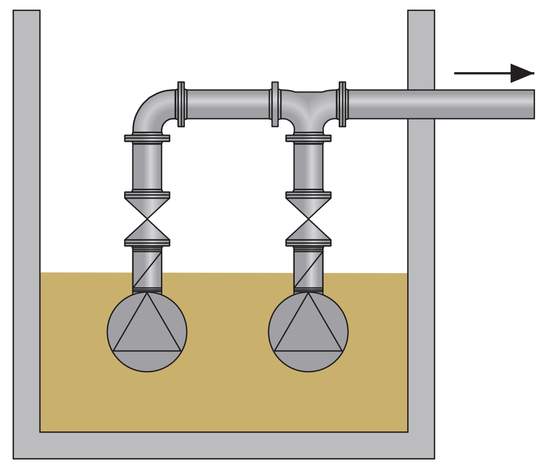


In systems with several pumps, a distinction is made between the following operating modes:

Parallel operation

The aim of parallel operation is to increase the volume flow. The term refers to the operation of two or more pumps, during which all pumps pump simultaneously into a common pressure pipe (with accordingly separate valves and separate supply pipes). If all pumps pump simultaneously, the volume flows of the same delivery head can be added up to calculate the total volume flow.

Parallel operation



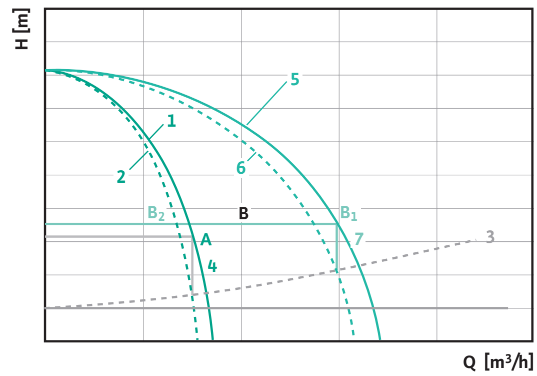
Like with individual operation, the duty point is the intersection point between the pump curve and the system curve. Every pump continues to run on its own pump curve. With identical pump types, that means that all pumps have the same volume flow (see graphical calculation procedure). However, please note that the supply pipe for the collection pressure pipe has its own valves with corresponding losses. These must be deducted in the calculation of the duty point.

Basically, these rules also apply to the operation of two pumps of different sizes, where both pumps run on their own pump curve and the volume flow is split up accordingly (at the same pressure, addition of the volume flows).

There are various reasons for using several pumps:
- Parallel operation with base-load pump and corresponding cut-in of peak-load pumps. The peak-load pumps are only cut in in the event of increased requirements that the base-load pump cannot fulfil (e.g. higher sewage flow than the maximum volume flow of the base-load pump).
- Parallel operation for splitting up the volume flows to reduce operating costs or in the event of severely varying conditions.
- Operation of one pump with standby pump – cut-in if the duty unit fails.

Temporary pump cycling should always be taken into account, in order to optimise the distribution of the operating hours among all pumps and thus ensure a longer service life of the installation. The multi-pump switchgears from Wilo offer this function.

Graphical calculation procedure



1) Drawing of the pump curve for pump 1
2) Reduction of pump curve 1 by the losses (e.g. due to valves or clogging) in the pressure pipe (up to the collecting pipe)
3) Drawing of the system curve
4) Vertical projection of the intersection point of the system curve with the reduced pump curve upwards up to the original pump curve.
5) Drawing of the pump curve for pump 2 (addition of the volume flow for the same delivery head)
6) Reduction of pump curve 2 by the losses (e.g. due to valves or clogging) in the pressure pipe (up to the collecting pipe)
7) Vertical projection of the intersection point of the system curve with the reduced pump curve upwards up to the original pump curve.

A = duty point of the pump for individual operation
B_1 = duty point of the system for parallel operation
B_2 = duty point of pump 1 or 2 in isolated view for parallel operation

Series connection

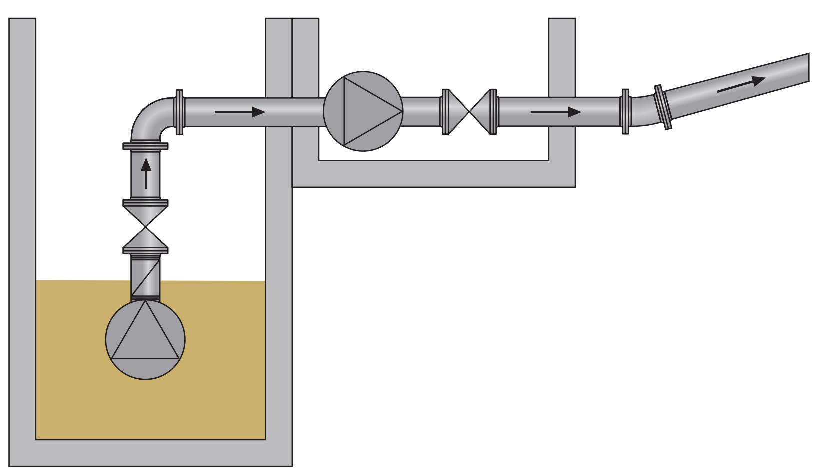
The aim of the series connection is an increase in pressure (delivery head). The term refers to the operation of two or more pumps, during which all pumps pump simultaneously into a common pressure pipe (with accordingly separate valves and separate supply lines).

To calculate the corresponding overall curve of the pumps, the pressure values are added for the same volume flow.

However, the assessment of a series connection is doubtful, since various difficulties may occur.

These may include cavitation as well as turbine effects, where the first pump drives the second pump, meaning that both pumps may be damaged. Accurate dimensioning and constant monitoring are essential.

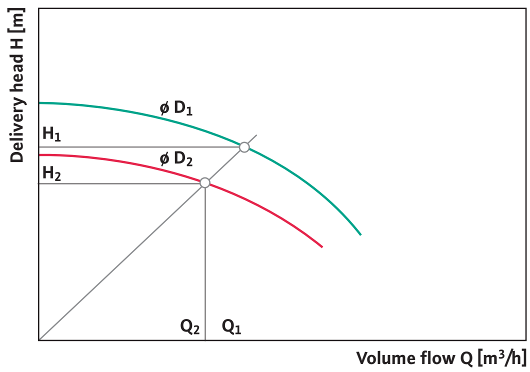
Series connection



Power correction due to modification of the impeller

Attention
Observe the dimensioning of the motor.

Modification of the impeller diameter



$$\frac{Q_1}{Q_2} \approx \left(\frac{D_1}{D_2}\right)^2 \quad D_2 \approx D_1\sqrt{\frac{Q_2}{Q_1}}$$

$$\frac{H_1}{H_2} \approx \left(\frac{D_1}{D_2}\right)^2 \quad D_2 \approx D_1\sqrt{\frac{H_2}{H_1}}$$

A modification of the impeller diameter means a modification of the motor power.

$$\frac{P_1}{P_2} \approx \left(\frac{D_1}{D_2}\right)^3 = \text{speed n}$$

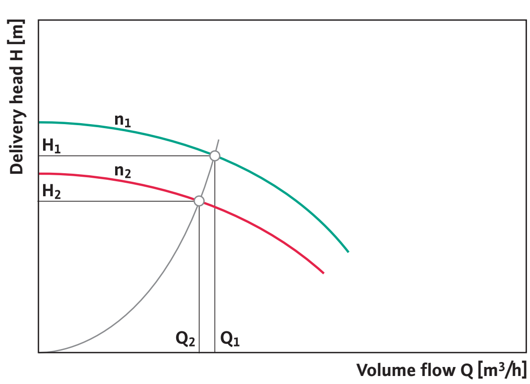
If the correction of the volume flow Q or of the delivery head H compared to the original curve is necessary, a correction of the impeller diameter might be favourable. A reduction of the impeller diameter is practical, which is only possible with radial impellers and, to a limited extent, with semi-axial impellers. The efficiency of the pump is then reduced.

Power correction due to change of speed

By changing the speed of a centrifugal pump, its pump curves are changed.

According to the law of similarity, the following conditions apply to the volume flow Q and the delivery head H:

Varying the speed



If the speed is doubled:

- Volume flow Q = double value
- Delivery head = fourfold value
- Power requirement P = eightfold value

$$\frac{Q_1}{Q_2} = \frac{n_1}{n_2}$$

$$\frac{H_1}{H_2} = \left(\frac{n_1}{n_2}\right)^2$$

Power correction due to modification of the frequency

When frequency converters are used the following needs to be observed.

Hydraulic changes:
- Duty point moves down along the system curve
- Delivery head and volume flow fall
- Pipe frictions losses fall
- Power requirement falls

Electrical changes:
- Rotor losses increase
- Rotor heating increases
- Motor efficiency increases
- More powerful motor necessary
- Torque remains constant
- Power consumption is reduced

Why are frequency converters used?
- To save energy costs
- To achieve a continuous pumping performance
- To automate processes
- To adapt the pump output

Converter:
Submersible pumps by Wilo can be operated with commercially available frequency converters. "Current-controlled", "voltage-controlled" and pulse-width modulated converters can be used.

Interference voltage:
Submersible motors with wet winding are at a higher risk due to voltage peaks than dry motors. Suitable auxiliary equipment (throttles, filters) for the reduction of harmful voltage peaks should be used.

To comply with the EMC guidelines (electromagnetic compatibility), the use of shielded lines or the installation of the cable in metal pipes and the installation of filters might be necessary.

Motor protection:
- PTC thermistor temperature sensor (PTC), as well as
- Resistance temperature sensor (PT 100)

Explosion-protected motors are always to be equipped with PTC thermistors.

Motor and ambient loads in the case of converter supply:
Compared to operation with a sinusoidal power supply, the motor and its surroundings are exposed to additional loads by:
- Heating up of the winding and of the ferro-magnetic circuit
- Alternating torques
- Development of noise
- Shaft voltage and bearing currents
- Winding insulation load

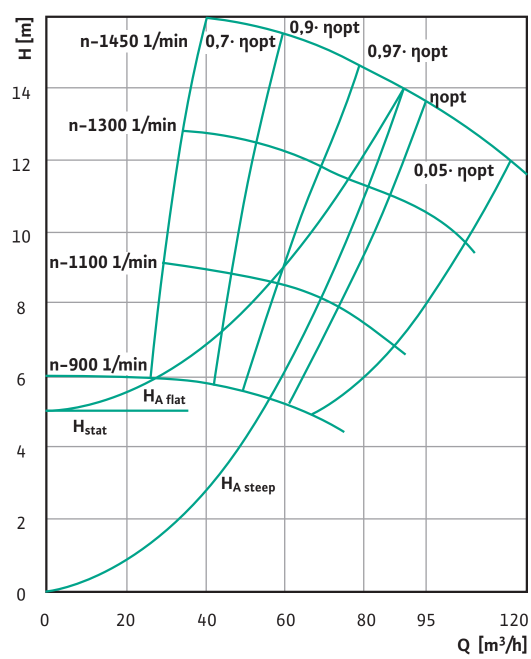
Change of frequency

Power data	Frequency 50 Hz	60 Hz
n	950 rpm	1140 rpm
	1450 rpm	1740 rpm
	2900 rpm	3480 rpm
Q	100 %	≈ 120 %
H	100 %	≈ 145 %
P	100 %	≈ 175 %

$$n = \frac{120 \cdot f}{P}$$

f = frequency
P = number of poles

Modification of the duty point



If the speed is reduced, all duty points move along a parabola at almost constant efficiency towards the zero point.

What reserve should a frequency converter have? Approx. 20 %.

What reserve should the motor have? Additionally at least 10 %.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Wear

When operating centrifugal pumps, especially the pump impellers and the pump housing are exposed to varying loads. Depending on the application, these may even result in the destruction of the pump. The main influential factors for wear are the fluid and the duty point of the pump. These influential factors determine the corresponding types of wear that need to be counteracted by different measures, e.g. the use of special materials.

Types of wear

- Corrosion
- Abrasion
- Cavitation

Corrosion

Corrosion is the destruction of materials by chemical or electro-chemical reactions with their environment. In most cases, corrosion develops at a pH value of 4 – 10 and with non-alloyed cast iron. In this cases, it is oxidation caused by the oxygen in the air. The reaction product is called rust. The aggressiveness of the fluid may be increased by various ingredients, such as e.g. conditioning agents, free carbonic acid etc. Another very important corrosion factor is the pH value.

Abrasion

Abrasion refers to the removal of material from an object (here the pump or pump components). This can be done by constituent parts of the fluid (e.g. sand). The solid constituents are rubbed against the material by the flow rate or the pressure increase in the pump housing so that material is gradually removed. This is very similar to the sand paper effect.

Cavitation

See "Cavitation" chapter (page 25).

pH scale (reference temperature 25 °C)

pH value	Chemical reaction
1 to 3	Highly acidic
4 to 6	Slightly acidic
7	Neutral
8 to 10	Slightly alkaline
11 to 14	Highly alkaline

Materials in pump construction

Abrasite (wear-resistant chilled cast iron)

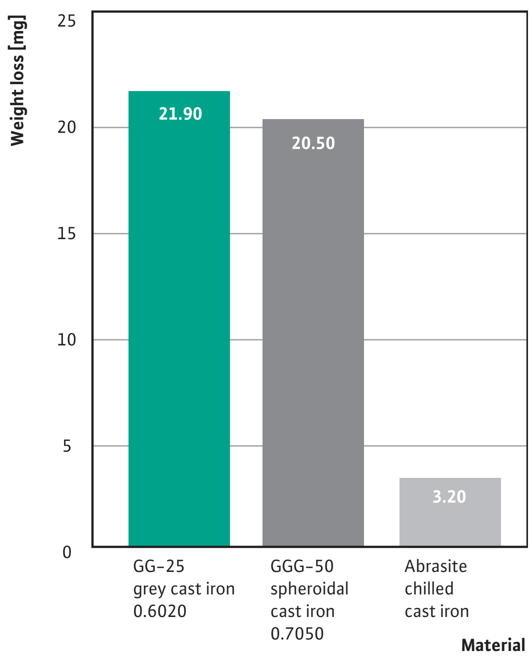
For many years now, Abrasite is in use for pump housings, pump impellers, mixer heads and upstream macerators. The hard cast chrome has a high wear resistance due to a martensitic basic structure with a high proportion of chrome composite carbides.

Service life:

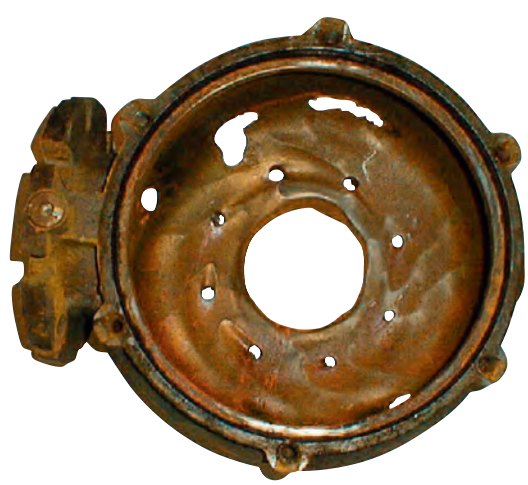
Due to this material, the service life is seven times higher than with normal cast material under the same application conditions.

Abrasite
- *Prevents abrasion*
- *Chilled cast iron with 23 % chrome*
- *Martensite microstructure*

Comparison of materials



Pump housing FA 10.22W in grey cast iron version after 6 weeks of use in the grit chamber



Material version

	Property	Advantages	Applications
Abrasite chilled cast iron	High-alloy cast chrome	• High mechanical resistance • Used in fluids with pH > 6	• Pump housing • Impellers • Upstream macerators
RF version 1.4581	Corrosion-resistant material	• Very good corrosion resistance to acids and alkalis	• Pump housing • Impellers
RF version 1.4517	Corrosion and acid-resistant duplex cast steel	• High resistance to inter-crystalline corrosion and stress corrosion cracking • Excellent strength and durability values	Used in fluids with • Acid content • Acidic washing suspensions with high chloride content • Sea water and brackish water • Salt and mixed salt solutions

Ceram – Modern corrosion and abrasion protection

Components that come into contact with the fluid are subject both to highly corrosive as well as abrasive influences. For this, WILO offers its fluid ceramic coating, Ceram. This provides reliable protection against this type of stress.

Normal heavy corrosion protection methods, such as zinc dust priming with three coats of tar epoxy resin are called onion layer models. The advantage of zinc dust priming is that the zinc dust sacrifices and the zinc carbonate can seal microscopic cracks. This is referred to as the self-healing effect of the coating. The disadvantage is that the wet adhesion of this zinc dust priming isn't very high. Because of the onion layer model of conventional solvent-containing coatings, the adhesive force depends on the quality of the individual layers.

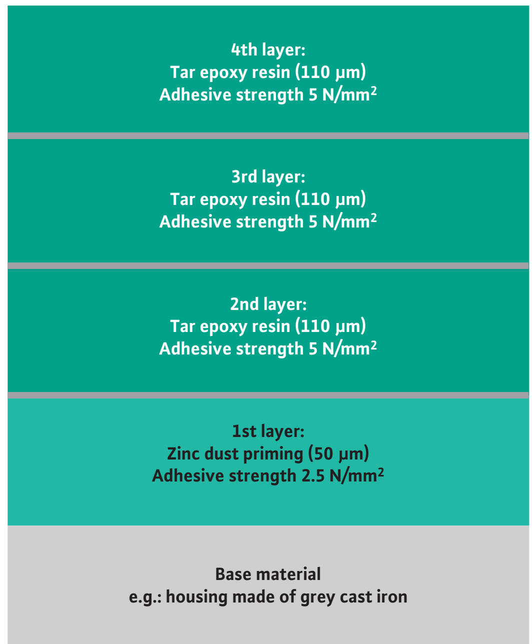
The diagram on the right shows the structure of a tar epoxy resin coating with a zinc dust priming layer. The coating consists of 4 individual layers with a total coating thickness of 380 µm. The three dark grey lines represent the weak points of this coating. The black line is the predetermined breaking point.

The Ceram coating, on the other hand, is based on the diamond model. It unifies the positive properties of two materials by combining ceramic particles in one polymer matrix.

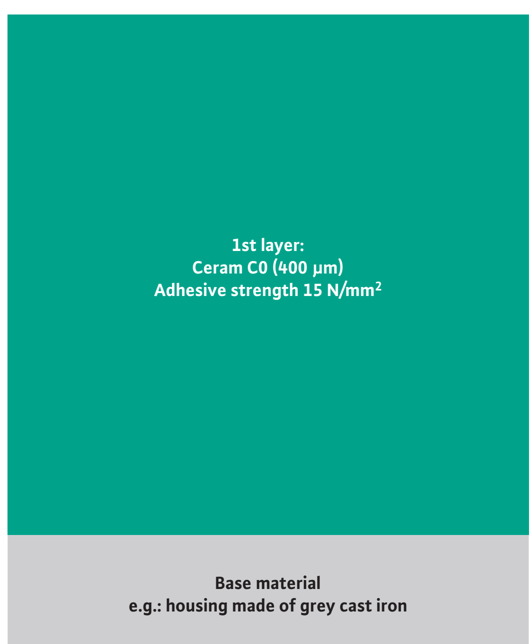
The ceramic particles are enclosed in the matrix. Thus, there are no predetermined breaking points and the adhesion is very high, e.g. in the case of Ceram C0 15 N/mm³. Since Ceram is solvent-free, these coatings can be applied with one layer.

The diagram on the right shows the structure of a Ceram C0 coating. The coating consists of a single layer with a total coating thickness of 400 µm. By applying it using the airless spraying method, a very high surface quality is achieved.

Tar epoxy resin coating with zinc dust priming layer



Structure of a Ceram C0 coating



Ceram quality	Layers	Thickness [mm]	Application
Ceram C0	1	0.4	Complete outer and inner coating
Ceram C1	1 – 3	1.5	Impeller and suction port coating
Ceram C2	1	1.5	Coating of the pump housing (inside)
Ceram C3	1	3	Coating of the pump housing (inside)

Ceram coatings are available in four quality levels. These are distinguished in terms of their resistance to abrasive corrosion. While corrosion resistance is very good for all four quality levels, resistance to abrasion increases the higher the ordinal number (C0 = low protection from abrasion; = very good protection from abrasion) of the coating, since increasingly coarser ceramic particles are processed. The individual layers get increasingly thicker and the mixture of large, medium-sized and small aluminium oxide particles is such that even in the case of abrasion with fine sand, the coatings are very stable.

For use in special fluids, the individual Ceram qualities can be combined with one another, e.g. C2 + C1. The Ceram coating is also very well suited for use in maritime environments.

Ceram quality	Composition	Properties
Ceram C0	• Solvent-free epoxy polymer with solvent-free polyamine hardener and various extenders.	• Tough and durable coating with high mechanical and chemical resistance and very good abrasion resistance. • Excellent wet adhesion and compatibility with cathodic corrosion protection as single-layer coating on steel surfaces. • Very good adhesion to steel surfaces. • Replaces coatings containing tar. • Cost-saving due to the long service life, low maintenance and easy reparability. • Tested by the "Bundesanstalt für Wasserbau" (German Federal Institute for Hydraulic Engineering) (BAW). • Solvent-free. • Hardened coating has a high-gloss finish.
Ceram C1	• Polymer/ceramic composite material made of a base compound and reinforcement. • Base compound: A modified polymer made up of two parts with an aliphatic hardening agent. • Reinforcement: A mixture (protected by proprietary rights) made up of aluminium oxide and extenders. • This ceramic mixture has excellent abrasion resistance and can be very easily applied.	• The completely hardened Ceram C1 coating has a glossy finish, no pores and is easy to clean, mechanically very resistant, abrasion-proof and has excellent adhesive properties. • Ceram C1 hardens without shrinking and is resistant to a large number of chemicals, oils, greases, solvents, diluted organic and inorganic acids and bases and saline solutions. • Ceram C1 reduces friction and improves flow and efficiency. • Excellent corrosion protection.
Ceram C2	• Polymer/ceramic composite material made of a base compound and reinforcement • Base compound: A modified polymer made up of two parts with an aliphatic hardening agent. • Reinforcement: A mixture (protected by proprietary rights) made up of aluminium oxide and silicon carbide particles. • This ceramic mixture has excellent abrasion resistance and can be very easily applied.	• Excellent abrasion resistance ensures long operation and usually lasts longer than a welded-on metal coating. • Can be easily moulded on to any metal surface. • Its tough synthetic resin structure resists temperature shocks and impacts. • Excellent adhesion ensures reliability and prevents stripping. • Simple application reduces work expenses and downtimes. • Withstands chemically varying operating conditions where metals fail. • Practical 4:1 weight and volume mixture ratio.
Ceram C3	• Polymer/ceramic composite material made of a base compound and reinforcement • Base compound: A modified polymer made up of two parts with an aliphatic hardening agent. • Reinforcement: A mixture (protected by proprietary rights) made up of aluminium oxide and silicon carbide particles. • This ceramic mixture has excellent abrasion resistance and can be very easily applied.	• Excellent abrasion resistance ensures long operation and usually lasts longer than a welded-on metal coating. • Its tough synthetic resin structure resists temperature shocks and impacts. • Excellent adhesion ensures reliability and prevents stripping. • Simple application reduces work expenses and downtimes. • Withstands chemically varying operating conditions where metals fail. • Can be easily moulded on to any metal surface. • Practical 4:1 weight and volume mixture ratio.

Comparison of materials

Since water is being used ever more conservatively, there is an increasing amount of contaminants in relation to the amount of water. This means that the concentration of corrosive and abrasive constituents is higher. Sewage units are always exposed to this aggressive fluid. Corrosion and abrasion affect the surfaces and material structures of the units, sometimes with considerable impairment to the material, and thus also to the performance.

This significantly reduces the hydraulic efficiency. This results in the units having an increased current consumption. On the other hand, the pumps no longer work at their optimum, the radial forces increase, there is more stress on the bearings and mechanical seals, and the service life of the machines is reduced.

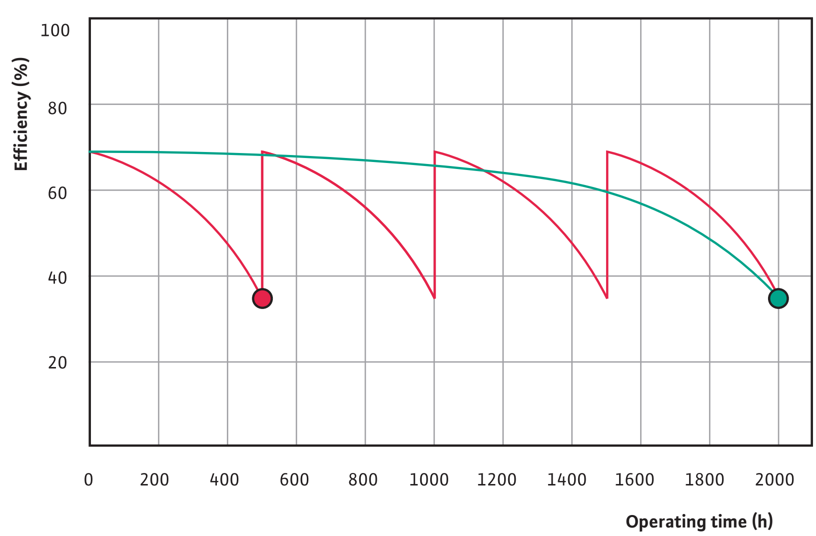
When standard materials are used, such as grey cast iron, under high stress, it may be necessary to exchange the components already after 500 hours of operation. Ceram coatings allow the service life to be increased by a factor of 4, and this at the same high degree of efficiency, which means minimum energy costs.

If one takes the overall costs over the entire service life of the pump into account, the investment costs for a unit coated with Ceram are less than 10 % and thus negligible. In addition, there is a high savings potential due to fewer repairs being required, resulting in fewer system downtimes. The amortisation is then usually quickly reached due to the higher efficiency.

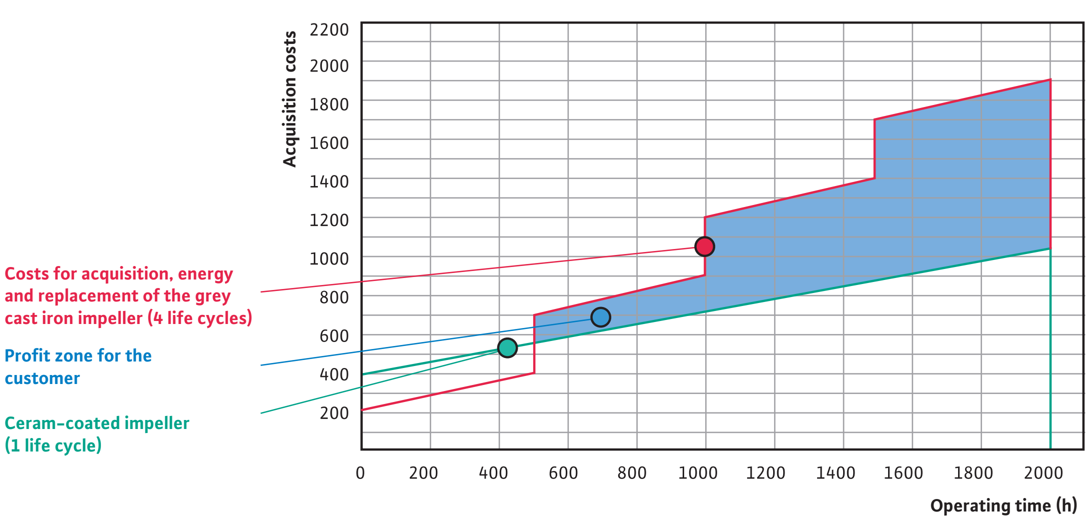
Comparison: Impeller made of grey cast iron versus impeller with Ceram

The Ceram-coated impeller is only replaced after 2000 hours

The impeller made of grey cast iron must be replaced after 500 hours



Comparison: Acquisition costs and service life



Pumping stations

With pumping stations, economic efficiency is improved in terms of the drainage of sewage – as opposed to the free-flow pipeline – due to the avoidance of greater installation depths of the pipe in the ground under buildings which is difficult to access.

Pumping stations must be designed so that there is the same reliability of disposal as with the free-flow pipe system. Automatic and largely trouble-free operation is the basic requirement. Unhygienic and dangerous maintenance work must be restricted to a minimum.

A basic distinction is made between two types of construction, dry well installation and wet well installation.

The advantages of dry well installation are the machine system that can be accessed at all times and the higher degree of hygiene, due to the fact that the pumps are not submerged in the fluid. An operational building above ground can be used for the control technology and/or sanitary installations.

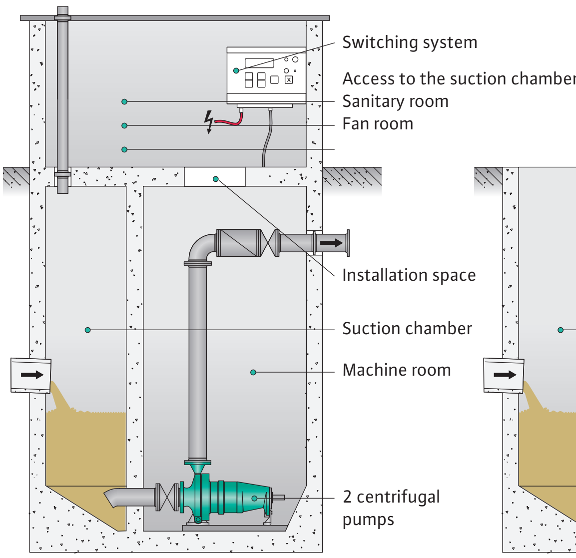
With wet well installation, however, the more simple construction saves costs. Pumps are not installed directly in the fluid. An operational building is generally not required. The electrical unit is installed in an outdoor cabinet.

Depending on the size of the pumping station, sumps made of site-mixed concrete, ready-made concrete sumps, GRP or sumps made of PEHD are used as the construction. Compared to ready-made concrete sumps, the latter have the advantage that they can be produced absolutely gap-free and tightly sealed up to a diameter of 3.5 m. Any infiltration of water from the outside is thus not possible.

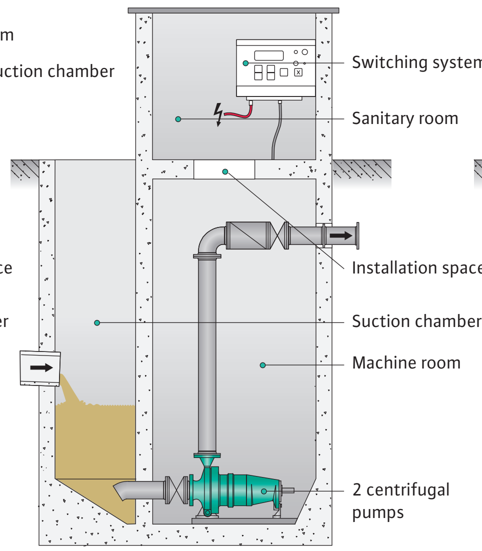
For dry well installation, PEHD sumps offer the advantage that, due to the use of profiles for the sump walls, there is a very small k value that prevents the formation of any condensation on the inner surfaces. That keeps the entire inside system corrosion-free.

Examples of pumping station designs with pumps in horizontal dry well installation

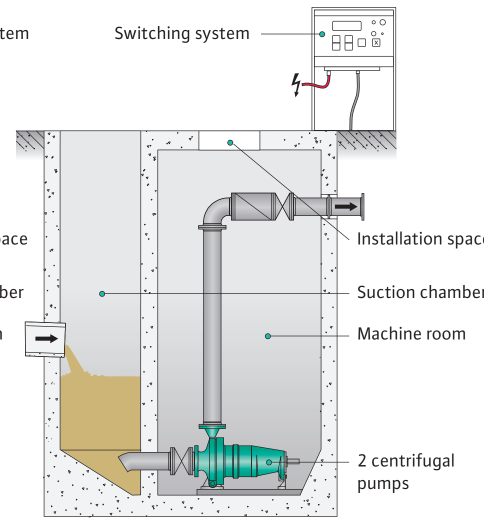
Suction chamber ventilation above roof



Suction chamber open at the top or covered, depending on local conditions

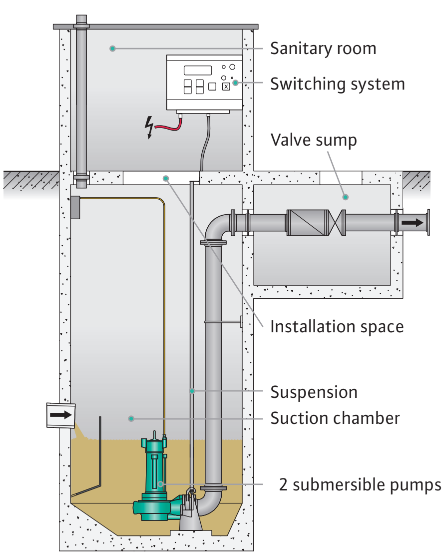


Suction chamber open at the top or covered, depending on local conditions

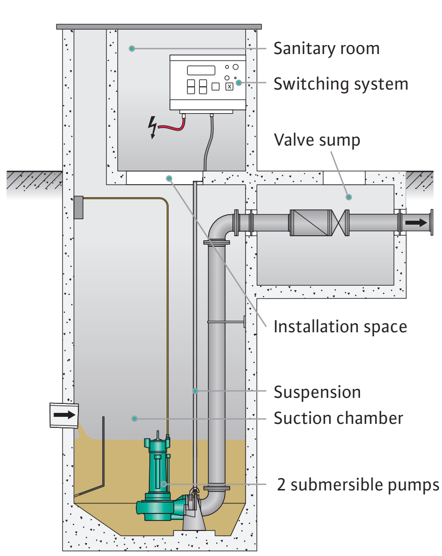


Examples of pumping station designs with pumps in wet well installation

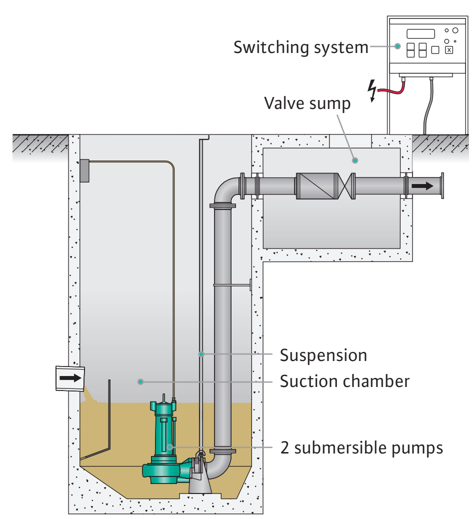
Suction chamber ventilation above roof



Suction chamber open at the top or covered, depending on local conditions



Suction chamber open at the top or covered, depending on local conditions



Determining the volume flow

To determine the size of the pumping station, the daily sewage inflow must be determined.

It is affected by:
- The type of the drainage method (mixed or separation system)
- Size and structure of the drainage area
- Number of inhabitants (PE = population equivalent)
- Number and type of connected industrial and commercial areas

The total inflow of a pumping station is calculated from two parts:
Total inflow = rainfall quantities + sewage quantities

Rainwater inflow

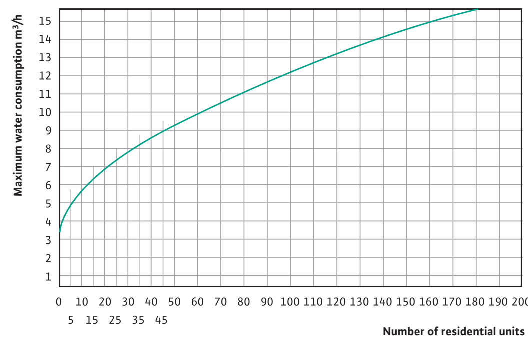
The rainwater inflow quantity depends to a large degree on the location. The quantity must be determined by the planning engineer, or the civil engineering office must be consulted.
In Germany, for example, the quantities fluctuate between 36 and 144 $l/(m^2 \cdot h)$ for North or South Germany.

Sewage inflow quantity

For residential areas with single and two-family houses, there are two options for determining this value:
- With a diagram
- With a formula

Normally one can consult the waterworks for the quantity, since the consumption of potable water is equivalent to the sewage quantity.

Residential areas with single and two-family houses



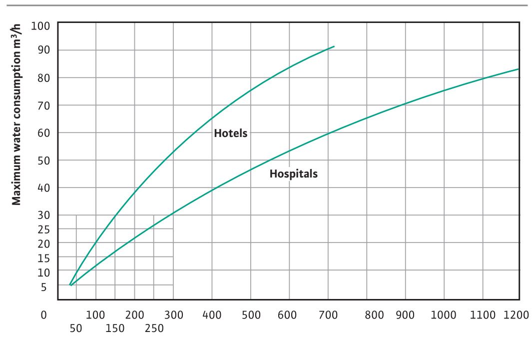
$$Q_{max} = \frac{E \cdot a}{14 \cdot 60 \cdot 60}$$

$= 0.003$ l/s

or = 10l/h/person

For hotels and hospitals, there are two options for determining this value:
- With a diagram
- By counting all toilets, showers, washing machines etc.

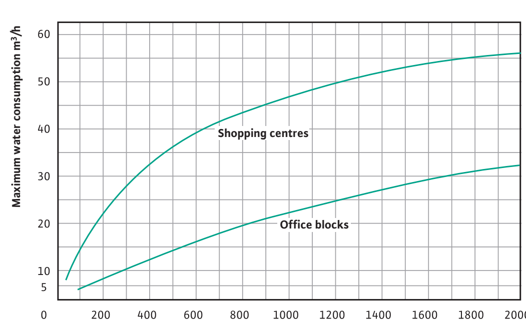
Diagram: Hotels and hospitals



$$Q_s\,[l/s] = K \cdot \sqrt{\Sigma\, DU}$$

For shopping centres and office buildings, the sewage inflow quantity is determined using a diagram.

Shopping centres and office buildings



For all other buildings, the quantity must be determined individually, by counting the toilets, showers, washing machines etc.

Abbreviation	Description
Q_{max}	Maximum flow l/s
E	Inhabitants
a	Consumption per person/day, e.g. in Germany 150 l/day
Q_s	Drainage flow in seconds
K	Factor for the type of building
DU	Drainage to be expected

Calculation of the pump sump, impoundment volume

The useable impoundment volume of the suction space depends on the permissible switching frequency and the flow of the largest installed pump. For two identical pumps and automatic, alternating activation, the volume can be cut in half.

Permissible switching frequency S:
up to approx. 35 kW – 15 activations per hour.

For larger motor capacities or higher switching frequencies, consultation with us is required. The volumes indicated in the diagram are minimum values in order to guarantee smooth pump operation under unfavourable conditions. This is the case when the flow for a pump is half the volume flow. This results in a maximum number of activations per hour.

Useable volume formula

$$V_{useable}\,[m^3] = \frac{0.9 \cdot Q}{Z}$$

Abbreviation	Description
Q	Volume flow of the largest pumps [l/s]
Z	Switching frequency [1/h]

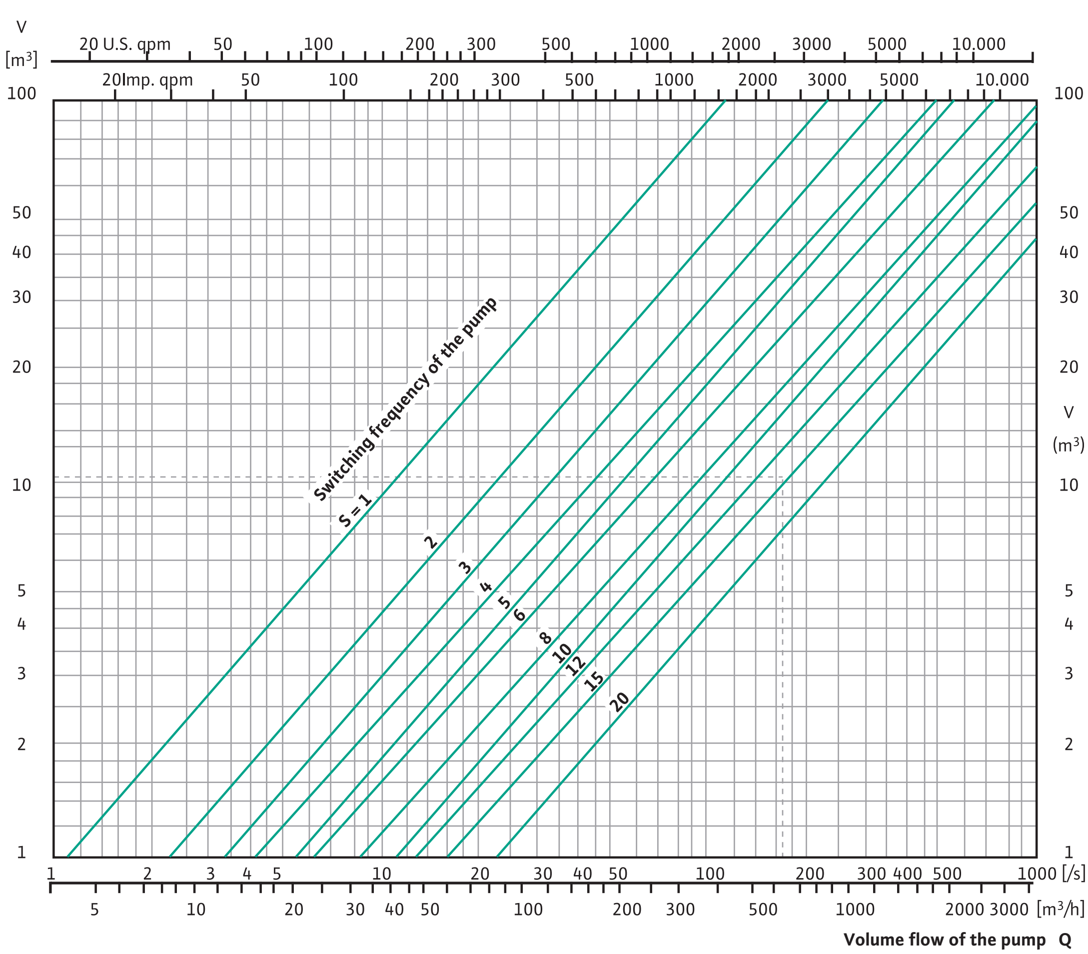
The result is for one pump, for two pumps the result is halved.

$$= \frac{0.9 \cdot l/s}{starts/h \cdot 2\ pumps}$$

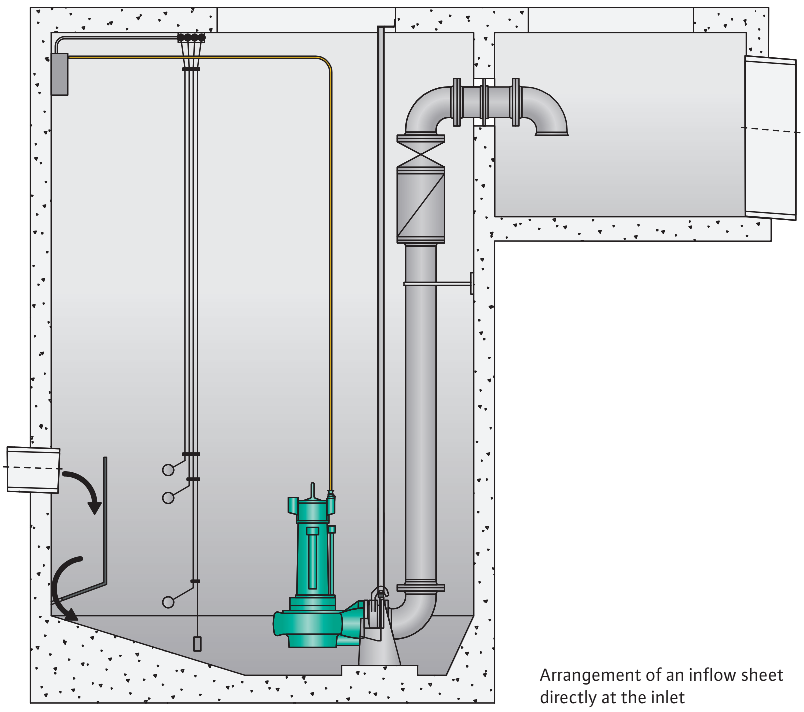
$$= \frac{900 \cdot 30}{10 \cdot 2}$$

= 1350 l useable

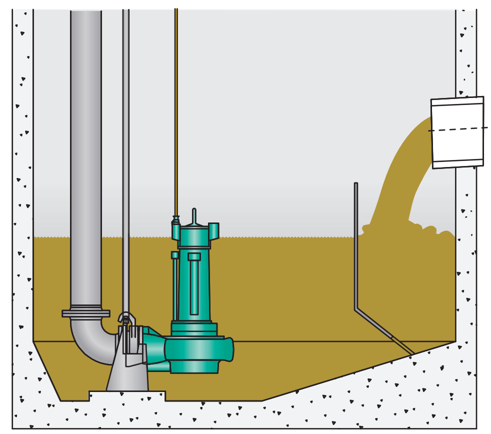
Useable sump volume



Arrangement of an inflow sheet directly at the inlet



Arrangement of an inflow sheet directly at the inlet

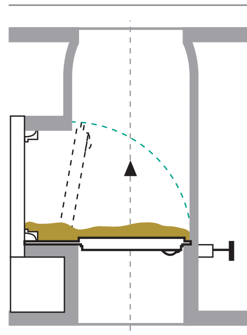


Sump equipment

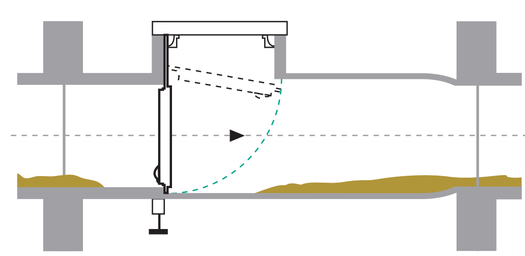
Sump pumping stations are normally simple and cost-effective pumping stations that are equipped with submersible pumps. The submersible pumps are directly in the sewage collection sump. There is generally not much space there. It is therefore important that the individual functional components do not have a negative effect on each other. One should especially make sure that the inlet is arranged correctly in the sump pumping station. No water jet should develop that directly affects the pump. If a water jet hits the surface of the water, air bubbles form and there is increased turbulence in the direct vicinity of the water jet. Pumps which are arranged in this disturbance range, do not run smoothly at all and therefore their surface life is not satisfactory. The pumps therefore need to be protected effectively from the inclusion of air and turbulence. The installation of an inflow sheet is an effective measure. The lower edge of the inflow sheet must always be submerged, i.e. it must reach down to below the minimum water level in the collection sump (see figure).

As a rule, sewage pumping stations have an ascending pressure pipe. After switching off the pump, the solids in the fluid, in particular the heavy constituents (e.g. sand), flow back into the pressure pipe. The return unit must be arranged in such a way that the returning solids cannot be deposited directly in the return unit and impair its operation.

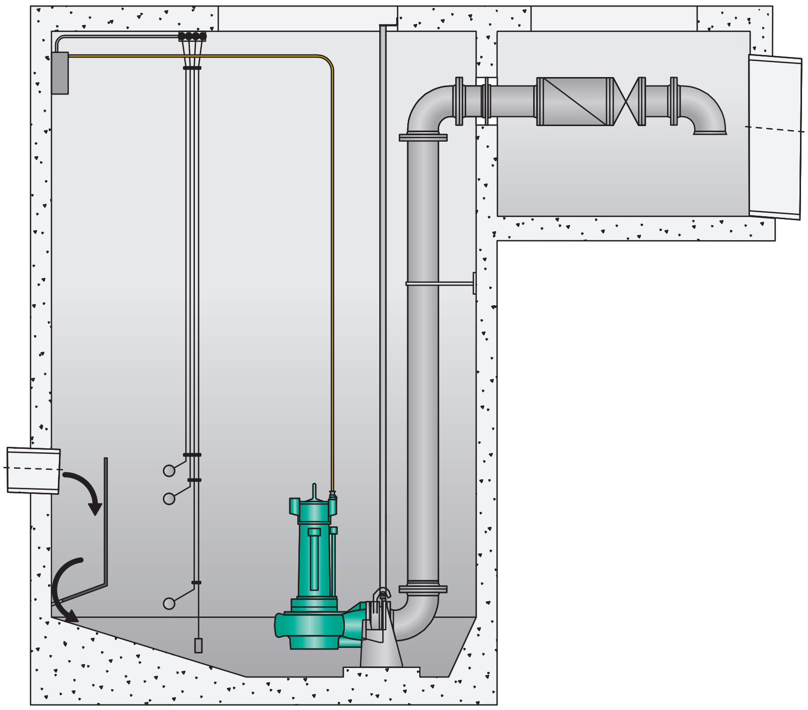
Vertical position: Solid deposits directly in the non-return valve



Horizontal position: Solid deposits directly upstream and downstream of the non-return valve



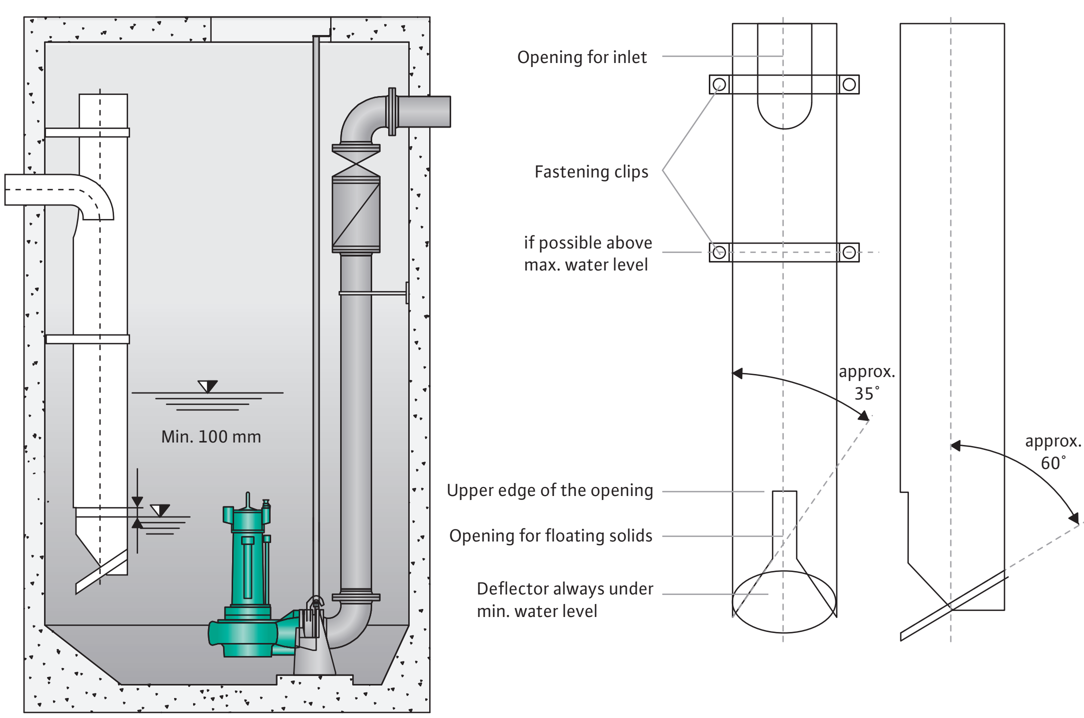
Arrangement of the return unit in the valve sump



With a long pressure pipeline, the return unit must always be arranged horizontally.

In addition, access to the valves should be easy and unproblematic for any inspections and cleaning required. With sump pumping stations, it is practical to install the valves in a separate sump directly on the pumping station (see figure).

Arrangement of the pilot tube direct at the inlet



The recommended arrangement of the pilot tube ensures the ventilation of the water and the reduction of the kinetic energy in very narrow spaces.

Advantages:
- Commercially available plastic pipe (or steel pipe), e.g. DN 300 for a flow rate of up to 40 l/s
- Not much space required
- Simple fixation
- Independent of the sump shape

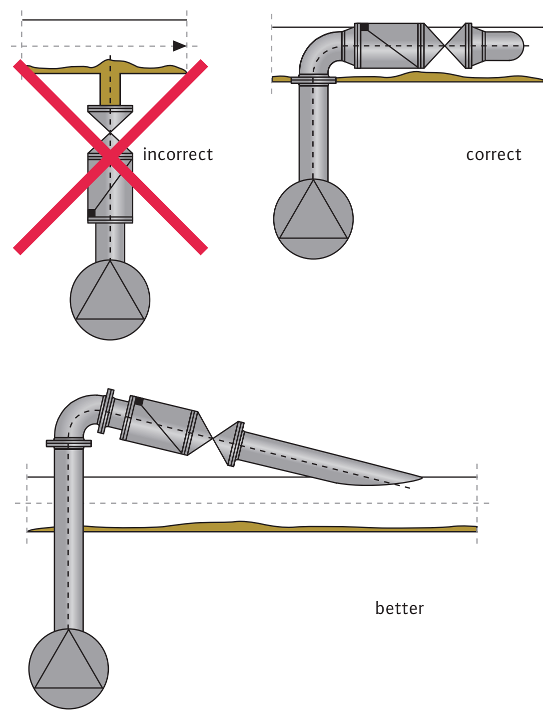
When pumping sewage, one should always take into account that solids in the fluid may be deposited. A high concentration of these solid deposits results in malfunctions of valves and pumps. If pumps are connected to a collection pipe, it must be ensured that such deposits cannot enter the return units or pumps.

In practice, that results in the following requirements:

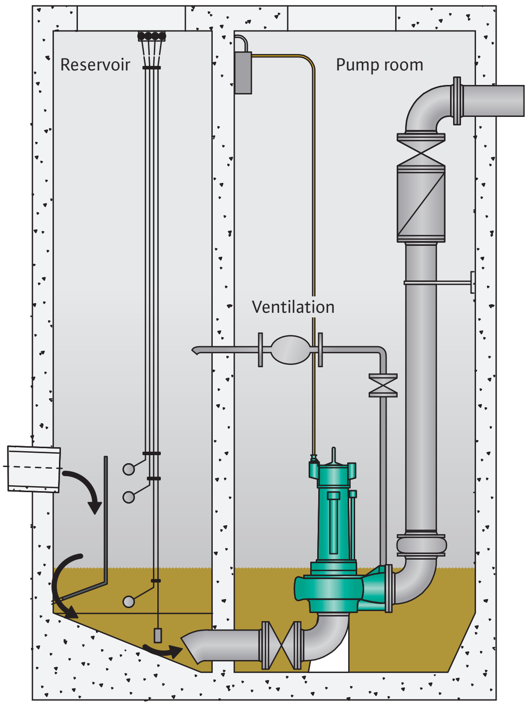
The connection must not be established at the bottom of the collection pipe. In this case, the solids would be able to flow directly into the single pipe and cause malfunctions to the return unit and pump there. Single pipes are therefore always connected towards the top of the collection pipe in the direction of flow. The valves (return unit and slide valve) should also be arranged directly in front of the connection point (see figure).

Additional protection can be achieved if the single pipe is guided over the collection pipe and connected to the collection pipe towards the top in the direction of flow (see figure).

Connection of pumps to a collection pipe



Ventilation of pumps in dry well installation



With non-self-priming centrifugal pumps, the fluid must flow to the pumps. Pumping is only started when the impeller of the centrifugal pump is practically completely pressurised with water.

During the initial operation of a pumping station, the pump and the pipe are vented so that the fluid can ascend in the pump or pipe according to the suction head or the intake pressure.

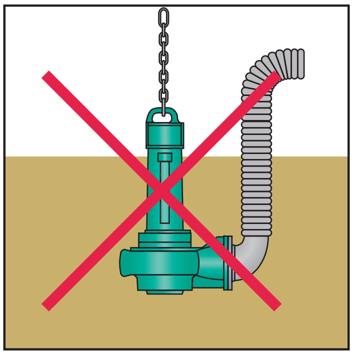
Normally, this ventilation is performed once prior to initial operation by venting the pump at the pressure port or by venting the non-return valve.

Once the pump housing is flooded, the pump can start pumping at any time.

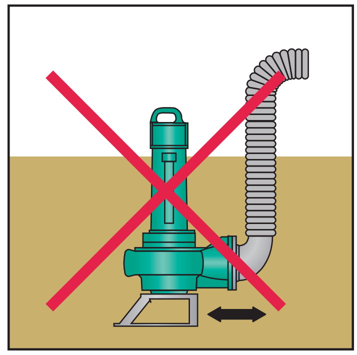
Continuous ventilation is not required if the pump is deactivated once a minimum water level is reached. The minimum water level is defined so that the impeller of the pump is always flooded and no air can be sucked in through the suction pipe.

If this requirement cannot be implemented, constant ventilation must be ensured. For this purpose, a ventilation pipe is normally installed from the pressure port of the pump into the air chamber of the collection sump (see figure).

Installation of sewage pumps



incorrect



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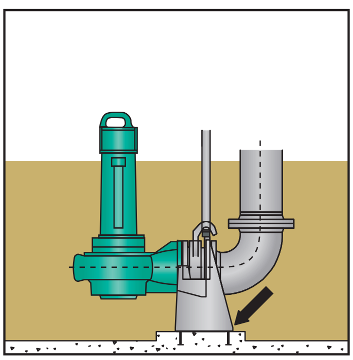
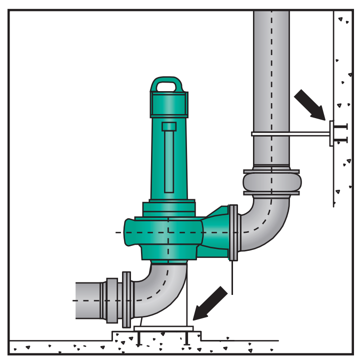


Wet sump installation, foot elbow fastened to solid surface



Dry well installation, pump base fastened to solid surface

If several pumps are running in a pumping station, a collective vent pipe is fitted as a practical option above the maximum water level. Each individual pump is then connected to the collective ventilation pipe via its own ventilation pipe.

For stationary operation (longer operating time), a pump should not be installed freely on a smooth surface. Due to the starting pressure, flow pulses and natural vibrations, the pump would constantly move on the smooth surface, resulting in a large number of blows. In this case, the pump must be fastened to the ground or by other means in order to be fixed in its position.

The fixation of the pump must be performed on a static and firm system that does not produce, transfer or reflect any (or hardly any) vibrations itself.

Foot elbows (dry well installation) or a suspension unit (wet well installation) directly on the floor of a solid construction (or sump) are well suited for the fixation of the pump.

It is extremely unfavourable to fasten the pump to a system that itself vibrates at high frequency or that is exposed to such vibrations.

Wet well installation

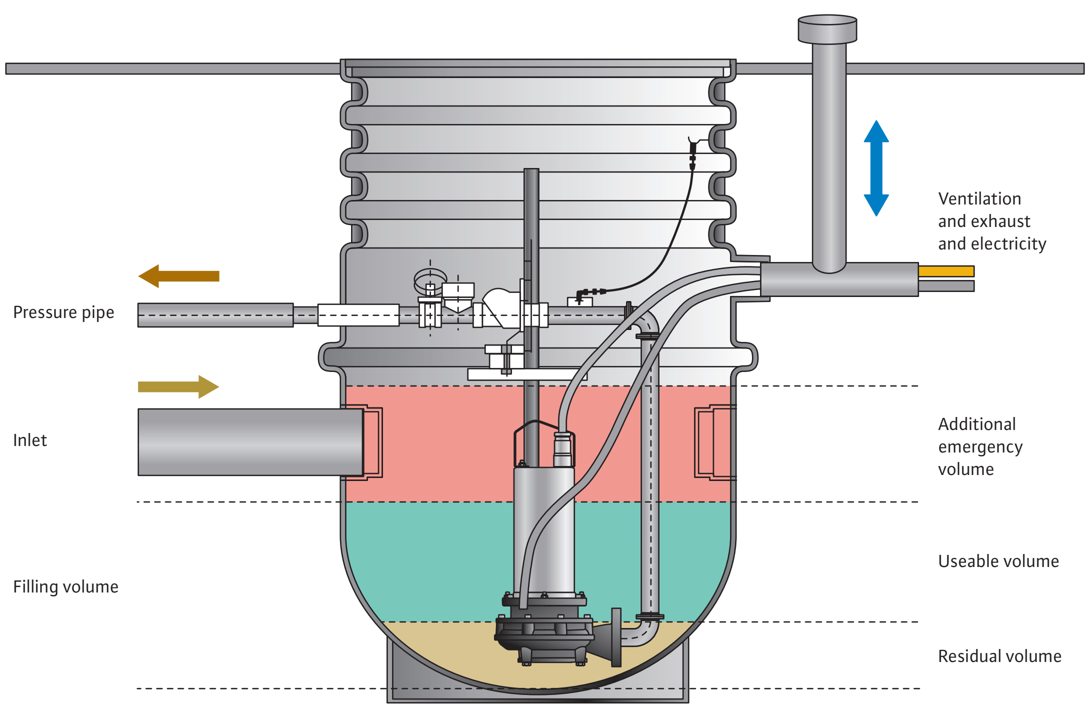
The pumps (submersible pumps) are submerged in the fluid. Since this variant is a potentially explosive suction area, explosion-protected submersible motors are to be used.

The pumps are normally connected to the ongoing pressure pipe by means of a catch, over a coupling base.

Pulling the pumps for maintenance purposes is possible from above with a chain, without having to release screws or drain the water.

During planning, it is necessary to distinguish between the filling volume and the useable volume. The useable volume is calculated as the difference between ON and OFF switching points. Pumps with internal motor cooling have a lower OFF switching point, the motor can run in non-submerged condition. With all other motors, the OFF switching point is normally the upper edge of the motor.

Pumps station: Wilo-DrainLift WS



Dry well installation

A pump sump is connected to the dry machine room upstream. The system can be walked at all times. Explosion protection for the motors is not necessary.

Dry-installed pumps can have a standard motor as the drive, which drives the pump via resilient coupling or v-belt drive. Vertical installation with mounted motor and shaft connection via coupling is also possible.

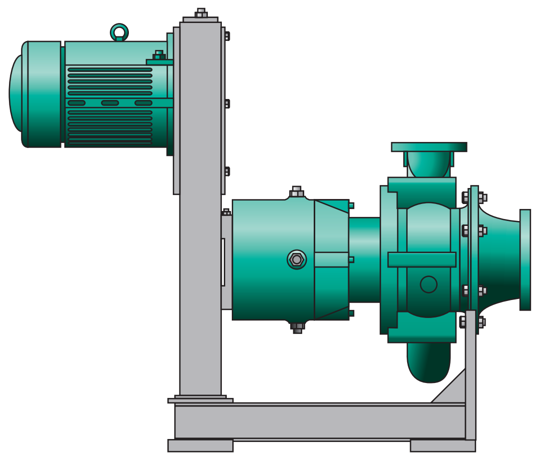
The better choice is the dry installed submersible pump, which can be installed horizontally (please observe the manufacturer's information) as well as vertically. It has internal oil circulation cooling or jacket cooling. In addition, the units are fully submersible, so that disposal remains ensured even when the pumping station is submerged.

The OFF switching point must be set carefully here too. It must always be above the hydraulic unit, otherwise there is a risk of air inclusion, which would block the next pumping operation.

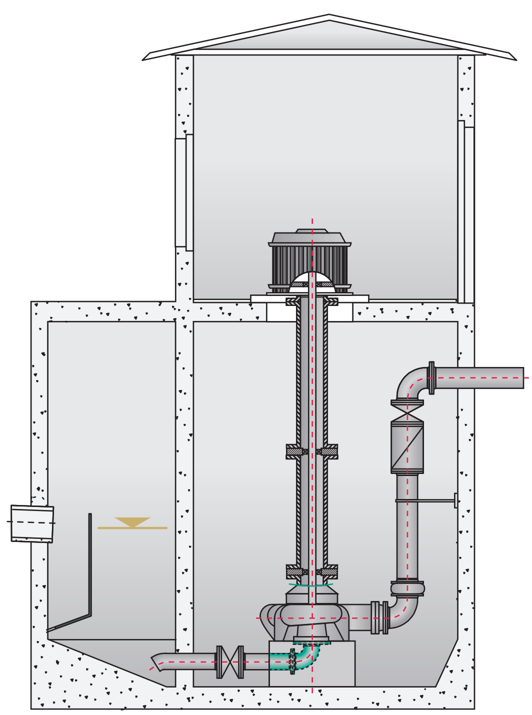
Flow conditions

Pumps for volume flows up to 100 l/s: When the pump is switched on, the pump's fluid must flow with a headwater pressure of at least 0.5 m. To avoid the intake of air, the submersion of the suction port in water should also always be at least 0.5 m. The pump's inlet pipe must be installed as a constantly ascending line.

Dry-installed pumps with standard motor and v-belt drive



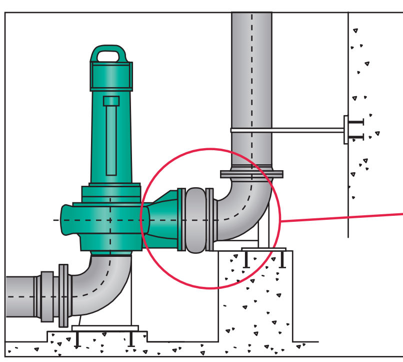
Vertically installed pumps with mounted motor with coupling



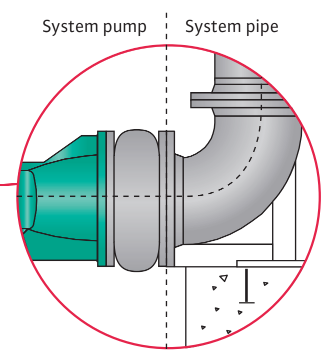
Attention
In both cases, sufficient motor cooling must be ensured.

Dry-installed submersible pumps with internal closed-circuit cooling without additional ventilation

Pressure pipe connection of sewage pumps



Dry well installation, pump base fastened to a solid surface



Pipes are vibrating systems. Due to the flow and deflection, forces develop that result in the natural vibration of the pipe. In addition, pipes also transfer and reflect vibrations that were transferred to them. In the case of a rigid connection between pipe and pump, there is therefore constant mutual interference.

The connection to longer pipes must not be rigid. Instead it should be established using compensators.

Reliable sewage transport

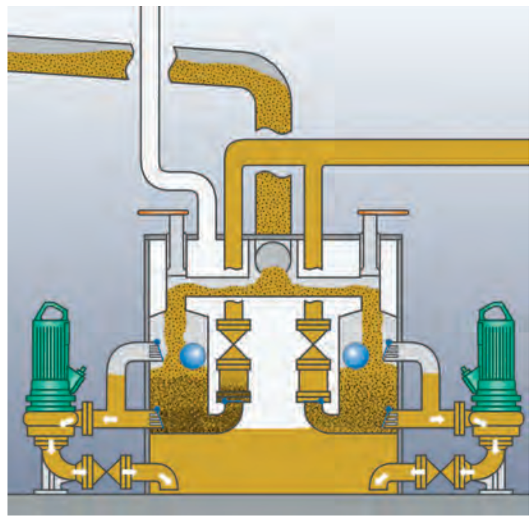
Wherever municipal and industrial sewage is produced, it must be collected and fed to the water treatment system. Underground pumping stations in the PEHD sump or for concrete sumps are ideally suited for this purpose. They work reliably and also provide maximum protection against corrosion.

Solids separation system

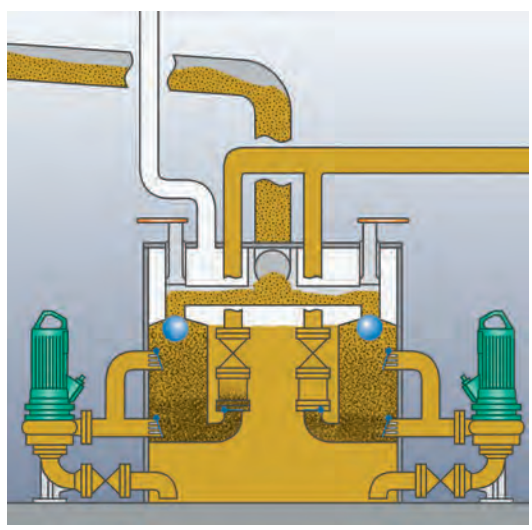
Function
With this installation, the inflowing sewage flows into the distribution tank and from there into the open solids separation tank. There, the solid matter is retained by the separation flaps and the solids are "filtered out". Only prepurified sewage is now able to pass through the pump into the large, combined collection tank. While the collection tank is filled, the water level in the solids separation tank rises. The shut-off ball automatically closes the inlet.

Now, pumping starts according to the level. The pump pumps in the reverse direction and opens the separation flaps with the volume flow of the prepurified drainage and sewage. The sewage flows through the solids separation tank and thus conveys the "filtered-out" solids into the outgoing pressure pipe.

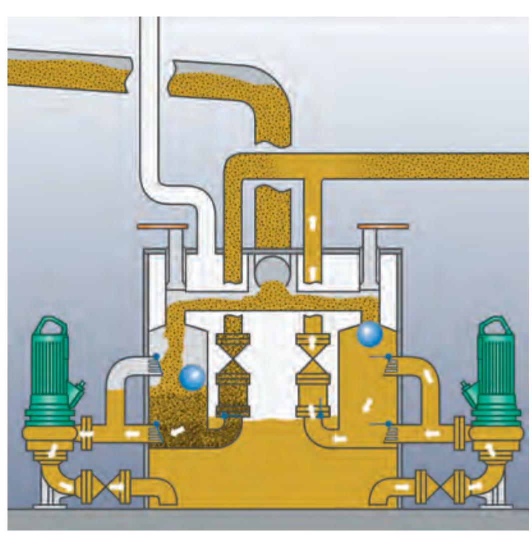
Then, the entire solids separation system is flushed and cleaned. Pumping is stopped again, depending on the level. The shut-off ball drops and enables a new filling process. During this pumping process, the sewage is pumped into the other solids separation tank. The low operating costs result from the use of pumps with small ball passages, since a smaller motor power is sufficient for these.



Both sides: Filling process



Activation point is reached



*Left filling process –
right pumping process*

Underground pumping stations with dry-installed pumps and solids separation system

During the pumping process, the pumps themselves do not come into contact with the solid matter in the sewage.

This has the following advantages:
- Low maintenance and operating costs for the moving pump components
- Pump room is dry, clean and odourless
- Hygienic conditions for maintenance and installation work
- Configuration as double-pump station; the system remains fully functional even during the maintenance of a pump
- Submersible sewage pumps with adjusted impeller
- No corrosion problems, no effect on the formation of hydrogen sulphide
- Use of pumps with ball passage < 80 mm, thus reduced fuel requirements and higher efficiency
- Less wear, since the solids are not pumped by the hydraulic unit
- Submersible sewage pumps with protection class IP 68 (submersible)
- Almost complete drainage of the collecting space, since with this system, every pumping operation takes place far below the hydraulic unit. With each filling process, the air above the inlet is forced out of the pump housing. The volume of the collecting space is thus also almost the useable volume

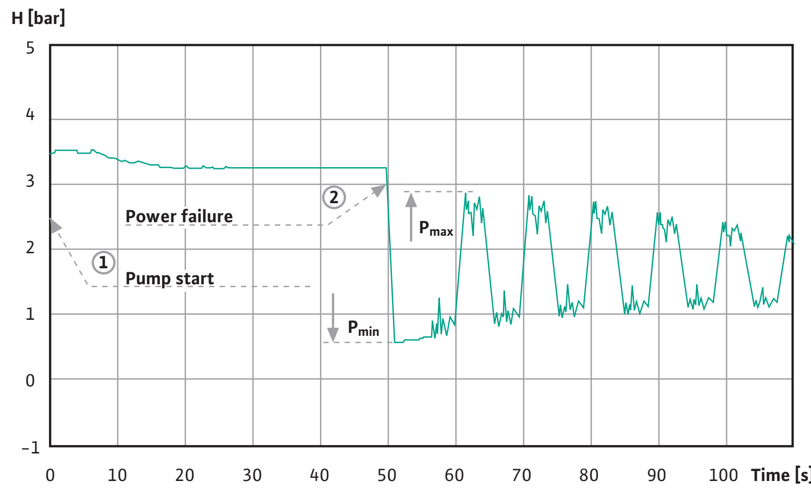
Pressure surge calculation

Pressure surges and their cause

If the mass flow rate in a pipe is accelerated or decelerated, the corresponding kinetic energy is converted into energy in the form of pressure. The decelerating or accelerating unit (e.g. pump, valve, non-return valve etc.) is referred to as the point of interference. Before or after the point of interference, there is a pressure increase or reduction, depending on whether acceleration or deceleration took place. These maximum pressure values that continue on both sides of the point of interference, are called positive and negative pressure surges. The higher the positive or negative acceleration is, the higher the resulting pressure surge. The pressure surges move at a speed of 200 m/s to 1300 m/s along the pipe (depending on: E-module of the pipe material, E-module and density of the fluid, dimension and bearing of the pipe).

At the reflection points (e. g. cross-section changes, gate valves, T-pieces, pumps, drain etc.), the pressure surges are partially reflected. The individual overpressure and underpressure waves interfere with each other, resulting in cancellation and increasing effects. In the event of severe deceleration (e.g. power failure ⇒ sudden shutdown of the pump), the vapour pressure of the fluid (approx. 0.03 bar) might be reached, resulting in the separation of the fluid column. When the separated fluid columns join again, this may result in severe water hammers.

Pressure progression downstream of the pump at the height of the non-return valve (calculation result)



1 Pump start **2** Power failure

The following faults may be the cause of pressure surges

Fault	Effect
in the power supply	• Power failure: Pump stops according to the moment of inertia. • Failure of the control voltage for valves.
in the system plan	• Selected starting time too short: Strong filling surge if the pipe is empty. If air is trapped, the bubbles move through the pipe at high speed. • Selected stopping time too short: The accelerated water column moves on and creates an underpressure. • Insufficient or incorrect ventilation and bleed valves planned. • The pump speed changes too fast. • Selection of unsuitable return units.
in the system	• Check valves are closed too quickly (operating error ...). • Faulty check valve. • Ventilation and bleed valves fail. • Sudden clogging of the pump. • Fluttering of moving parts in valve, pressure vibrations.

Dangers due to pressure surges

Danger to the system components

- In the worst case fracture of the pipe due to overpressure or underpressure.
- Destruction of the valves.
- Destruction of the pumps.
- Loosening of sleeve joints.
- Due to severe pressure gradients, the pipe may be loosened its fixation or even pulled out of the fixation.

Development of noise

- Closing of the non-return valves causes noise and vibrations.
- The mass movement in the pipe causes rumbling noises.
- Trapped air shoots through the pipe at high speed in the form of bubbles.
- This noise may be so loud that residents are disturbed.

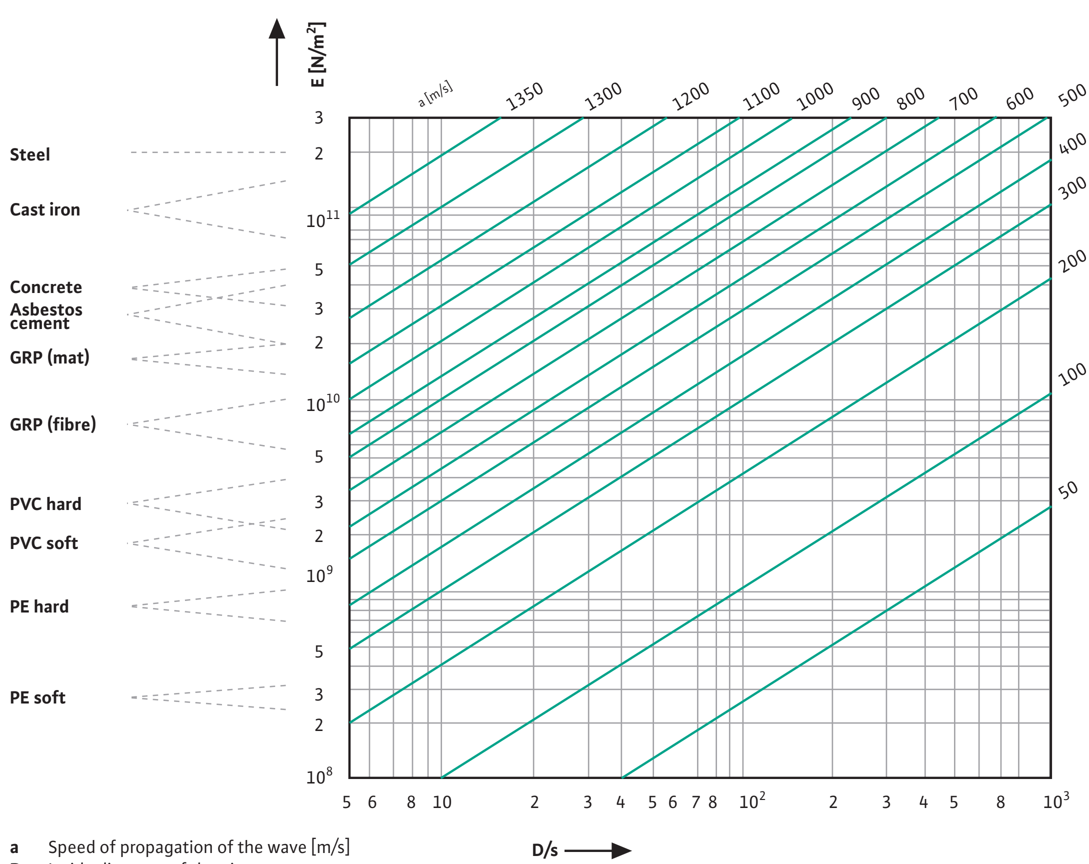
Assessment of pressure surges

The factors mentioned below are significant for danger to pressure pipes by pressure surges.

The risk of pressure surges increases:

- the longer the pipe
- the higher the change in speed (i.e.: the higher the flow rate)
- the shorter the time during which the change in speed takes place
- the higher the speed of propagation of the wave
- the greater the manometric delivery head

Speed of propagation according to the E module of the pipe (for pipes filled with water)



a Speed of propagation of the wave [m/s]
D Inside diameter of the pipe
s Wall thickness of the pipe
E E-module of the pipe [N/m²]

Pressure surge calculations

Unsteady flow processes in pipes carrying fluids cause dynamic loads that can exceed the static loads by far. Such situations occur, for example, when pumps are started and stopped or during the activation or operation of valves that release or stop the flow of the fluid. To be able to quantify the corresponding loads and dimension any damping measures, dynamic pressure surge calculations are necessary. In addition, the technical monitoring agencies also demand a corresponding document for systems to be newly installed.

Potable water pipes and hot water pipes for transporting long-distance heat and sewage lines are especially at risk in the event of the sudden stopping of pumps due to a power failure. In such a situation, projected soft starting is no use. In addition, all pumps stop at the same time. In most cases, that results in the vapour pressure being fallen short of and the extensive formation of vapour bubbles in the pipe. In the swing-back phase, the vapour bubbles collapse and cause very high pressure waves with steep faces. These can destroy the pipes immediately if the compressive strength is exceeded accordingly or, if they spread within the installation, they can cause damage to pipes and valves elsewhere.

The generated pressure gradients are one effect of the collapsing vapour bubbles that is frequently underestimated. Even if the compressive strength of the pipe still has a reserve, the severe dynamic pressure differences over a short length can move the pipe, release it from its fixation or damage the pipe, branches and flange connections due to the leverage effect.

Pressure calculations according to the characteristics method

In the partial differential equations for pressure surge processes in pipes, the location and time coordinates are linked via the positive and negative wave spread speed (the characteristics) and thus transform the partial differential equations into a set of normal differential equations. The latter are then solved numerically according to a differential method. At present, that is the most accurate method for the solution of pressure surge problems in pipes and pipe systems.

The advantages of this method are:

- Reliably fulfilled stability criteria.
- Adjustment to any starting and boundary conditions.
- Highly complex installations can be handled.
- The method is very clear and promotes the understanding of the physics.
- Programming errors are soon noticed due to implausible processes.

According to the latest computer technology, the calculated pressure vibrations are displayed dynamically on the screen. That enables efficient working, in particular for the analysis of variants and the dimensioning of pressure surge damping measures. With the applied computer program, new issues can be dealt with without problems. In addition, only those elements are included in each program that are required for the solution of the corresponding use case. That means that even highly complex tasks can be solved using a PC.

This combination of program development and usage ensures that the focus on the basic physical processes is not lost. Ultimately, only those who know the basic calculation principles and are aware of their limits, are able to interpret the results correctly and implement them in a responsible manner in practice.

Results of the pressure surge calculation

As the result of the process, a detailed documentation is handed over, consisting of explanatory text and the description of the calculated results, mainly in graphical form. If the problem at hand permits this, demo programs are also provided, which allow the examined scenarios to run dynamically on one's own PC. That contributes significantly towards the comprehension of the physics of the pressure surge processes.

Potable water lines are preferably protected from pressure surges by pressure tanks. The tank dimensions and the type of connection required are determined during computer operations. In the case of long supply pipes on the suction side of the pumps, pressure surge damping tanks may also be necessary there. That is why it is advisable to examine the problem of pressure surges in due time so that space requirements can be taken into account.

Pipes in sewage and industrial water applications are protected against the risks of pumps stopping in the event of a power failure by accordingly dimensioned ventilation and bleed valves along the line. The necessary air power values of the valves are determined in the calculations as well as their number and installation points. According to the required air power, suitable products of relevant companies are specified.

Documents required for the correct calculation of the pressure surges

- Overview diagram of the overall system. Frequently, connections are of significance that would seem to be irrelevant at first sight (connections that do not flow). These connections create energy dissipation and thus affect the pressure surge calculation.
- Topography of the line layout (longitudinal cuts or height curve chart with line routing entered).
- Specification of the pipe material (e.g. PE-HD, PVC, GGG, St etc.).
- Exact pipe dimensions, i.e. pipe inner and outer diameters (or wall thickness, SDR ratio or pipe series). The old specification of the "DN" diameter is not sufficient!
- Safety factor or pressure stage of the pipes.
- Pipe roughness
- All data on the installations of the entire pipeline (positions, type, zeta values etc.).
- Pump curves (delivery head, power, $NPSH_{pump}$ value, moment of inertia of the pump and motor).
- Switching of the pumps and planned operating system.
- If problems concerning the opening or closing procedures of slide valves are to be examined: hydraulic diagrams of the units (zeta/degree of opening or kv/degree of opening diagrams).
- If a pressure tank is to be used: pipe diameter of the pipe section at the point where the connection to be considered.

Avoidance of unacceptable pressure surges

In long pipes or at high flow rates, very high pressure surges may occur when the pump is started or stopped, which could damage valves and sealing units. To reduce these pressure surges, various different types of equipment are possible: e.g. installation of an electric slide valve, installation of a pressure tank, speed-controlled starting and stopping of the pump, installation of several non-return valves etc.


Feld 2
Feld 3
Feld 4
Feld 5

Basic electrical engineering principles

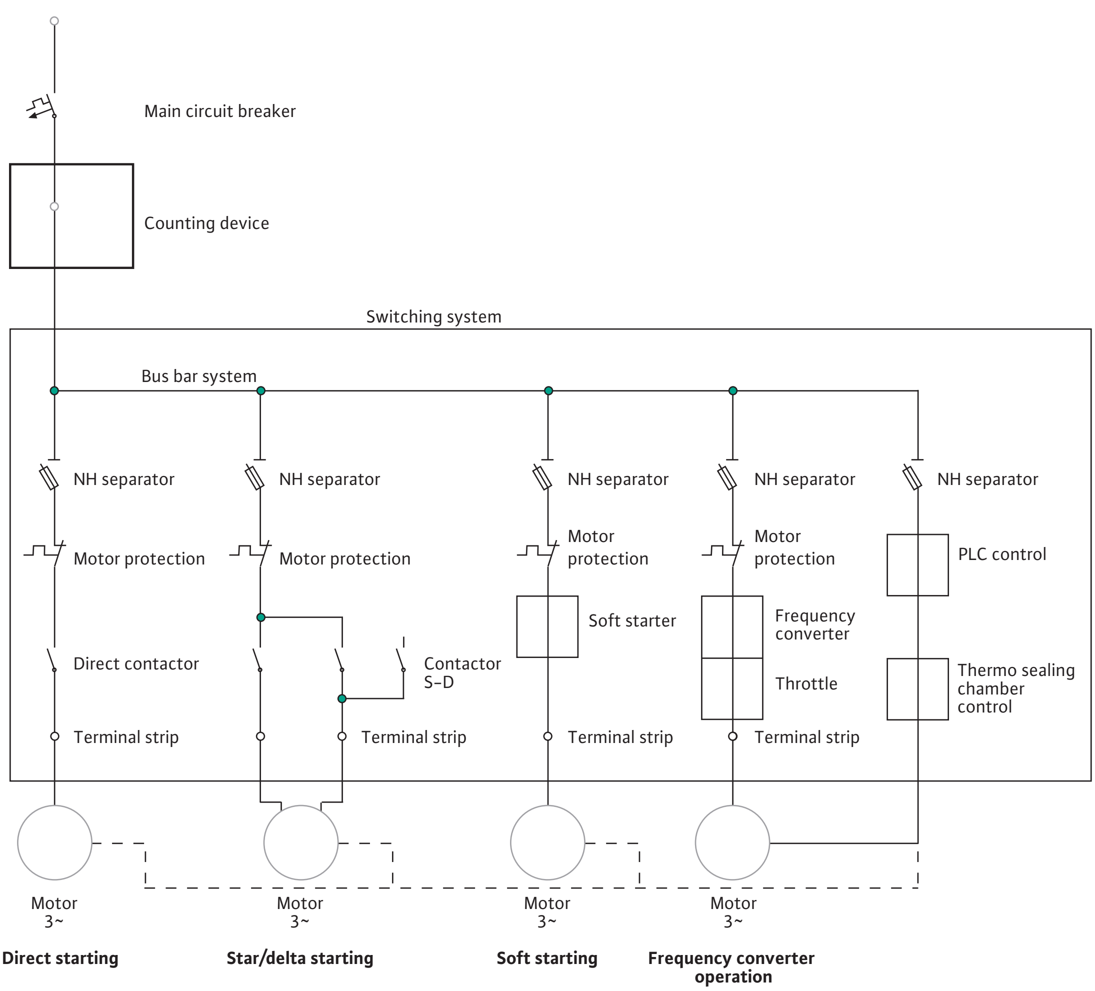
To be able to operate pumps of the latest generation reliably and economically, the corresponding switching system/control is just as important as the pump itself. That applies to the motor's energy supply as well as the monitoring and control of the pump or of the mixer.

The following section assists you in the correct planning and configuration of the electrical system. The contents contain general basic information as well as special topics that are to be observed when using our products.

German/European standards and legal specifications were used as the basis.

The system structure diagram illustrates the route from the energy provider to the consumer. Various different activation types may be applied that are displayed here as examples.

Schematic structure of a switching system with various activation types for the motors



Electrical systems

The supply of energy in the form of electricity is ensured by the electricity supply companies. They provide the transfer point including the counting unit. When an electrical system is installed, the technical connection specifications of the relevant energy provider are to be observed.

Mains type

For the distribution of the electrical energy, specifications were made that define the structure of the mains system, e.g. DIN VDE 0100-300.

Mains types are distinguished by the following:
- Number of outer conductors
- Voltage and type of current
- Frequency
- Voltage

These standardised definitions ensure that the system works and that the protective measures are effective. Systems used in practice are identified in a standardised manner using letters.

The abbreviations used have the following meanings:

First letter:
Connection to earth of the supplying current source

T Direct earthing of a point (neutral point of the transformer)

I Either insulation of all active parts from earth or connection of a point to earth via an impedance

Second letter:
Connection to earth of the component of the electrical system

T Component earthed directly, regardless of any existing earthing of any point of the power supply

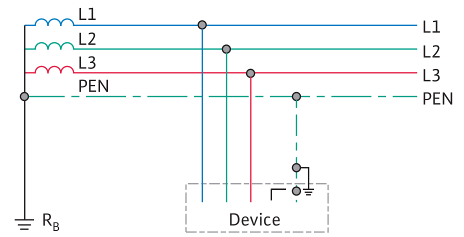
N Component connected directly to operational earth. In AC voltage systems, the neutral point is generally the earthed point.

Other letters:
Layout of the neutral conductor and the protective conductor

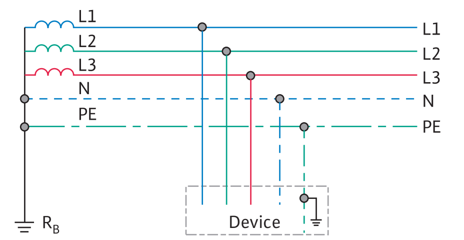
S Neutral conductor and protective conductor are separated

C Neutral conductor and protective conductor are combined in one conductor

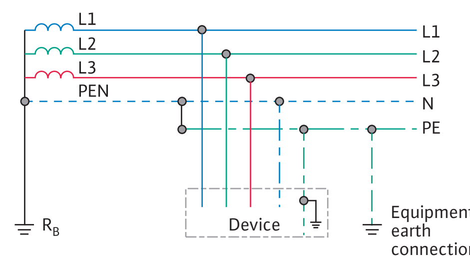
TN-C power supply
- Transformer's neutral point earthed (operational earthing)
- Component connect directly to operational earth via PEN conductor
- Neutral conductors and protective conductors within the entire system are combined in a single conductor



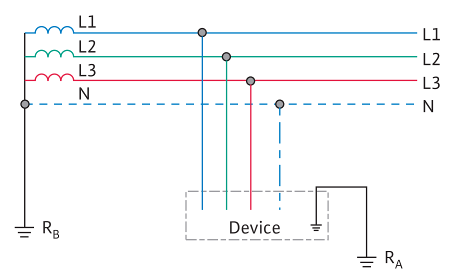
TN-S power supply
- Transformer's neutral point earthed (operational earthing)
- Component connect directly to operational earth via protective conductor
- Neutral conductors and protective conductors are separated within the entire system



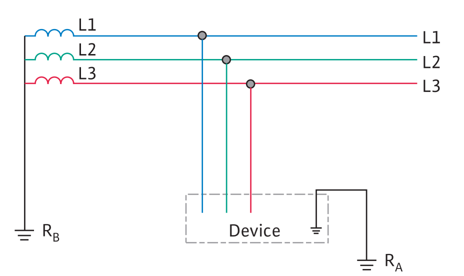
TN-C-S power supply
- Transformer's neutral point earthed (operational earthing)
- Component connect directly to operational earth via PEN or protective conductor
- Neutral conductors and protective conductors are separated in parts or combined in the system



TT power supply
- Transformer's neutral point earthed (operational earthing)
- Component earthed directly



IT power supply
- System components are earthed
- Active parts are insulated from earth



Protective measures (DIN VDE 0100-410)

The various protective measures are for protecting persons and animals from dangerous shock currents or an electrical shock. Two basic measures need to be observed:

- Protection against direct contact
  Basic/operational insulation that prevent live parts from being touched under normal conditions

- Protection against indirect contact
  Measures that prevent contact with an unacceptably high voltage in the event of a fault

The maximum contact voltage is:
- 50 V AC voltage or 120 V DC voltage for humans
- 25 V AC voltage or 60 V DC voltage for animals

Protection classes:
(DIN EN 50529 / VDE 0470 Part 1)
The degree of protection that a housing offers e.g. against direct contact is defined by the IP code (International Protection). It consists of "IP" and two figures (e.g. IP 54).

First figure:
- Protection of persons from access to dangerous parts
- Protection of the equipment from infiltration of solid matter

Second figure:
- Protection of the equipment from penetration of water

	First figure		Second figure
Code figure	**Protection against contact**	**Protection against foreign body**	**Protection against water**
0	No protection	No protection	No protection
1	Protection against contact with back of hand	Protection against solid foreign body with a diameter of 50 mm	Protection against water dripping vertically
2	Protection against contact with fingers	Protection against solid foreign body with a diameter of 12.5 mm	Protection against water dripping at an angle (15°)
3	Protection against contact with tools	Protection against solid foreign body with a diameter of 2.5 mm	Protection against sprayed water at an angle of up to 60°
4	Protection against contact with a wire	Protection against solid foreign body with a diameter of 1.0 mm	Protection against water splashing from any direction
5	Protection against contact with a wire	Dust protection	Protection against water jets
6	Protection against contact with a wire	Dust-proof	Protection against strong jets of water
7	–	–	Protection against temporary submersion in water
8	–	–	Protection against permanent submersion in water

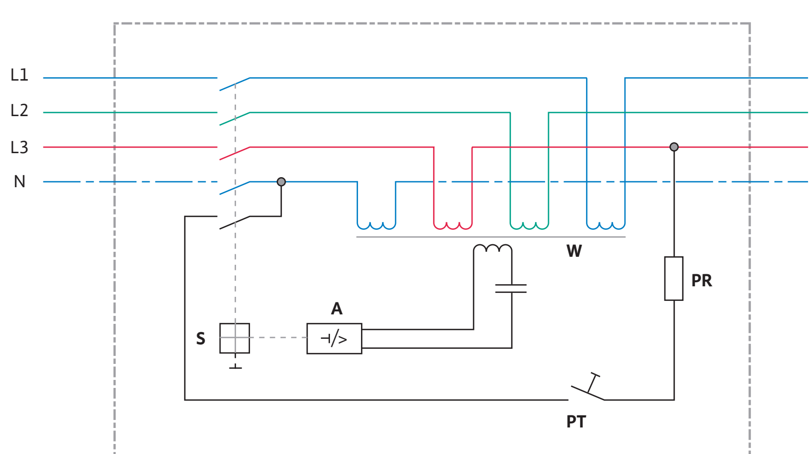
Protection in the event of indirect contact: (DIN VDE 0100 Part 410)
Protection in the event of indirect contact means that no unacceptably high contact voltage can occur in the event of a fault.

Terminology:
(DIN VDE 0100 Part 200)

Protective conductor:
A conductor that is required for the protective measures in the TN/TT mains system against electric shocks. It establishes the electrical connection to one of the following parts:
- Components of the electrical equipment
- External conductive parts
- Main earthing terminal, main earthing strip, potential equalisation strip
- Earth electrode
- Earthed point of the current source or artificial neutral point

Function:
In the event of an insulation fault, the protective conductor ensures that no unacceptably high contact voltage can occur at the component of the equipment and that the upstream overcurrent protection shuts down the faulty device. Depending on the mains type, the protective conductor can be designed as "PE" or as a combination with the neutral conductor as "PEN". (Design according to DIN VDE 0100, Part 540)

Structure and function of a residual-current-operated protection switch



S Switch lock
A Trigger
W Sum current converter
PT Test button
PR Test resistance

Potential equalisation:
The potential equalisation brings the components of electrical equipment and external conductive parts to the same or almost the same potential. So that other conductive parts (e.g. pipes or building structures) do not conduct any unacceptably high voltage in the event of a fault, these parts must be connected to the potential equalisation.

The following parts must be integrated into the system's potential equalisation:
- Foundation earthing equipment
- Protective conductor or PEN conductor
- Metal water pipes
- Metal sewage pipes
- Central heating
- Earthing conductor for aerial
- Earthing conductor for telephone system
- Metal parts of the building structure
- Conductor to the lightning protection earth system

Additional protection by residual current-operated protective device (RCD):
The residual-current-operated protection switch provides the best protection and is used as a protective measure in various different types of main systems.

It provides additional protection against the following:
- Direct contact with active parts
- Dangerous voltage in the event of indirect contact in the case of a fault
- Fires with short circuits to ground

The figure shows the basic structure of the residual current operated device. The most important component is the sum current converter. It registers inflowing and outflowing currents. If the system is working correctly, these currents are equal and generate a magnetic field according to Kirchhoff's law, the sum of which is zero.

If, due to a fault in the system, current flows back along the protective conductor or the earthing equipment (i.e. past the sum current converter), a voltage is induced in the sum current converter that triggers the switch lock.

This triggering only takes place with a very short delay time, i.e. the effective time of a contact voltage in the event of direct or indirect is very short. That ensures much better personal protection than with normal protective measures (e.g. overcurrent protection).

In the event of a fire, the residual current operated switch also provides better protection than the usual protective units, since short circuits to ground are remedied that are not detected by overcurrent devices.

Three-phase asynchronous motors

All motors that are used in sewage applications are designed as asynchronous motors with squirrel cage motor.

This design offers some advantages that have lead to these motors being used very frequently in drive systems:

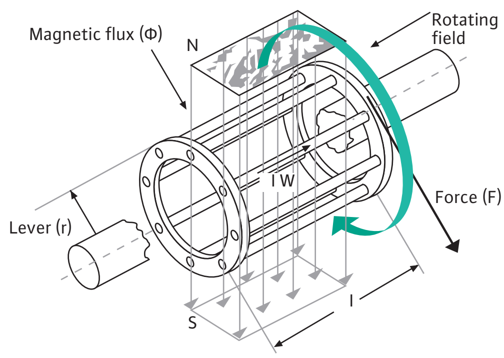
- Simple and cost-effective
- Long service life
- Low-maintenance
- No brush wear
- Can be severely overloaded for short periods
- Can be used in potentially explosive areas
- Starting despite high counter-torque without any aids

General design and function

Stator design
The stator consists of a layered laminated core with grooves. The winding is drawn into these grooves. In three-phase motors, this winding consists of three lines that are arranged on the stator's laminated core, offset by 120°.

Rotor design
For the majority of motors, the rotor winding (cage) has an aluminium die-cast design. Motors with a higher power (> 150 kW) are made with copper rods in the rotor. The laminated core with the cage is also made of layered sheet metal.

Squirrel cage motor with excitation field of the stator




Cage with rods set crosswise

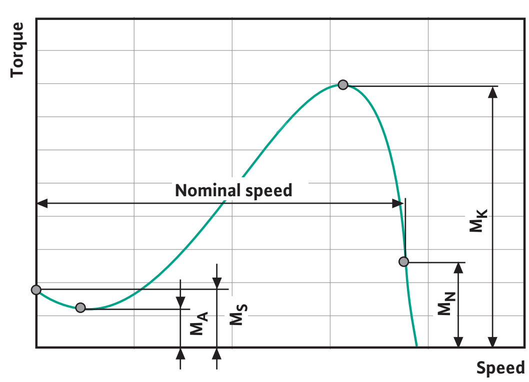
Function

When the three-phase current winding is connected to the power supply, the rotating field in the stator winding rotates at synchronous speed. It also flows through the rotor's cage and induces an AC voltage with mains frequency in succession in the individual rods of the cage in the event of a standstill.

Due to the induced rotor voltage, a rotor current flows, which generates the rotor's magnetic field. The resulting torque accelerates the rotor in the direction of the stator's magnetic field.

If the rotor rotates at the same speed as the rotating field, i.e. at synchronous speed, there is zero torque. If a resistance torque is applied at the rotor, the rotor's speed stays under that of the rotating field. Then, the rods of the cage are cut again by the rotating field, a voltage is induced and a motor torque takes effect. That is why, with asynchronous motors, the rotor must run "asynchronously" to the rotating field of the stator in order to generate a torque. The difference in speed is referred to as slip.

Torque progression of a squirrel cage motor

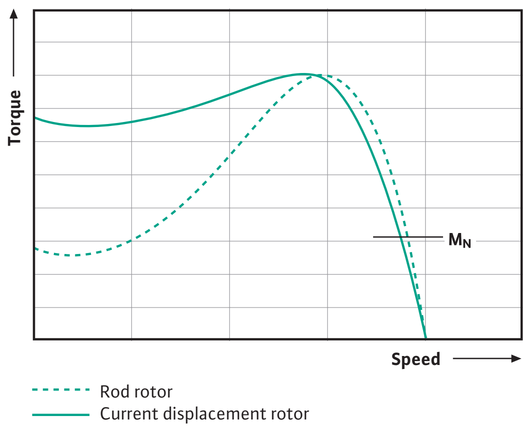


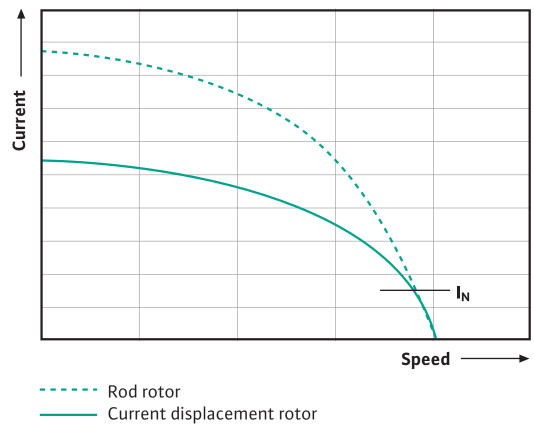
MA Starting torque
MS Pull-up torque
MK Pull-out torque
MN Nominal torque

Torque progression

The figure shows the typical torque progression of a squirrel cage motor with distinct pull-up torque. This torque progression can be influenced by the rod shape of the squirrel cage. Since the pump curve is very steep at the nominal torque, the speed of the motor hardly fluctuates in the event of a change in load.

The specific values depend on the shape of the rotor's rod





Speed

The following relationship applies to the calculation of the motor's speed:

$$n = \frac{f}{p}(1 - s)$$

Abbreviation	Description
n	Speed
f	Mains frequency
p	Number of pole pairs (half the number of poles)
s	Slip

To change the speed of the motor, there are the following options:

- Increasing the slip, "s", by reducing the mains voltage
- Changing the number of pole pairs
- Changing the mains frequency, "f", normally by the use of a frequency converter

Typical speeds for a mains frequency of 50 Hz

Pole number/ Pole pair number	Synchronous speed [rpm]	Speed at nominal load [rpm]
2/1	3000	approx. 2900
4/2	1500	approx. 1450
6/3	1000	approx. 950
8/4	750	approx. 725
10/5	600	approx. 575

Starting methods

A disadvantage of asynchronous motors with squirrel cage motor is the relatively high starting current that may be 4 – 8 times the nominal current. Since no disruptive voltage frequencies occur when the motors are switched on, energy providers specify measures for limiting the starting current.

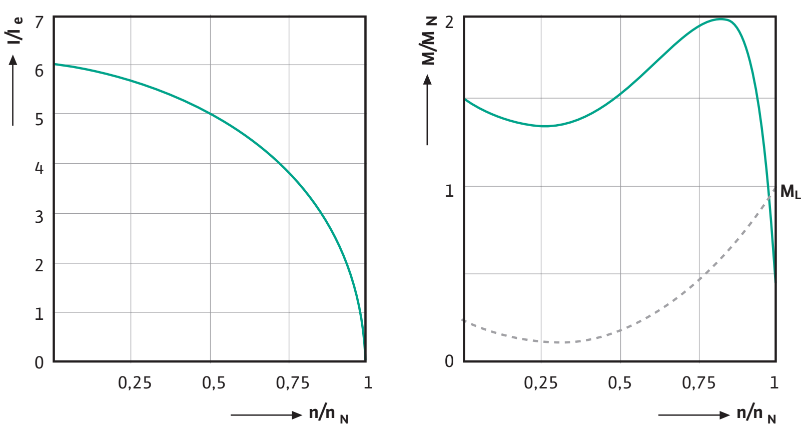
The reduction of the starting current can be achieved by reducing the stator voltage. Converter operation is an exception to this rule.

The normal starting methods are described in the following.

Direct starting

Direct starting is the simplest way to switch on a three-phase motor. In this case, the motor is connected directly to the power supply.

Current/speed curve – Torque/speed curve

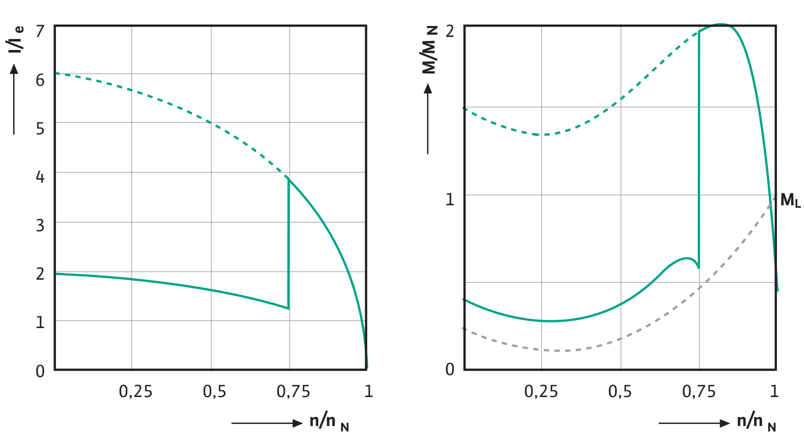


Advantages	Disadvantages
• Motor with 3 connections required • Simple switchgear • Low price • High starting torque	• High starting current • High load on the mechanical components • Only suitable for low and medium power

Star-delta starting

Starting three-phase motors using star-delta switching is the most familiar variant and widely used. It is used for three-phase motors from low to high power.

Current/speed curve – Torque/speed curve



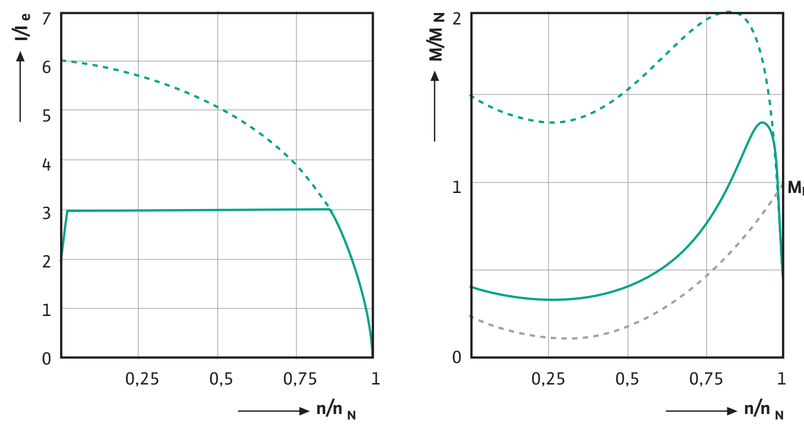
Advantages	Disadvantages
• Simple switchgears • Low price • Lower starting current compared to direct starting	• Six motor connections required • Reduced starting torque • Current peak on switching over from star to delta • Mechanical load on switching over from star to delta

Soft starter (electronic motor start)

Like the pump curves for direct starting and star-delta starting, this method causes high current and torque jumps. These can have a negative effect on the power supply and the motor, particularly at high power.

The soft starter, which is adjusted to the load machine, increases the voltage of the motor continuously. The motor can thus be accelerated without mechanical knocks and current peaks. Soft starters are an electronic alternative to traditional star-delta switching.

Current/speed curve – Torque/speed curve

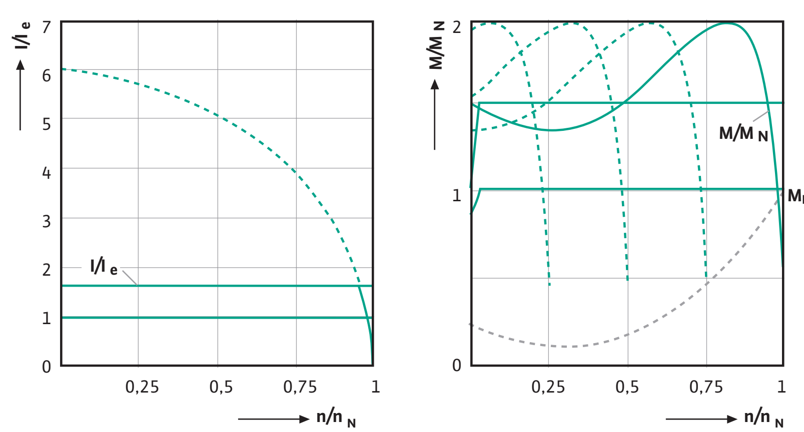


Advantages	Disadvantages
• No current peaks • Maintenance-free • Reduced adjustable starting torque • Adjustable current limit • Motor with 3 connections required • Soft starting and stopping	• Possibly additional costs at low power • Additional power dissipation if the soft starter is not bridged after starting

Frequency converter

The frequency converter is mainly used for applications that require a drive that can be speed-changed. Due to the option of controlling the output frequency, the motor can be started and stopped gently, adjusted to the hydraulics. This option also means that various currents or torques cannot be exceeded during the starting phase (two examples in the diagram).

Current / speed curve – Torque / speed curve



Advantages	Disadvantages
• Speed adjustment and control as desired during operation • Adjustable current limit • 4-quadrant operation • No wear • Extensive motor protection functions	• High costs • Additional power dissipation • Possibly additional costs due to EMC measures

Operating modes

The operating mode determines the permissible duty cycle of motors. One should always make sure that the built-in temperature control of the motors is connected correctly. It ensures that the temperature classes of the windings are adhered to in the event of the operating time being exceeded or the wrong operating mode.

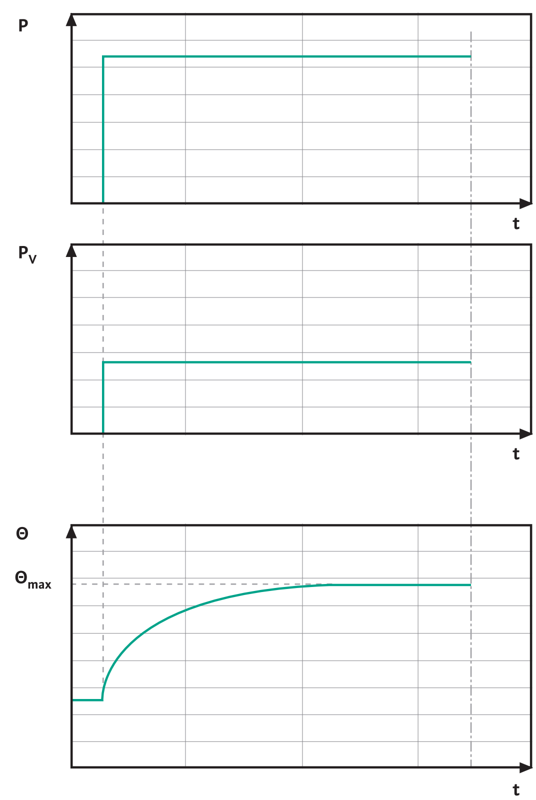
S1 Permanent operation

Definition:

Operation at a constant load until the machine can reach the thermal state of inertia.

The machine is designed in such a way that cooling is sufficient at the specified conditions.
The operating mode does not give any information as to whether the machine is to be operated dry or wet. If no operating mode is stated on the name plate of a machine, S1 permanent operation applies.

S1 Permanent operation



P	Load
P_V	Electrical losses
Θ	Temperature
$Θ_{max}$	Maximum temperature
t	Time

S2 Short-term operation

Definition:

Operation at constant load and with a duration that is not sufficient to reach the thermal state of inertia, and a following standstill time, during which the fallen machine temperatures only deviate from the temperature of the coolant by less than 2 K.

The power dissipation of the machine is higher than can be dissipated via the coolant. In S2, the permissible operating time is always also specified (e.g. S2 15 min). After this operating time, the machine must cool down again to the ambient temperature. This operating mode is mainly used for dry-installed machines.

S3 Intermittent operation without affecting the starting current

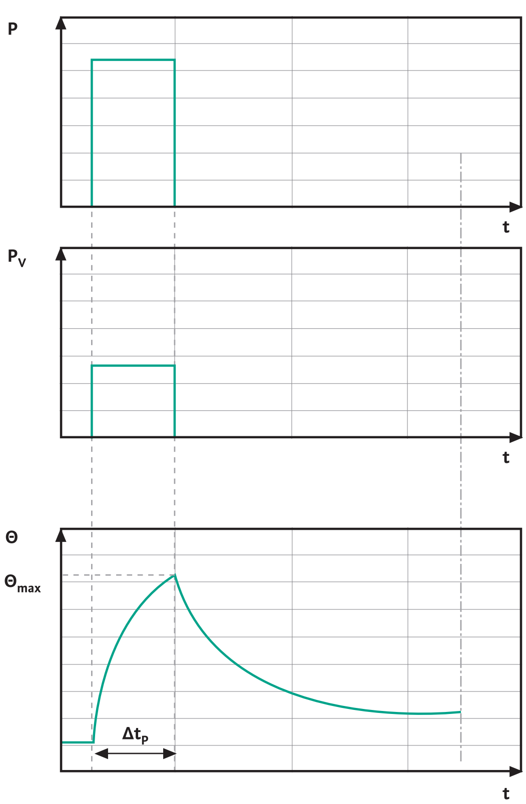
Definition:

Operation that consists of a sequence of identical cycles, each one consisting of an operating time with constant load and a downtime, and the starting current does not have a significant effect on the excess temperature.

The power dissipation of the machine is higher than can be dissipated via the coolant. In S3 operating mode, the cycle duration is specified in percent and the cycle time is also specified.

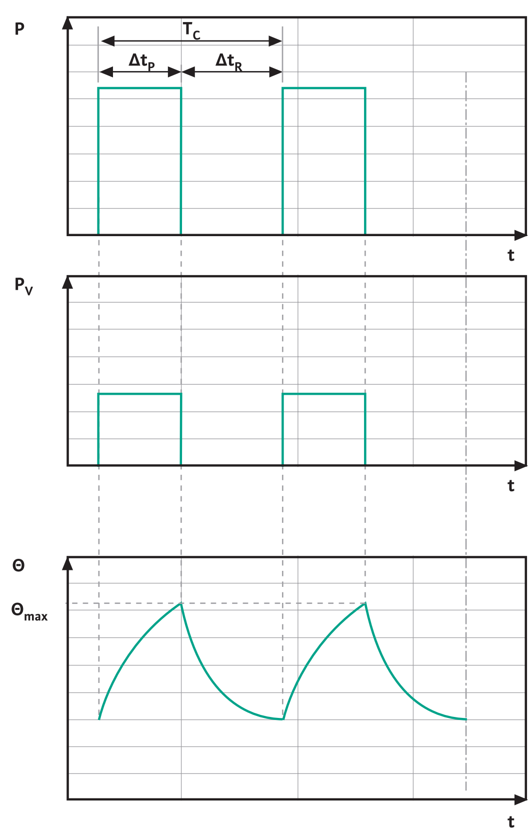
Example for S3 25 % 10 min: The duty cycle is 2.5 min and the pause 7.5 min. If no cycle duration is specified, a duration of 10 min applies.

S2 Short-term operation



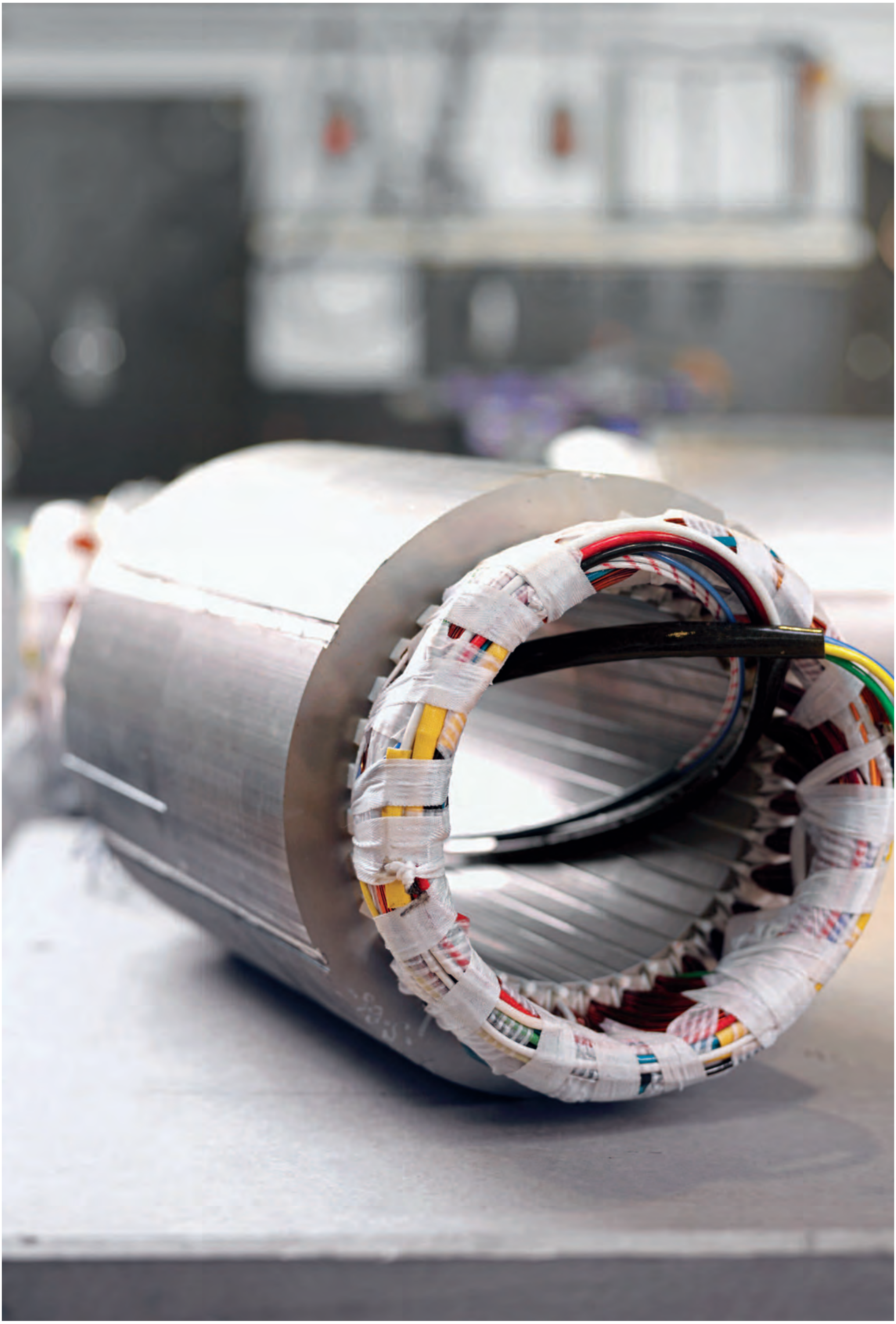
P Load
P_V Electrical losses
Θ Temperature
Θ_{max} Maximum temperature
t Time
Δt_P Operating time with constant load

S3 Intermittent operation without any effect on the starting current



P Load
P_V Electrical losses
Θ Temperature
Θ_{max} Maximum temperature
t Time
T_C Run time
Δt_P Operating time with constant load
Δt_R Downtime with dead windings relative activation duration = $\Delta t_P / T_C$

Other operating modes are S4 to S10.



Product-specific dimensioning

Motor protection

To operate a motor safely, it must be protected from heating up too much. Unacceptable motor overheating can be caused by a fault that increases the motor current:
- Overload
- Phase failure
- Undervoltage
- Blocking

These faults can be detected by a motor protection relay or a motor protection switch, which then shut down the motor. Motor protection relay and motor protection switch may not be adjusted to more than the motor's nominal current.

Motor protection relay

Principle of operation:
Thermal protection is provided by bimetals that are heated up by heating windings through which the motor current flows. A separate bimetal with corresponding heating winding is provided for each electrical conductor to the motor. If the current consumption of just one winding of the motor exceeds the specified value for several seconds, the bimetal, which is deformed by the heat, triggers the switch lock and switches the motor contactor off. The motor is also shut down after a short while in the event of a phase failure (uneven heating of the bimetal strips). In the event of thermal triggering, the switch can only be turned back on again once the bimetals have cooled down. Motor protection relays do not shut the motor down directly. They only have a contact for a relatively small switching capacity. This contact is used to activate a contactor that shuts the motor down in the event of a fault. Unlike the motor protection switch, a motor protection relay does not have a short-circuit trigger. That is why fuses should be installed in the supply line for one or more motors that are protected with a motor protection relay. Furthermore, with motor protection relays, restarting can be set manually or automatically. Restarting should be performed manually, to prevent constant activation and deactivation if there is a fault.

Motor protection switch

Motor protection switches can be used to switch the operation of motors on and off. Thermal triggering works according to the principle of the motor protection relay. However, the operator is able to shut down the motor during operation or in the event of a fault. Furthermore, most motor protection switches also have a magnetic fast trigger mechanism that protects the line downstream and the motor from short-circuits. In small current ranges, these switches are short-circuit proof, i.e. a back-up fuse is not necessarily required.

Other faults that may result in an increase in heat:
- Dry running of motors that may only be operated in submerged state
- Unacceptably high fluid temperature / ambient temperature
- Impermissible running times during short-term operation

These faults do not have any effect on the motor's current consumption and can therefore not be detected by the overload protection connected upstream. For these types of faults, temperature sensors are used that are embedded in the component to be protected (motor winding).

Fuse protection of motors

Reference values for nominal motor currents and smallest possible "slow-blow" or "gL" short-circuit fuses

The nominal motor currents apply to normal internally and surface-cooled three-phase motors.

Direct starting:
The fuses apply to the specified nominal motor currents and direct starting: maximum starting current 6 x nominal motor current, maximum starting time 5 s.

YΔ starting:
Maximum starting current 2 x nominal motor current, maximum starting time 5 s. Adjust the motor protection relay in the line to 0.58 x nominal motor current.

Motors with a higher nominal current, a higher starting current and/or a longer starting time require larger short-circuit fuses. The maximum permissible value depends on the switchgear or motor protection relay.

See "Reference values for three-phase motors" table on the next page.

Reference values for three-phase motors

Motor power			220 – 230 V nominal motor current	Fuse for direct motor start	Fuse for motor start YΔ	240 V nominal motor current	Fuse for direct motor start	Fuse for motor start YΔ	380 – 400 V nominal motor current	Fuse for direct motor start	Fuse for motor start YΔ	415 V nominal motor current	Fuse for direct motor start	Fuse for motor start YΔ	500 V nominal motor current	Fuse for direct motor start	Fuse for motor start YΔ	660 – 690 V nominal motor current	Fuse for direct motor start	Fuse for motor start YΔ
kW	cos φ	%	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A
0.06	0.7	59	0.38	1	1	0.35	1	1	0.22	1	1	–	–	–	0.16	1	1	–	–	–
0.09	0.7	60	0.55	2	2	0.5	2	2	0.33	1	1	–	–	–	0.24	1	1	–	–	–
0.12	0.7	61	0.76	2	2	0.68	2	2	0.42	2	2	–	–	–	0.33	1	1	–	–	–
0.18	0.7	61	1.1	2	2	1	2	2	0.64	2	2	–	–	–	0.46	1	1	–	–	–
0.25	0.7	62	1.4	4	2	1.38	4	2	0.88	2	2	–	–	–	0.59	2	2	–	–	–
0.37	0.72	6	2.1	4	4	1.93	4	4	1.22	4	2	–	–	–	0.85	2	2	0.7	2	2
0.55	0.75	69	2.7	4	4	2.3	4	4	1.5	4	2	–	–	–	1.2	4	2	0.9	2	2
0.75	0.8	74	3.3	6	4	3.1	6	4	2	4	4	2	4	4	1.48	4	2	1.1	2	2
1.1	0.83	77	4.9	10	6	4.1	6	6	2.6	4	4	2.5	4	4	2.1	4	4	1.5	4	2
1.5	0.83	78	6.2	10	10	5.6	10	10	3.5	6	4	3.5	6	4	2.6	4	4	2	4	4
2.2	0.83	81	8.7	16	10	7.9	16	10	5	10	6	5	10	6	3.8	6	6	2.9	6	4
2.5	0.83	81	9.8	16	16	8.9	16	10	5.7	10	10	–	–	–	4.3	6	6	–	–	–
3	0.84	81	11.6	20	16	10.6	20	16	6.6	16	10	6.5	16	10	5.1	10	10	3.5	6	4
3.7	0.84	82	14.2	25	20	13	25	16	8.2	16	10	7.5	16	10	6.2	16	10	–	–	–
4	0.84	82	15.3	25	20	14	25	20	8.5	16	10	–	–	–	6.5	16	10	4.9	10	6
5.5	0.85	83	20.6	35	25	18.9	35	25	11.5	20	16	11	20	16	8.9	16	10	6.7	16	10
7.5	0.86	85	27.4	35	35	24.8	35	35	15.5	25	20	14	25	16	11.9	20	16	9	16	10
8	0.86	85	28.8	50	35	26.4	35	35	16.7	25	20	–	–	–	12.7	20	16	–	–	–
11	0.86	87	39.2	63	50	35.3	50	50	22	35	25	21	35	25	16.7	25	20	13	25	16
12.5	0.86	87	43.8	63	50	40.2	63	50	25	35	35	–	–	–	19	35	25	–	–	–
15	0.86	87	52.6	80	63	48.2	80	63	30	50	35	28	35	35	22.5	35	25	17.5	25	20
18.5	0.86	88	64.9	100	80	58.7	80	63	37	63	50	35	50	50	28.5	50	35	21	35	25
20	0.86	88	69.3	100	80	63.4	80	80	40	63	50	–	–	–	30.6	50	35	–	–	–
22	0.87	89	75.2	100	80	68	100	80	44	63	50	40	63	50	33	50	50	25	35	35
25	0.87	89	84.4	125	100	77.2	100	100	50	80	63	–	–	–	38	63	50	–	–	–
30	0.87	90	101	125	125	92.7	125	100	60	80	63	55	80	63	44	63	50	33	50	35
37	0.87	90	124	160	160	114	160	125	72	100	80	66	100	80	54	80	63	42	63	50
40	0.87	90	134	160	160	123	160	160	79	100	100	–	–	–	60	80	63	–	–	–
45	0.88	91	150	200	160	136	200	160	85	125	100	80	100	100	64.5	100	80	49	63	63
51	0.88	91	168	200	200	154	200	200	97	125	100	–	–	–	73.7	100	80	–	–	–
55	0.88	91	181	250	200	166	200	200	105	160	125	–	–	–	79	125	100	60	80	63
59	0.88	91	194	250	250	178	250	200	112	160	125	105	160	125	85.3	125	100	–	–	–
75	0.88	91	245	315	250	226	315	250	140	200	160	135	200	160	106	160	125	82	125	100
90	0.88	92	292	400	315	268	315	315	170	250	200	165	200	200	128	160	160	98	125	125
110	0.88	92	358	500	400	327	400	400	205	250	250	200	250	250	156	200	200	118	160	125
129	0.88	92	420	500	500	384	500	400	242	315	250	230	315	250	184	250	200	–	–	–
132	0.88	92	425	500	500	393	500	500	245	315	250	–	–	–	186	250	200	140	200	160
147	0.88	93	472	630	630	432	630	500	273	315	315	260	315	315	207	250	250	–	–	–
160	0.88	93	502	630	630	471	630	630	295	400	315	–	–	–	220	315	250	170	200	200
184	0.88	93	590	800	630	541	630	630	340	400	400	325	400	400	259	315	315	–	–	–
200	0.88	93	626	800	800	589	800	630	370	500	400	–	–	–	278	315	315	215	250	250
220	0.88	93	700	1000	800	647	800	800	408	500	500	385	500	400	310	400	400	–	–	
250	0.88	93	803	1000	1000	736	1000	800	460	630	500	–	–	–	353	500	400	268	315	315
257	0.88	93	826	1000	1000	756	1000	800	475	630	630	450	630	500	363	500	400	–	–	–
295	0.88	93	948	1250	1000	868	1000	1000	546	800	630	500	630	630	416	500	500	–	–	–
315	0.88	93	990	1250	1250	927	1250	1000	580	800	630	–	–	–	445	630	500	337	400	400
355	0.89	95	–	–	–	–	–	–	636	800	800	–	–	–	483	630	630	366	500	400
400	0.89	96	–	–	–	–	–	–	710	1000	800	–	–	–	538	630	630	410	500	500
500	0.89	96	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	515	630	630
600	0.90	97	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	600	800	630

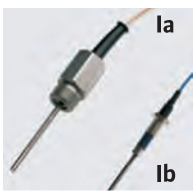
Monitoring equipment

The integrated monitoring units are for protecting the motor:

- Excess temperature in winding/bearing/oil
- Overpressure in the motor
- Water penetrates
  - Sealing chamber
  - Leakage chamber
  - Motor compartment
  - Terminal compartment

The possible sensor equipment depends on the different motor types. The individual sensors with the corresponding relays are described in the following.

Overview of the monitoring equipment



DI electrode
Moisture control in terminal compartment (b), motor compartment (b) and sealing chamber (a+b)

Bimetal
Winding temperature monitoring in the motor compartment

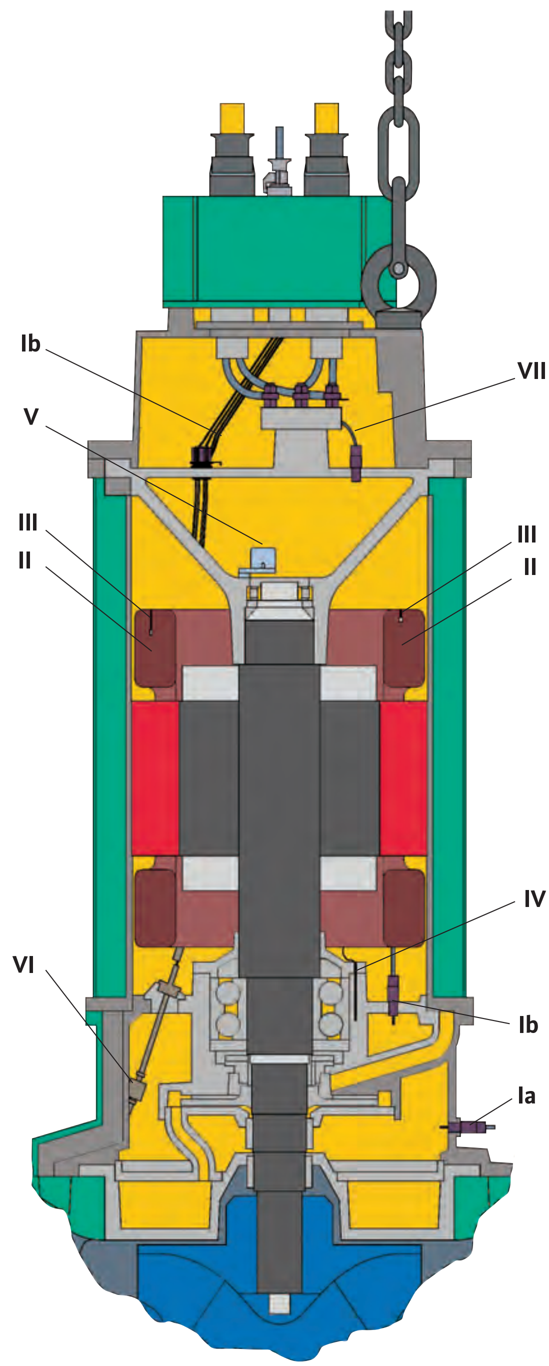
PTC thermistor temperature sensor
Winding temperature monitoring in the motor compartment

Pt 100
Winding temperature and bearing temperature monitoring

Thermal float switch
Oil level and oil temperature monitoring in the motor compartment (FO/FK motors)

Float switch
Leakage monitoring in the control compartment

Pressure switch
Pressure control in the motor compartment



Bimetal temperature sensor

Bimetal temperature sensor

Description:

Bimetal temperature sensors are mechanical switches that trigger a switching operation as the result of the effect of heat. "Normally closed contacts" are used, i.e. when the tripping temperature is reached, the electrical circuit is interrupted. When the temperature drops accordingly (hysteresis), the sensor closes automatically again. 2 or 3 temperature sensors are installed in series in the windings. Another application option is the monitoring of the oil temperature in oil motors. In Ex motors for submerged operation and in special versions, there are 2 temperature circuits with different tripping temperatures.

Application for the following:

- Slowly rising temperatures, e.g. obstruction of cooling by deposits
- Overload
- Surfacing of motors that may only operate in submerged state
- Unacceptably high ambient temperatures
- Operating time too long during S2 operation

Advantages:

- Potential-free contact
- High switching capacity
- No special evaluation relay required
- Lower costs

Disadvantages:

- Can only be used to a limited extent in the event of blocking
- Large dimensions
- The switching temperature is determined by the sensor

Technical data:

Switching capacity: 250 V AC/2.5 A at cos $\varphi = 1$
The sensors are designed as NC contacts.
Connection designation of the control line:
20 – 21 Deactivation
20 – 22 Advance warning

Due to the high switching capacity, it is possible to integrate the bimetal temperature sensor directly in the control circuit of the contactor circuit. With Ex-protected motors, a restart interlock must be implemented for the high temperature circuit.

PTC thermistor sensor/ thermistor/PTC

PTC thermistor sensor/thermistor/PTC

Description:

PTC thermistor sensors are temperature-sensitive resistors. These sensors do not have any mechanical components. When the nominal activation temperature (NAT) is reached, the electrical resistance of the sensors increases rapidly. This change is evaluated by an electronic switchgear. 3 temperature sensors are installed in series in the windings. In large machines and special versions, there are 2 temperature circuits each with various tripping temperatures (e.g. 130 – 140 °C). A switchgear is required for each temperature circuit (e.g. WILO-CM-MSS).

Application for the following:

- All types of temperature protection
- Blocking of sewage motors
- Motors for speed control (specification for Ex motors on the converter)

Advantages:

- Very small
- Fast reaction time (also referred to as full motor protection)
- Long service life
- Standardised version in accordance with DIN 44081/44082

Disadvantages:

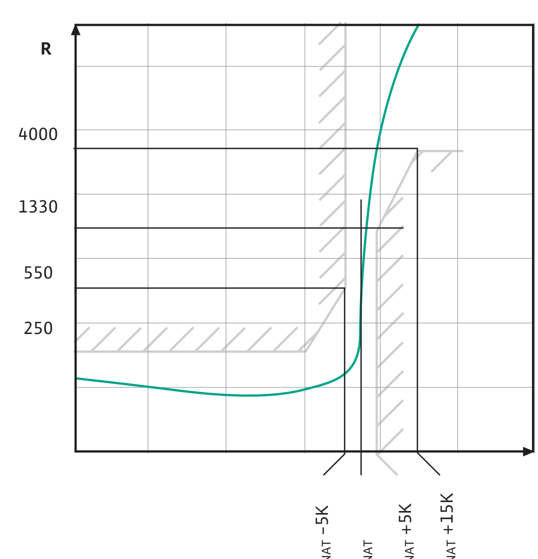
- May only be operated at low voltage
- A special PTC thermistor relay is always required
- The switching temperature is determined by the sensor

Technical data:

Max. control voltage:	< 7.5 V
Cold resistance	
Single/drilling:	80 – 250/250 – 750 Ω
Resistance at NAT:	> 1300 Ω

Connection designation of the control line:
10 – 11 Deactivation
10 – 12 Advance warning

For the evaluation of PTC thermistor sensors, an appropriate relay is always to be used. PTC thermistors must be used for explosion-protected motors that are operated at the frequency converter.



Temperature sensor PT 100

Description:

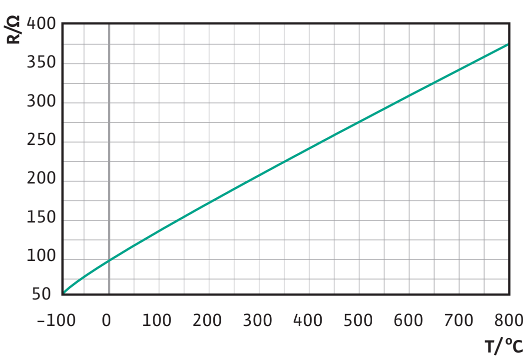
PT 100 sensors are temperature-dependent resistors with an almost linear pump curve. At 0 °C, the resistance is 100 Ω. The change of resistance is between 0 and 100 °C 0.385 Ω/K.

This change is evaluated by an electronic switchgear (e.g. WILO DGW 2.01 G). The switching temperature is determined by the setting on the switchgear, not by the sensor. In addition to the adjustment of the switching points, the temperature can also be measured.

Application for the following:

- Slowly rising temperature
- e. g. obstruction of the cooling output due to deposits
- Overload

P1-100 pump curve



- Surfacing of motors that may only operate in submerged state
- Unacceptable ambient temperature
- Long running time during S2 operation
- Blocking only to a limited extent

Advantages:

- Monitoring can be adjusted precisely to the operating temperature
- Several switching points per sensor possible
- Additionally, indication of the temperature

Disadvantages:

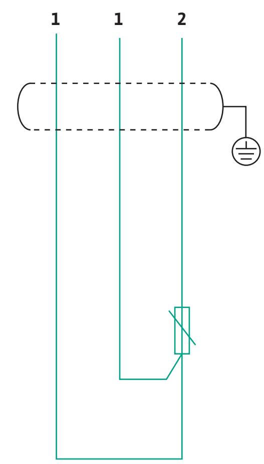
- A special PT 100 relay is always necessary
- Sensor and evaluation very expensive
- For explosion-protected motors, additional bimetals or PTC thermistor necessary

Technical data:

Resistance at 0°C:	100 Ω
Change of resistance:	~ 0.385 Ω/K
Measurement current:	< 3 mA
Connection designation of the control line:	1 – 2

In order to be able to compensate the fault caused by the line resistance, the connection is usually established in the form of three-wire switching. Almost all PT 100 evaluation relays support this connection.

Temperature sensor PT 100



PT 100 three-wire switching

Leakage floater

Description:

Leakage floaters are mechanical switches that trigger a switching operation in the event of fluid penetration. Therefore if fluid penetrates the leakage chamber via the second mechanical seal, the motor can be shut down or a warning emitted. Normally closed contacts" are used, i.e. if fluid enters the leakage chamber, the electrical circuit is interrupted.

Technical data:

Resistance closed (normal)	~ 0 Ω
Resistance open (triggered)	infinitely
Connection designation of the control line:	K20 – K21

No special relay is required for the evaluation. The switching capacity of the floater contacts deviates with different motor types and must therefore be taken from the connection diagram for the respective motor.

Float switch

Pressure switch

Pressure switch

Description:

Pressure switches are mechanical switches that trigger a switching operation in the event of overpressure in the motor. They are used in motors that have an oil-filled motor compartment. "Normally closed contacts" are used, i.e. when an overpressure builds up in the motor, the electrical circuit is interrupted.

Technical data:

Switching capacity: 250 V AC/2.5 A at cos φ = 1

Resistance closed (normal)	~ 0 Ω
Resistance open (triggered)	infinitely
Connection designation of the control line:	D20 – D21

No special relay is required for the evaluation.

Thermal float switch

Thermal float switch

Description:

Thermal float switches are mechanical switches that trigger a switching operation in the event of a low oil level or if the temperature in the motor is too high. They are used in motors that have an oil-filled motor compartment. "Normally closed contacts" are used, i.e. if there is a lack of oil or if the temperature of the oil is too high, the electrical circuit is interrupted.

Technical data:

Switching capacity: 250 V AC/2.5 A at cos φ = 1

Resistance closed (normal)	~ 0 Ω
Resistance open (triggered)	infinitely
Connection designation of the control line:	20 – 21

No special relay is required for the evaluation.

DI electrode

Conductive electrodes

Description:

Conductive electrodes (based on the measurement of the resistance) are used to evaluate conductive fluids. The sensor consists mainly of a rust-proof electrode rod. It is used to measure the conductivity of the fluid in relation to a reference earth (motor housing). This change is evaluated by an electronic switchgear (e.g. Wilo-NIV 101). The switching resistance is determined by the setting on the switchgear, not by the sensor.

Electrodes are used for the following:

- Internal sealing chamber monitoring
- External sealing chamber monitoring
- Motor compartment monitoring
- Terminal compartment monitoring

A special electrode relay is always required, e.g. Wilo-NIV 101/A, NIV 105/S or ER 143 (for potentially explosive areas). The sensitivity of the relay is to be set to > 20 kΩ.

Monitoring relay

Different monitoring relays are available for the evaluation of the sensors described. Some types are listed in the following.

Monitoring relay	Usage	Function description	Other functions
PTC thermistor relay Wilo CM-MSS 	• Connection of PTC thermistor temperature sensors • Connection of bimetal temperature sensors • Evaluation of other switching contacts, such as e.g. leakage floaters	The relay is used for temperature monitoring with restart interlock. Up to six PTC sensors can be connected in series. If the temperature of the PTC thermistor rises above its deactivation temperature, the relay triggers and saves this fault.	• Short-circuit monitoring that can be switched off, for connecting bimetals (T1 and T2x) • Memory that can be switched off (bridge between S1 and T1) • Approved for operation with Ex motors • Reset button
PT 100 Temperature controller Wilo DGW 2.01 	• Winding temperature monitoring • Bearing temperature monitoring	The relay measures the resistance of a PT100 temperature sensor and indicates the measured temperature directly on the display. Two limit values for advance warning and deactivation can be configured. These affect two separate output relays.	• Display for direct temperature indication and configuration • Keys for entering the values • Adjustable reaction in the event of a sensor fault • Connection in three-wire switching for line compensation
Sealing chamber/motor compartment monitoring Wilo NIV 101 	• Motor compartment monitoring • Sealing chamber monitoring • Terminal compartment monitoring	The relay provides an AC voltage at terminals E0 and E1. If an electrode is submerged in a conductive fluid, an alternating current can flow. That switches the integrated relay. If the electrode is not moistened, the relay is energised to ensure optimum self-monitoring. An LED indicates the switching status of the relay.	In addition, the relay provides the option of evaluating a PTC thermistor temperature sensor or bimetal sensor.
Ex-rated cut-off relay for level control and moisture monitoring Wilo ER143 	• Connection of electrodes or floaters in the potentially explosive area • Filling level control • Indication of the limit level • Dry-running protection • Sealing chamber monitoring	Like Wilo NIV 105/S, but designed as intrinsically safe Ex-i relay. On immersing the electrodes at E1(min) and E2(max), the relay is energised. When both electrodes surface again, the relay is de-energised. The relay itself must not be installed in the potentially explosive area!	• Switching between standby current and operating current possible • Sensitivity is adjustable • Activation and deactivation delay

Cables/lines

Type of application:	Drainage and sewage		Pure water
Water type according to DIN 4045 and 4046	NSSHÖU	OZOFLEX(PLUS) H07RN-F	Hydrofirm(T) S07BB-F
Potable water	–	–	M
Ground water	+	o	+
Sea water	+	+	+
Rainwater	+	+	+
Surface water	+	+	+
Wastewater	+	M	–
Sewage	+	+	–
Industrial water	+	+	+
Cooling water	+	+	+
Mixed water	+	+	o
Underground mining	M	–	–
Construction sites	+	+	–
Flame-resistant	+	+	–
Application temperature	60 °C	60 °C	60 °C

M = main field of application, + = suitable o = suitable to a limited extent, – = not suitable

On selecting the cables, the following aspects should be observed (selection according to ambient influences, DIN VDE 0100, Part 300):

- Ambient temperatures
- External heat sources
- Presence of water
- Presence of foreign matter
- Presence of corrosive or contaminated substances
- Mechanical loads
- Vibrations
- Other mechanical loads
- Presence of plants and/or mould growth
- Presence of animals
- Exposure to the sun
- Effects of earthquakes
- Wind
- Building structure

Type abbreviations for cables and lines

Destination code

Harmonised destination	H
Approved national type	A

Nominal voltage U_o/U

300/300V	03
300/500V	05
450/750V	07

Insulation material

PVC	V
Natural and/or styrol-butadiene rubber	R
Silicon rubber	S

Sheath material

PVC	V
Natural and/or styrol-butadiene rubber	R
Polychloroprene rubber	N
Glass fibre braid	J
Textile braid	T

Characteristics during installation

Flat, divisible line	H
Flat, non-divisible line	H2

Conductor type

Single-wire	U
Multi-wire	R
Finely stranded for lines for permanent installation	K
Finely stranded for flexible lines	F
Very finely stranded for flexible lines	H
Tinsel cord	Y

Number of wires ...

Protective conductor

without protective conductor	X
with protective conductor	G

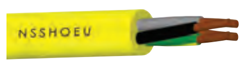
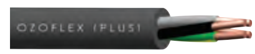
Nominal cross-section of the conductor ...

Examples of complete line names

PVC wiring line, 0.75 mm²
finely stranded: H05V- K 0.75 black

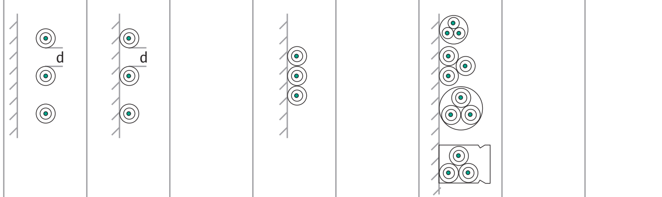
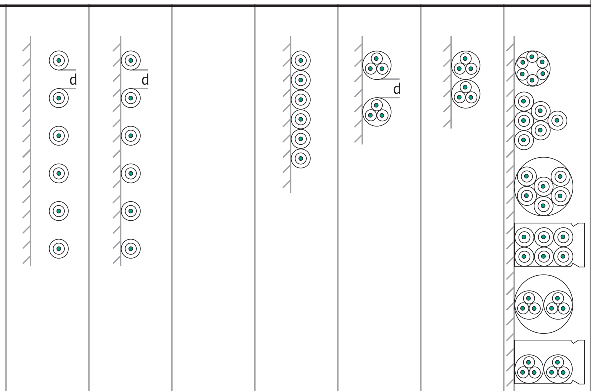
Heavy rubber hoseline, 3-core, 25 mm²
without green/yellow protective conductor:
A07RN-F3X2.5

The following tables give an overview of the fields of application of the cables used by Wilo:

Type	NSSHÖU	Ozoflex (Plus) H07RN-F	Hydrofirm (T) S07BB-F, S07BBH2-F
			
Design	Rubber hose line	Rubber hose line	EPR-insulated hose line, Hydrofirm(T)
Nominal voltage	U 0/U 450/750 V	U 0/U 450/750 V	U 0/U 450/750 V
Maximum operating temperature	60 °C	60 °C	60 °C
Maximum operating temperature at the conductor	90 °C	90 °C	90 °C
Notes	The lines with a firm connection between the inner and outer sheaths are suitable for operation in wastewater and sewage.	Permitted for a firm and protected installation in pipes with a nominal voltage up to 1000 V AC voltage (conductor to conductor) or a DC voltage up to 750 V to earth.	Constant usability in water has been verified by tests.
Site of application	In dry, moist and wet rooms and outdoors. In agricultural and inflammable facilities. In potentially explosive areas according to DIN VDE 0165.	In dry, moist and wet rooms and outdoors. In agricultural and inflammable facilities. In potentially explosive areas according to DIN VDE 0165.	In ground water and potable water in water depths of up to 500 m. Can also be used in industrial, cooling, surface and rain water and in sea water. Under certain conditions in combined wastewater, not in chlorine water. Can be used indoors and outdoors, but not in potentially explosive areas.
Permitted load	For heavy mechanical loads for heavy-duty equipment and tools on construction sites, in industry, at quarries, surface and underground mining.	For medium mechanical loads including the connection of commercially used electrical equipment and tools, e.g. large boilers, heater plates, drilling machines, circular saws, mobile motors or machines at construction sites. For permanent installation, e.g. in provisional buildings and direct installation on components of lifting equipment and machines.	For medium mechanical loads for the connection of electrical equipment, in particular for devices that are used constantly in water, e.g. submersible pumps, underwater floodlights. For water temperatures up to 60 °C.

Permitted ampacity of cables (DIN VDE 0298 Part 4)

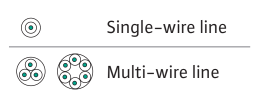
Ampacity of H07RN-F (Ozoflex Plus), NSSHÖU and S07BB-F, S07BBH2-F (Hydrofirm lines) at permanent operation up to 30 °C ambient temperature and 90 °C conductor temperature

Direct activation								
Gap:	1	2	3	4	5	6	7	8
Installation types for 3 loaded wires								
Activation YΩ or 2 cable parallel								
Installation types for 6 loaded wires								
Nominal cross-section t Copper line [mm²]	Load capacity [A]							
1.5	35	33	31	29	28	23	19	18
2.5	45	43	40	38	36	30	25	24
4	62	59	54	52	49	41	34	32
6	80	76	70	68	64	53	45	42
10	111	106	97	94	88	74	63	59
16	149	141	131	126	119	99	84	79
25	197	187	173	167	157	131	111	104
35	244	231	214	207	195	162	137	129
50	304	289	267	258	243	202	171	161
70	376	357	331	319	300	250	212	200
95	453	430	398	385	362	301	255	240
120	529	503	465	449	423	352	299	281
150	608	577	535	516	486	404	343	323
185	693	659	609	589	554	461	391	368

The following must be taken into account:
- Load on the lines during uninterrupted operation
- Load on the lines in the event of a short circuit
- The correct use of the insulated power cable is a prerequisite
- Only the conductors for operational current are taken into account
- A symmetrical load is assumed
- The most unfavourable operating conditions are assumed and the most unfavourable routing

For installations in water, the installation type in column 1 can be assumed for single-wire lines and in column 6 for clusters and multi-wire lines.

The protective conductor is not considered to be a loaded wire and can always be installed.



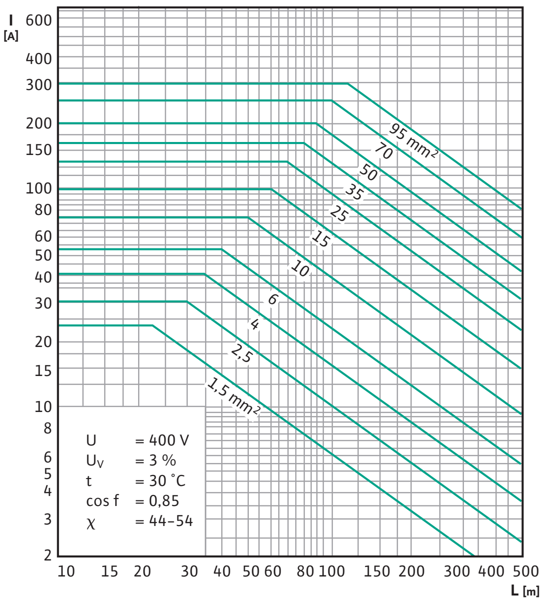
In the event of deviating ambient temperatures, the load capacities are to be converted with the factors f:

°C	10	15	20	25	30	35	40	45	50	55	60	65	70
f	1.15	1.12	1.08	1.04	1.00	0.96	0.91	0.87	0.82	0.76	0.65	0.58	0.50

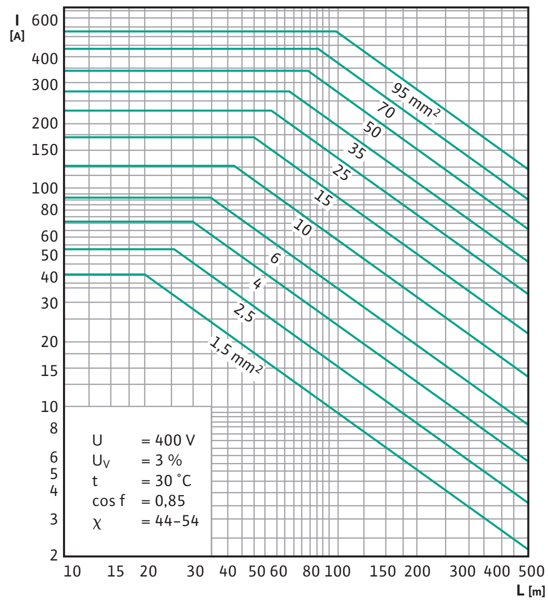
When determining the line cross-section, it must be taken into account that the voltage drop may not exceed about 3 %. When selecting the cross-section, the regulations of the local energy providers and above all the customer's requirements in terms of the cost-effectiveness of the system are to be taken into account.

Dimensioning or selection of the cables in relation to length (L) and current (I)

Direct starting, multi-wire line



Star-delta starting, multi-wire line



Required calculation formulae

Voltage loss:

$$U_V = \frac{C \cdot I \cdot L_K \cdot \cos\varphi}{A \cdot U} \; [\%]$$

Power dissipation:

$$P_V = \frac{U_V}{\cos\varphi^2} \; [\%]$$

Calculation for other operating voltages:

$$L_{diagram} = \frac{400}{U} \cdot L_K$$

Abbreviation		Description
A	[mm²]	Line cross-section
C		Direct activation and starting transformer: 3.1
		Direct activation, 2 lines parallel: 1.55
		Star-delta activation: 2.1
I	[A]	Nominal current
L	[m]	Single line length (for selecting a diagram)
L_k	[m]	Current cable length
P_V	[%]	Power dissipation
U	[V]	Supply voltage
U_V	[%]	Voltage loss
cos φ		Power factor for I


ENTER
MENU
RESET
LOC
REM
Betrieb
Störung

Control technology

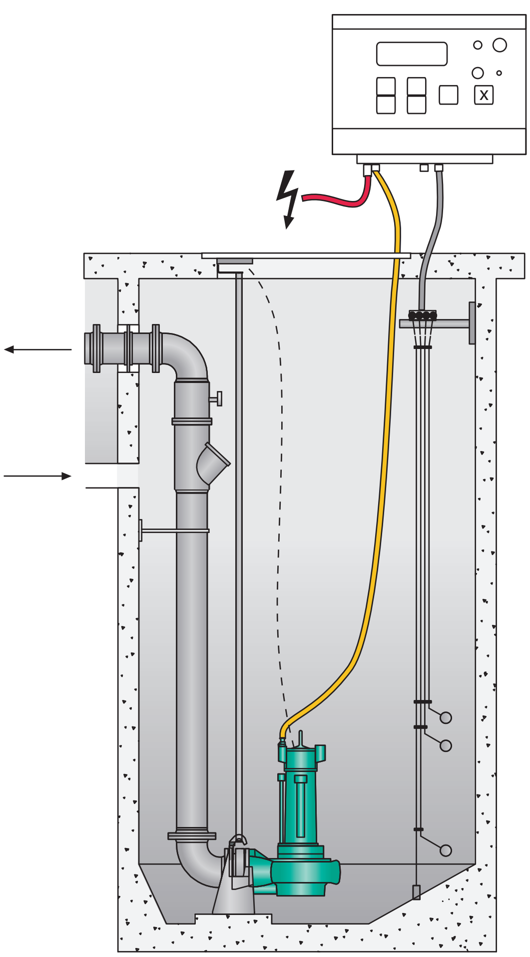
Level measuring systems

Level measuring systems are for measuring the water level in tanks. Depending on the application conditions, various systems are available.

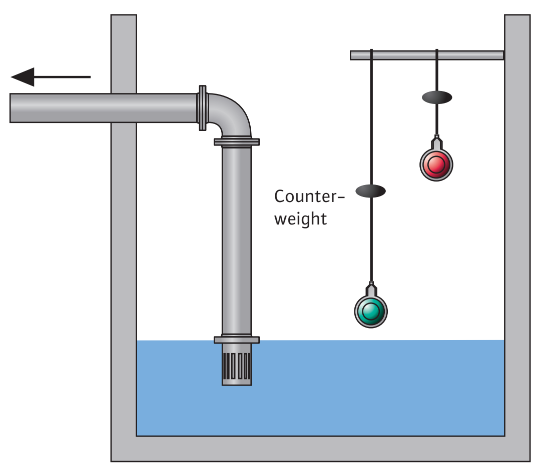
Float switch
With this method, switching contacts are closed or opened in a floating body according to the inclination angle.

Single-point float switch:
These floaters are fastened very shortly to the cable and have a slight difference between activation point and deactivation point. Some of these floaters are also available as heavy versions that tilt around their centre of gravity. To avoid the constant switching of the pump, at least two of these floaters must be used for level control. Due to their good floating properties, however, they are better suited for sewage applications.

Float switch



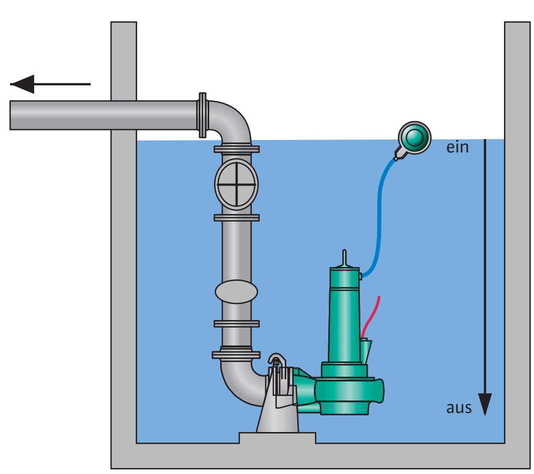
Single-point float switch



Two-point float switch:
These float switches have a larger angle between activation point and deactivation point. They are fastened to their pipe. That makes it possible to switch smaller differences with only one float switch according to the drawn-out pipe length.

A basic distinction must be between two different designs:

Two-point float switch



With float switches, one should always make sure that they can move freely in the sump. They can also be used in potentially explosive areas if they are operated via an ex-rated cut-off relay (Ex-i).

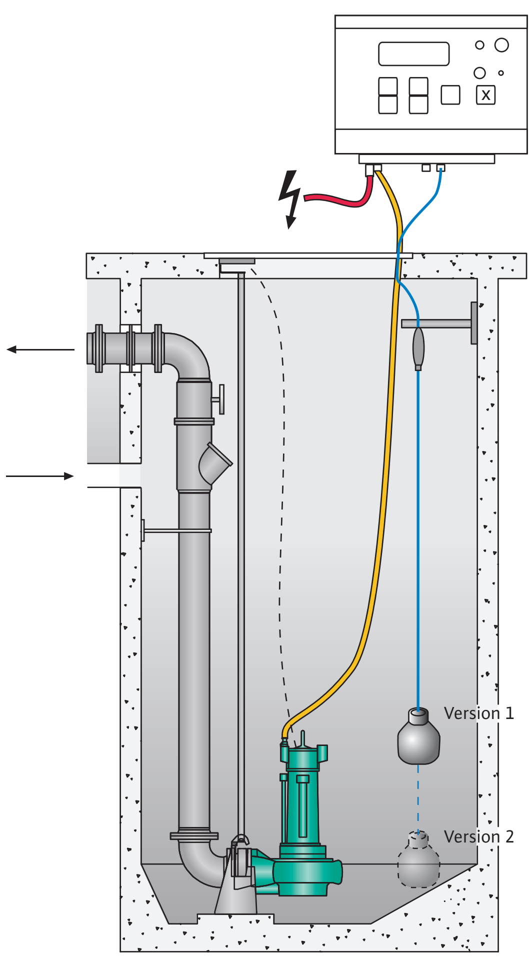
Dynamic pressure system (measurement of the hydrostatic pressure)
With this method, a measuring bell / velocity head bell is used to measure the pressure at the point of installation. The filling height of the fluid generates a pressure that is forwarded to the evaluation unit via a hose. In the evaluation unit, the pressure is converted into an electrical signal. That enables the continuous measurement of the filling level, and the switching points can be freely defined. A distinction is made between open systems and closed systems. The selection depends on the field of application and the type of fluid. The application in potentially explosive areas is possible.

Open system:
With this version, the bell is open in the direction of the fluid. After each pumping-out operation, the bell must surface to vent the system, Off according to time (bell above "Off" – version 1). Another way to vent the system is the connection to a small compressor (bubbling-through system), that vents the system permanently or periodically, Off according to the water level (bell always under water – version 2).

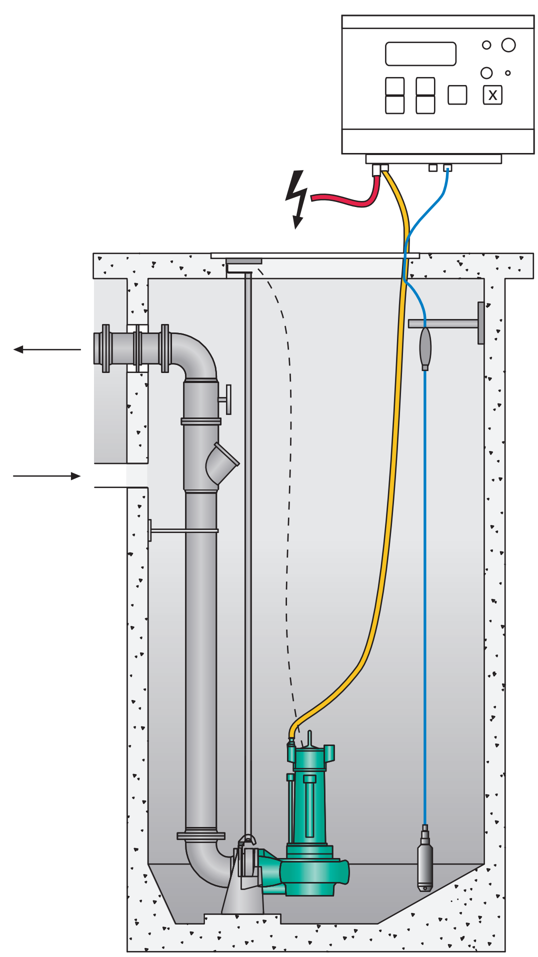
Closed system:
With this version, the air cushion in the bell is separated from the fluid by a diaphragm. The system is therefore suitable for heavily contaminated fluids. Leakages / air loss in the system result in measuring errors or the malfunction of the system.

Pressure probe (electronic pressure transducer)
Like the velocity head probes, the hydrostatic pressure is measured at the installation point here too. However, here a diaphragm is used to convert the pressure in the pressure transducer directly into an electrical signal.

Dynamic pressure system



Pressure probe



Conductivity (conductive measurement method)

In this case, submersible electrodes are connected to an evaluation relay. The relay detects whether fluid is present or not according to the resistance. The trigger resistance can be set on most relays. In this way, simple level controls for filling or draining can be implemented. The application as dry-running protection system is also very frequent. Not suitable for sewage pumping stations.

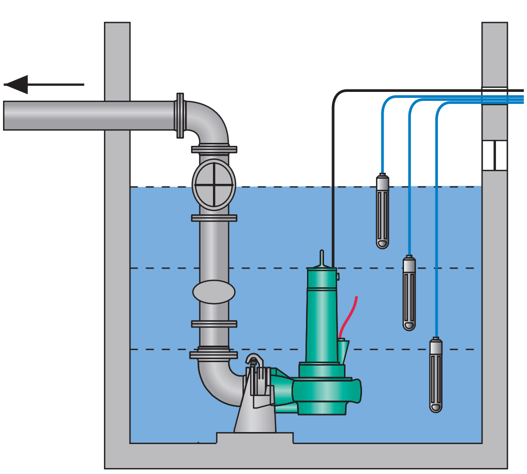
Ultrasound

Measurement with ultrasound is based on the measurement of the running time. The ultrasonic pulses emitted by a sensor are reflected from the surface of the fluid and detected by the sensor. The required running time is a measure for the distance passed in the empty tank. This value is deducted from the overall tank height, which results in the filling level.

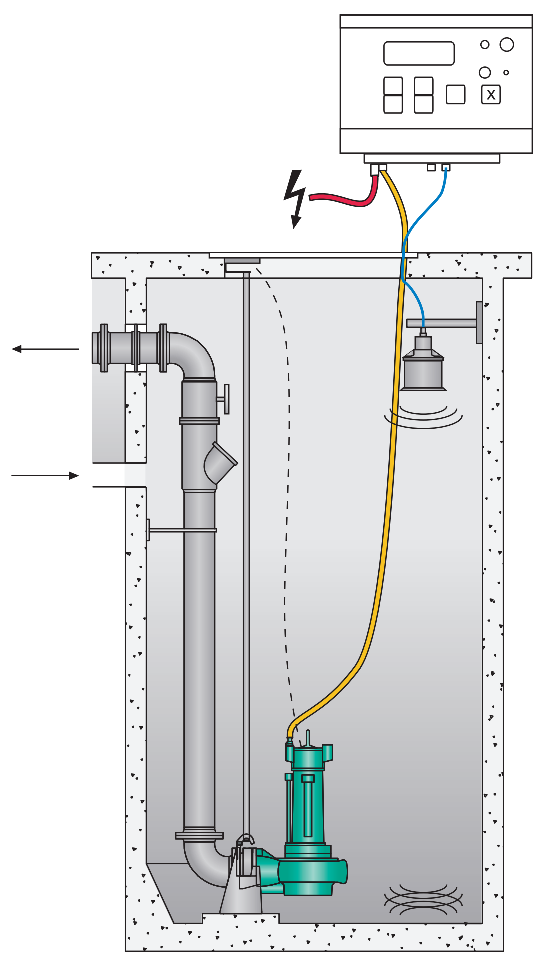
The advantage of this method is that measurement of the filling level in the tank is possible without contact, regardless of the fluid.

During the installation, one should ensure that the measuring cone emitted by the sensor is free of installations. A minimum clearance to the wall of the tank must also be complied with.

Submersible electrodes



Ultrasound



Switchgears – customer-specific solutions

Note:
You can find the standard range of Wilo switchgears in the product catalogues.

Modern system controls with remote action technology and remote diagnosis
In addition to ensuring the reliable monitoring of the machines, modern system controls also provide worldwide remote access to the system via GSM or GPRS (General Packet Radio Service).

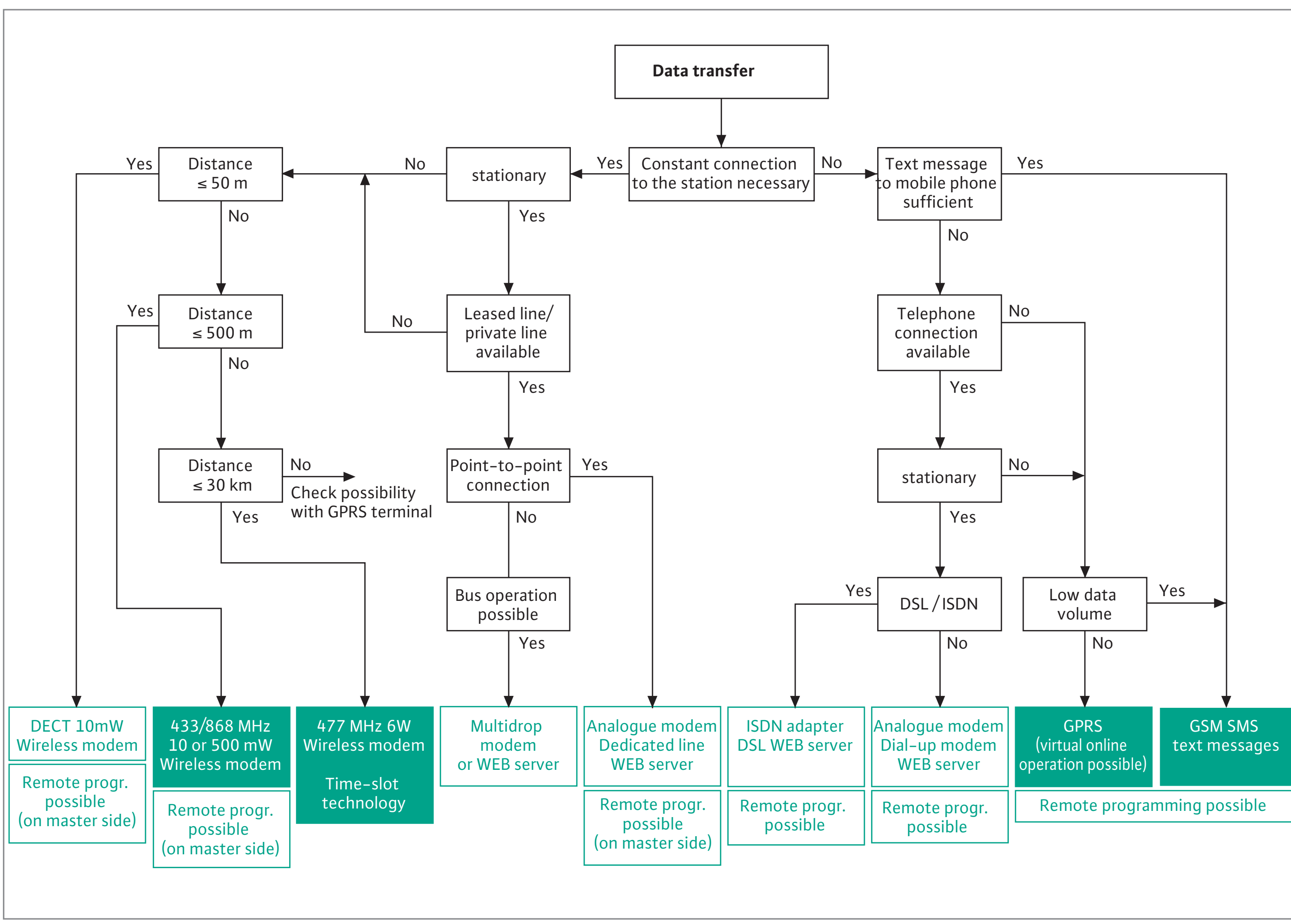
With modern systems, remote maintenance and fault diagnosis are no problem.

Especially the operators of municipal supply and disposal units are confronted with the problem of having to monitor and control widely distributed system components. However, there is no standard solution with remote action technology. A concept that is optimised for the system must be developed by means of the communication routes.

A basic distinction is made between two types:

Wireless communication	Wired communication
Data transmission via operational radio	Data transmission via private telecommunication cable
Radio data transmission via time-slot technology	Data transmission via bus system
Data transmission via GSM/SMS	
Data transmission via GSM/GPRS	

The selection is made according to the following criteria:



Further decision criteria are: Desired transfer protocol, transmission of values with timestamp, control centre connection, remote programming etc.

The systems on a green background are mainly used for sewage applications. The data volumes, any real-time data, the distance for transmission and all transmission routes and costs require special attention.

868 MHz, WLAN (interference-prone) and Bluetooth technology are particularly well suited for a water treatment system with short distances.

For outdoor constructions, the following applies: With GSM reception, GPRS is usually the most cost-effective transmission medium. For short distances (up to approx. 500 m) the 868 MHz technology is also suitable, provided data does not need to be transmitted in real-time.

For outdoor constructions without GSM reception, the time-slot technology, possible with radio repeaters, is the best solution.

If only simple fault signals are to be sent, then GSM fault transmitters on SMS basis are sufficient. The costs for GPRS lie within the same range if only one control centre is informed. If the SMS text messages are, for example, also to be sent using the mobile radio units of the industrial electricians, then fault transmitters on GSM SMS basis are to be preferred. SMS messages can also be implemented in parts via GPRS devices, however only at extra charge.

Reliability: Radio transmission systems based on GPRS are more reliable than SMS text messages, which may sometimes arrive with considerable delay.

Real-time: WLAN and Bluetooth are virtually real-time-capable (delay in ms) and GPRS (delay of approx. 2-4 seconds). With all other systems, this depends on the permitted "duty cycle" and the availability of the radio cells.

Data transmission via radio transmission

Operational radio 433 MHz:
- Transmission power up to 10 mW, 600 m distance (visual contact)
- No transmission costs, no longer recommended for industrial use, since garage doors, model cars etc. use this technology, which is why there may be radio interference
- Alternative: Operational radio 868 MHz

Operational radio 868 MHz:
- Transmission power 10 to 500 mW, 500 m to 10 km distance (visual contact)
- Application examples: Pump systems at a short distance from the control centre
- Advantage: Low acquisition and operating costs, suitable for solar installations
- Disadvantage: Only small transmission distances possible, transmission limited in time
- Alternative: GPRS, very low acquisition costs, very low operating costs, medium transmission costs

DECT:
- Is used by wireless telephones; not recommended for sewage applications due to the short range and other restrictions

Directional radio:
- High acquisition and maintenance costs, distances up to 50 km (visual contact).
- Only point-to-point connections, not suitable for sewage systems

Trunked radio:
- No transmission costs, however separate, expensive infrastructure required.
- Is not used any more for sewage applications, due to less expensive technology being available.

Time-slot technology:
This technology is particularly suitable for communication between the external stations of pumps, pipes and rain spillway basins, if there is no GSM reception. However, due to the relatively expensive radio devices (approx. € 1000) and higher costs for the antenna (approx. € 250), it is still more expensive, compared to GSM, even after several years of operation.

As the name already indicates, permanent data transmission is not possible. Within one minute, a "time slot" of only 6 seconds is available for transmission. However, that is normally sufficient for the exchange of data of several devices. After that, a transmission pause of 54 seconds must be maintained until the next transmission cycle can be started. In addition, there is the option of one-hour operation per day (see below), which is, however, not suitable for sewage applications.

- Time-slot control: 10 time slots (radio times) of 6 seconds each per minute
- Bandwidth: 70 cm band
- Frequency range: 447 – 448 MHz, 5 frequencies; Channel spacing: 12.5 kHz
- Data transmission rate: 4 800 bps to 9 600 bps
- Antenna output rating: 6 W max.
- SPECIAL frequency range in the 1:24 method (1 useable hour/day): 459.530 MHz; 459.550 MHz; 459.570 MHz; 459.590 MHz
- Channel spacing: 20 kHz ; Data transmission rate: 4 800 bps to 9 600 bps
- Specifications and fees for using the special frequencies
- Approval according to the ETS 300 113 standard
- Assignment of frequencies by the regulatory authority TP (RegTP)
- Regulation of frequency usage fees acc. to official register no. 30/1996, decree 228/1996

GSM CSD:
Not the best available technology any more. Was used frequently before GPRS. With GSM CSD data transmission, the connection between two stations needs to be established first, similar to voice communication via mobile phone. Depending on the use of the networks, this may take up to 30 seconds. Once the connection has been established, the data can be transmitted. In addition to the data volume, the connection time is also paid for, like for communication via mobile phone. Depending on the data transmission frequency and volume, the transmission costs for this technology are 2–10 times higher than comparable GPRS rates. However, the acquisition costs for the devices are identical to GRPS.

Only one single advantage remains with the GSM CSD method, compared to GPRS: As opposed to an IP address, the phone number is always static and can be accessed all over the world. That enables point-to-point connections between two substations. With GPRS, that is only possible with a few solutions.

GSM SMS:
A practical alternative for small fault transmission systems. Instead of a static connection between two participants, an SMS text message (maximum 160 characters) is sent. This message can be received by a mobile phone, a control with GSM or a control system with GSM. In addition to low basic fees, there is an extra charge for each SMS. An SMS text message can also be sent by some GPRS devices. That has the advantage that in addition to normal data transmission between substation and central system, persons, e.g. industrial electricians, can also be informed via the mobile radio unit.

UMTS:
In sewage applications, only of interest for mobile visualisation or process control systems. Not suitable for substations, since the costs are much higher and complete area coverage is only ensured in congested urban areas. However, it can be used in an optimum manner in combination with GPRS (substation ⇒ GPRS, mobile control system ⇒ UMTS), since the basic Internet technology is identical.

EDGE:
EDGE stands for Enhanced Data Rates for GSM Evolution and is used to upgrade traditional GSM/GPRS networks and thus achieve higher data transmission rates. As a further development of the normal GPRS standard where 40 kBit/s are achieved on average, EDGE provides the option of increasing the data transmission rate up to 220 kBit/s. Since no cheap end devices are available at present, this technology is not relevant yet. Apart from that, it would only enable faster data transmission than GPRS, which is of no significance for substations with their small data volumes.

WLAN:
WLAN uses the DSSS transmission technology (Direct Sequence Spread Spectrum) and is therefore not reliable in terms of transmission. If there are interference signals, the connection may be terminated very suddenly. The antennae of commercially available 802.11 end devices enable a range of 30 to 100 metres in free spaces. With the latest technology, even 90 metres can be achieved in closed rooms. Improved WLAN hardware should permit the connection of an external antenna. With external omnidirectional antennae and visual contact, 100 to 300 metres can be bridged outdoors. With broadcasting antennas, it is even possible to achieve several kilometres.

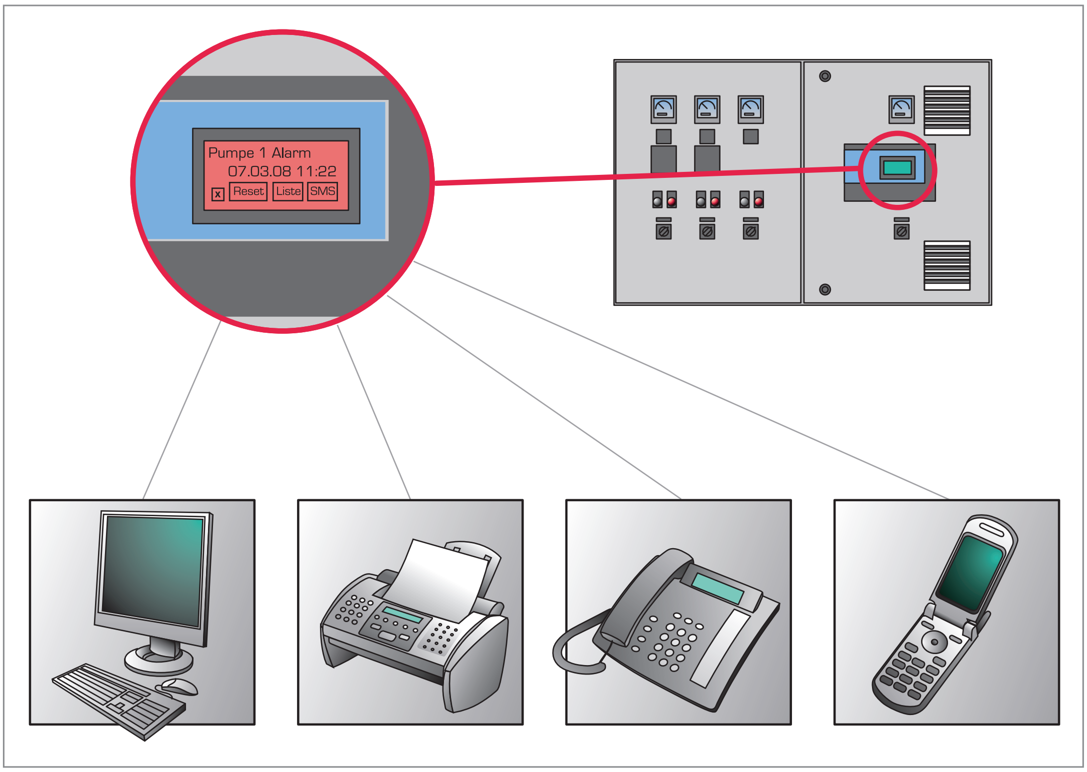
Bluetooth (2.4 GHz ISM band, up to a distance of max. 150 m):
Bluetooth uses the frequency hopping spread spectrum (FHSS). With this method that is particularly difficult to tap, a total of 79 channels are used. The individual channel switches every 0.625 milliseconds mutually between transmitter and receiver. That results in 1600 frequency jumps per second. Interference on individual channels is thus compensated and external access by third parties is prevented, since the jump sequence is unknown to third parties.

Additional data security is provided by the option of assigning a password to the devices, or, after successfully establishing a connection, making the devices invisible for other devices.

Classes and range

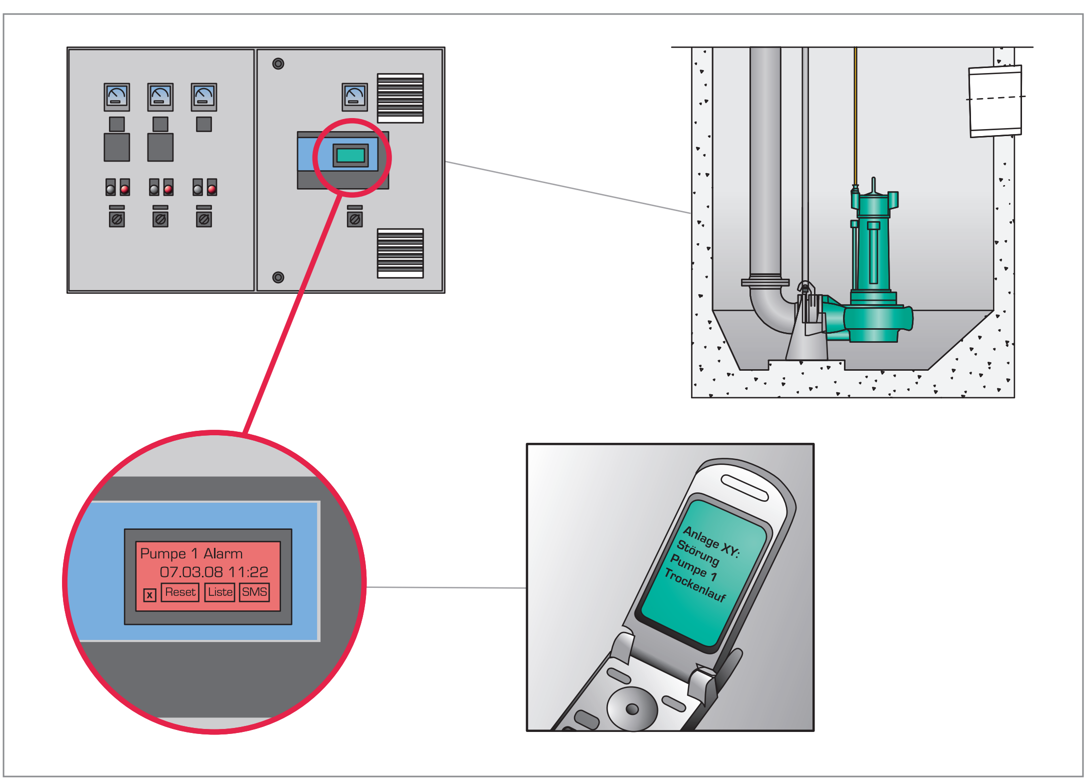
Class	Maximum power [mW]	Maximum power [dBm]	Range outdoors [m]
Class 1	100	20	~ 100
Class 2	2.5	4	~ 50
Class 3	1	0	~ 10

Practical example: GSM fault indication system



- *Alarm via mobile phone, fax, telephone, e-mail*
- *Message with station name, type of fault*
- *Time, date*
- *Timestamp*
- *Logging of the past 35 fault signals*
- *Remote acknowledgement via mobile phone*
- *Up to 4 call participants can be dialled up*

Practical example: Pumping stations – Remote control system with modern pump control



- *Water treatment systems*
- *Rain spillway basins*
- *Sewage pumping stations*

Function
- *Pump control*
- *Energy optimisation*
- *GPRS data exchange*
  - *Status signals*
  - *Measured values*
  - *Operating hours*
  - *Operating data*
  - *Fault signals*
  - *Alarm signals*
  - *Acknowledgement*
- *SMS text message*
  - *Industrial electrician*
- *Touchscreen for*
  - *Setpoint adjustment*
  - *Operating data display*
  - *Alarm display*

Danfoss
DISPLAY MODE
QUICK MENU
EXTEND. MENU
CHANGE DATA
CANCEL
OK
HAND START
OFF STOP
AUTO START
RESET
VLT 8000 AQUA
VLT
QUINT POWER
QUINT DC-UPS 10 A

Special features with the operation of soft starters or frequency converters

Soft starter

Sewage pumps can be started and stopped using soft starters.

The current to be set during starting or stopping is between 2.5 and 3.5 times the rated current. Due to the use of devices with the special option for pump drives, the starting current can be reduced even more (approx. 1.5 – 2.5).

The starting or stopping time is not critical for ball bearing sewage motors. Due to the upstream motor protection, starting or stopping should be completed within 30 seconds. With pure water motors with water-lubricated bearings, minimum speeds need to be observed. The number of the connections per hour can be found on the pump-specific motor data sheet (10 on average, see data of the soft starter).

The motor (e.g. cables etc.) is configured like for "direct activation".

The soft starter-stopper devices are only suitable to a limited extent for the reduction of pressure surges in pipes. We therefore recommend automatic slide valves and frequency converters and observation of the information previously given. After successful starting, we recommend the bridging of the soft starter.

If these recommendations are followed, unproblematic operation with soft starters is possible.

Frequency converter

Sewage pumps can be operated with commercially available frequency converters. These are normally designed as "pulse-width modulated" converters.

Basic equipment
Maximum frequency – Minimum frequency – Excess current – Starting time – Stopping time – Starting torque – Indication of current – Frequency – Speed – U/f characteristics (quadratic load curve for centrifugal pumps) – Protection against overvoltage, undervoltage

Special equipment
Fault diagnosis – Reduction of motor noise – Fading out of resonance frequencies – Remote data transmission – Remote control

Selection of motor and converter
Every WILO sewage motor can be used in series design. In the case of a rated voltage exceeding 415 V, the factory should be consulted. Due to the additional heating effect by harmonic waves, the rated output of the motor should be approx. 10 % above the pump's power requirement.

With appropriate output filters, it is possible to reduce the power reserve of 10 %.

The motor (e.g. cables etc.) is dimensioned like for "direct activation".

The converter is dimensioned according to the nominal motor current. A selection according to the motor power in kW can cause problems. If the frequency converter fails, a bypass with star-delta combination can additionally be provided. In this case, the cables must be dimensioned according to star-delta operation.

Minimum speed for sewage and drainage pumps
No minimum speed is specified for sewage and drainage pumps. However, one should make sure that the unit runs without jerks or vibrations, particularly in the low speed range. Otherwise, the mechanical seals could be damaged and become leaky.

Operation

It is important that the pump unit works throughout the entire control range without vibrations, resonance, alternating torque or excessive noise (consult the manufacturer).

Louder motor noise due to the power supply with harmonic waves is normal. During the configuration of the converter, do not fail to observe the setting of the quadratic pump curve (U/f curve) for pumps and fans. They ensure that the output voltage is adjusted to the pump's power requirement at frequencies < 50 Hz. Newer converters also provided automatic energy optimisation – with the same effect. For this setting and other parameters, please see the operating instructions of the converter.

Interference voltage

Sewage motors with enamelled wire winding can normally cope with the higher insulation loads due to converter operation. Suitable auxiliary equipment (throttles, filters) for the reduction of harmful voltage peaks, and for reducing the noise of the motor, are recommended. The quality of the output voltage has a direct effect on the service life of the winding.

Bearing currents

Bearing currents may occur with converter-supplied motors. These stress the motor's bearings and may damage the bearings, depending on the current value. Essentially, a bearing current only flows if there is voltage at the bearing's lubrication gap that is high enough to penetrate the insulation of the lubricant. There are various sources for this voltage:

The most important factors that decide on which mechanism the focus is placed, are the size of the motor and the earthing system of motor housing and shaft. The electrical installation, especially a suitable cable type, the perfect contacting of the earth conductors and the electrical shielding also play an important role, plus the rated voltage at the converter input and the voltage rise time at the converter output. The source of the bearing currents is the voltage at the bearing. There are three types of high-frequency bearing currents: circulating currents, earth currents via the shaft and EDM currents.

More information and recommendations are to be found in DIN CLC/TS 60034-25.

EMC

To comply with the EMC guidelines (electromagnetic compatibility), the use of shielded lines or the installation of the cable in metal pipes and the installation of filters might be necessary. The corresponding measures required to comply with the EMC guidelines depend on the converter type, the converter's manufacturer, the installed cable length and other factors. In individual cases, it is therefore necessary to look up the required measures in operating instructions for the converter or to directly consult the manufacturer of the converter.

Motor protection

In addition to the built-in electronic current monitoring in the converter or the thermal overload relays in the switching system, we also recommend the installation of temperature sensors in the motor. PTC thermistor temperature sensors (PTC) are suitable as well as resistance temperature sensors (PT 100). Explosion-protected motors are always to be equipped with PTC thermistors for FC operation. An approved motor protection relay must be used for the PTC thermistor, e.g. WILO CM-MSS.

Operation up to 60 Hz

Wilo motors can be adjusted up to 60 Hz, provided the motor was rated for the higher power requirement of the pump. The rated power is to be found on the 50 Hz data sheets.

Efficiency

In addition to the efficiency of the motor and the pump, the efficiency of the converter (~ 95 %) must also be taken into account. The efficiency of all components is reduced if the speed is reduced.

Summary

If one takes the previously mentioned aspects into account and follows the instructions for the converter, unproblematic, speed-controlled operation with sewage pumps is possible.


WILO
P-Typ Wilo-EMU FA15.84D
S/N 650054955
M-Typ T17.2-6/24KEx
248 mm
U 400 - 3 V
Q 42 l/s.
S1
I 13.60 A
H 6.7m
40 °C
21.7 A
Cosφ 0.82
12.5 m
P 6.00 kW
1.00
IP 68
F 50 Hz
13.60 A
MC D/Y
MFY 2008
N 927 1/min
Exno IBEXU 01 ATEX
II 2 G EEx d IIB T4
0102
Made by WILO EMU
WILO EMU GmbH
95030 Hof / Germany

Explosion protection

Installing electrical systems in potentially explosive areas

The EU Directive 99/92/EC "Minimum requirements for the improvement of health protection and of the safety of employees at risk due to explosive atmospheres" concerns the operation of systems at risk of explosion and is therefore intended for the operator. This directive only contains minimum requirements that can be supplemented by extended rules when applying them to national law. The was done in Germany by the implementation of Directive 99/92/EC in the industrial safety regulations. The German industrial safety regulations (BetrSichV) "Ordinance on safety and health protection during the provision of equipment and its use at work, on safety during the operation of systems that require monitoring and on the organisation of industrial work safety") include detailed specifications on the operation of Ex systems, in particular on the monitoring, inspection and maintenance of these systems.

The operator must assess the risk of explosion of the system according to Directive 99/92/EG, split the system up into danger zones and document all measures for the protection of the employees in the explosion protection documentation.

The following must be taken into account for the assessment of the explosion risks:

- Probability and duration of the presence of an explosive atmosphere
- Probability of the presence, the activation and the effectiveness of ignition sources
- The substances and processes used and their potential interaction
- The expected extent of the effect of explosions

The system operator must divide the areas that may have an explosive atmosphere into zones and ensure that the minimum requirements of the directive are complied with.

Zone classification and assignment of devices according to their category

	Zone	Duration of the presence of an explosive atmosphere	Device category
Gases, vapours, mists	0	Constant, long-term, permanent	1G
	1	Occasional	2G
	2	Rare	3G
Dusts	20	Constant, long-term, permanent	1D
	21	Occasional	2D
	22	Rare	3D

The operator must compile an explosion protection document that should at least include the following information:

- Risk assessment
- Protective measures taken
- Division into zones
- Compliance with the minimum requirements (technical and organisational measures)

Electrical systems in potentially explosive areas

The safety in potentially explosive areas can only be ensured by the close and good cooperation of all units involved.

Planning and installation

When new installations are planned, the question of any potential risk of explosion should be dealt with at an early stage. For the classification of explosive areas, in addition to the power of any sources of explosion due to flammable substances, the influence of the natural or technical ventilation must also be taken into account. The technical explosion parameters of the flammable substances used need to be determined. That is the prerequisite for the classification of the zones and decisions on the selection of the suitable equipment for the potentially explosive areas.

The operator must ensure that the system is installed correctly and checked prior to initial operation.

The installer must observe the installation requirements and correctly select and install the electrical equipment according to the application.

The manufacturer of explosion-protected equipment must ensure that every device that is manufactured complies with the certified design. That is ensured by an according quality management system. The identification number is documented on the name plate.

Maintenance and servicing

Electrical systems in potentially explosive areas are to undergo regular maintenance to ensure that safety is maintained. Maintenance and servicing work is only to be performed by trained personnel under the supervision of an expert.

Prior to maintenance and conversion work, it must be ensured that no explosive atmosphere is present. The work performed must be documented and compliance with the relevant regulations must be verified.
If alterations are made that could affect the explosion protection, an inspection must be performed by a skilled person with official authorisation. This inspection is not necessary if the alteration was performed by the manufacturer of the corresponding device.

Standards

The first standards for electrical equipment that apply throughout Europe were issued as EN 50014 – EN 50020 (requirements for equipment for potentially gas-explosive areas).
This set of standards was replaced step-by-step by the EN 60079 (VDE 0170) series.
In terms of ignition protection categories for flammable dust, the original EN 50281 standards were replaced with IEC 61241.

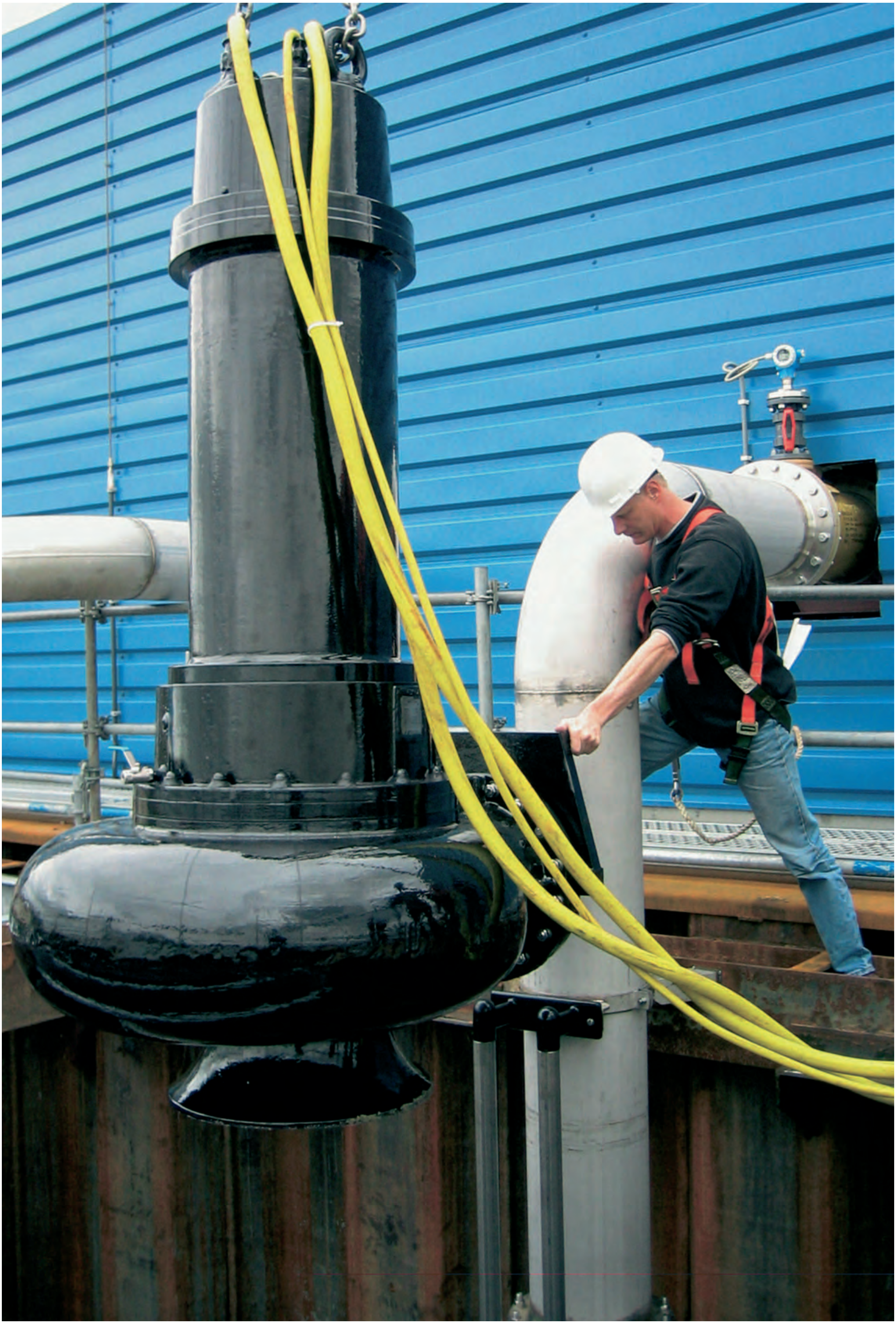
The following list specifies one of the ignition protection categories for electrical equipment for potentially gas- and dust-explosive areas:

Electrical equipment for potentially gas-explosive areas

	EN (old)	EN (new)	IEC
General requirements	EN 50 014	EN 60 079-0	IEC 60 079-0
Pressure-resistant enclosure [d]	EN 50 018	EN 60 079-1	IEC 60 079-1
Excess pressure enclosure [p]	EN 50 016	EN 60 079-2	IEC 60 079-2
Sand casing [q]	EN 50 017	EN 60 079-5	IEC 60 079-5
Oil casing [o]	EN 50 015	EN 60 079-6	IEC 60 079-6
Increased safety [e]	EN 50 019	EN 60 079-7	IEC 60 079-7
Intrinsic safety [i]	EN 50 020	EN 60 079-11	IEC 60 079-11
Ignition protection class [n]	EN 50 021	EN 60 079-15	IEC 60 079-15
Encapsulation [m]	EN 50 028	EN 60 079-18	IEC 60 079-18
Intrinsically safe systems		EN 60 079-25	IEC 60 079-25
Electrical equipment for zone 0	EN 50 284	EN 60 079-26	IEC 60 079-26
Intrinsically safe field bus systems		EN 60 079-27	IEC 60 079-27
Optical radiation [op]		EN 60 079-28	IEC 60 079-28

Identification of electrical equipment in accordance with ATEX

Example	Designation	Plain text	Overview
II	II 2 G Ex de IIB T4 **Device group**	Application in all areas except underground mining	**Device groups** I = Underground mining II = All areas except underground mining
2	II 2 G Ex de IIB T4 **Device category**	Application in Zone 1 or Zone 21	**Device categories** 1 = suitable for Zone 0 or 20 2 = suitable for Zone 1 or 21 3 = suitable for Zone 2 or 22
G	II 2 G Ex de IIB T4 **Fields of application**	Application in explosive gas medium	**Explosive media (atmosphere)** G = gas D = dust
Ex	II 2 G Ex de IIB T4 **Standard indication**	Device meets the current EU explosion protection standards	**Remarks:** Declaration of conformity without additional information
DE	II 2 G Ex de IIB T4 **Ignition protection class(es)**	Device equipped according to ignition protection classes for pressure-resistant enclosure (d) and increased safety (e)	**Ignition protection classes:** o= oil casing p =excess pressure enclosure (protection higher than with nP) q = sand casing d = pressure-resistant enclosure e = increased safety ia = intrinsic safety ib = intrinsic safety m = encapsulation
IIB	II 2 G Ex de IIB T4 **Explosion group** **Explosion protection application**	Device designed for explosion protection application group II for environments with medium explosion tendency	**Explosion groups:** A = low explosion tendency B = medium explosion tendency C = high explosion tendency **Explosion protection applications:** I = Underground mining II =All fields of application apart from underground mining
T4	II 2 G Ex de IIB T4 **Temperature class**	The maximum surface temperature of the device (in the case of a fault) of the device emitted to the surrounding area is 135 °C	**Temperature classes:** T1 = 450 °C T2 = 300 °C T3 = 200 °C T4 = 135 °C T5 = 100 °C T6 = 85 °C



Appendix

General notes

Sewage dimensioning
Data (empirical values) can vary in individual cases due to critical influencing factors

Facility	Wastewater
	[Litres per inhabitant]
Hospitals – per day and bed	250 – 260
Indoor swimming pools – per visitor	150 – 180
Schools – per day and pupil	10
Administrative buildings person-day	40 – 60
Barracks– person-day	250 – 350
Slaughterhouses – per livestock unit	300 – 400
Department stores without restaurant and air-conditioning – per employee	100 – 400
Department stores with restaurant and air-conditioning – per employee	500 – 1000
Public houses – day-bed	15 – 20
Hotels – day-bed	200 – 600
Campsites – site-day	200
Sports havens – berth-day	200
Motorway service area – seat-day	200

Size of residential area	Domestic wastewater
[Inhabitants]	[Litres per inhabitant]
250 000	250 – 300
50 000 – 250 000	225 – 260
10 000 – 50 000	200 – 220
5 000 – 10 000	175 – 180
5 000	150
below 5 000	70 – 150

Tables and diagrams for the calculation examples

Values for the characteristic drains K

Building types	K value
Irregularly used buildings such as residential buildings, restaurants, boarding houses, hotels, office buildings etc.	0.5
Hospitals, large catering complexes, hotels etc.	0.7
Regularly used buildings such as schools, frequently used installations such as in laundries, public toilets, public shower baths etc.	1.0*
Installations for special use such as laboratories in industrial plants	1.2

* If no other defined drainage values are known.

Connection values (DU) for sanitary objects (according to EN 12056-2:2000)

For single-case pipe systems with partially filled connection lines

Sanitary object		DU [l/s]	DU [m³/h]
Washbasin, bidet		0.5	1.8
Rinsing sink, domestic dish washer, drain		0.8	2.88
Shower without plug		0.6	2.16
Shower with plug		0.8	2.88
Washing machine for up to 6 kg of laundry		0.8	2.88
Washing machine for up to 10 kg of laundry		1.5	5.4
Commercial or industrial dish washer		2.0**	7.2
Urinal with flushing valve (single)		0.5	1.8
Up to 2 urinals		0.5	1.8
Up to 4 urinals		1	3.6
Up to 6 urinals		1.5	5.4
For each additional urinal		0.5	1.8
Floor drain:	DN 50	0.8	2.88
	DN 70	1.5	5.4
	DN 100	2.0	7.2
WC with 6 l cistern		2.0	7.2
WC with 7.5 l cistern		2.0	7.2
WC with 9 l cistern		2.5	9
Washbasin for foot care		0.5	1.8
Bathtub		0.8	2.88

** Please observe the specifications of the manufacturer.

Water consumption figures (according to DIN 1986-100, Table 4)

Application	From ... litres	To ... litres
Single/multi-family house		
Drinking, cooking, cleaning, per person/day	20	30
Washing clothes, per kg	25	75
Toilet flushing, once	6	10
Bath	150	250
Shower	40	140
Lawn sprinkling, per m^2/day	1.5	3
Vegetable sprinkling, per m^2/day	5	10
Hotel/municipal facilities		
School, per person/day	5	6
Barracks, per person/day	100	150
Hospital, per person/day	100	650
Hotel, per person/day	100	130
Public swimming-pool, per m^3/day	450	500
Fire hydrant, per second	5	10
Commerce/industry		
Slaughterhouse, per large livestock unit	300	500
Slaughterhouse, per small livestock unit	150	300
Laundry, per washing cycle	1000	1200
Brewery, per hectolitre beer	250	500
Dairy, per litre milk	0.5	4
Weaving mill, per kg fabric	900	1000
Sugar factory, per kg sugar	90	100
Meat factory, per kg meat/sausage	1	3
Paper mill, per kg fine paper	1500	3000
Concrete factory, per m^3 concrete	125	150
Building business, per 1000 bricks with mortar	650	750
Food industry, per kg starch	1	6
Food industry, per kg margarine	1	3
Weaving mill, per kg sheep wool	90	110
Underground mining, per kg coal	20	30
Agriculture		
Large livestock, per unit/day	50	60
Sheep, calf, pig, goat per unit/day	10	20
Transport		
Car wash	100	200
Lorry wash	200	300
Cleaning a goods wagon	2000	2500
Cleaning a poultry wagon	7000	30000

Abbreviations used

Abbreviation	Description
D	Direct activation
DM	3-phase motor
DN	Nominal diameter of the flange connection
EnEV	German Energy Savings Ordinance
f	Frequency (Hz), mains frequency required to operate the motor.
RCD	Residual-current operated device
GRD	Mechanical seal
GTW	Special cast type: white malleable cast iron
°d H	Degree of German water hardness, unit for assessing water hardness
H	Delivery head
I	Rated current (A), the current consumption of the motor when it is operated at rated output and rated voltage. The overload units must be set to this current, which may not be exceeded.
I_{ST}	Starting current (A), starting current of the motor during direct activation. Depending on the motor design, this value may between 4 times and 8 times the rated current. This value must be taken into account out for the selection of the short-circuit protection.
I_A	Starting current
I_N	Rated current (current at P_2)
I_W	Current consumption for shaft power requirement PW
IF	Interface
Inst.	Installation: H = horizontal, V = vertical
Int. MS	Internal motor protection: Pumps with internal protection against unacceptably high winding temperatures
IR	Infrared interface
KLF	PTC thermistor sensor
KTL coating	Cataphoretic coating: Coating with high adhesive strength for long-lasting corrosion protection
n	Speed (rpm), the shaft speed of the motor at rated power
P_1	Power consumption (kW), P_1 is the electrical power consumption of the motor when loaded at rated power (P_2).
P_2	Rated power (kW), the power P or also P_2 describes the maximum mechanical shaft power of the motor
P_N	Pressure class in bar (e.g. PN10 = suitable up to 10 bar)
PT 100	Platinum temperature sensor with a resistance value of 100 at 0 °C
Q (=) $\dot{V}$	Volume flow
RV	Non-return valve
-S	Float switch installed
SBM	Run signal or collective run signal
SF	Service factor, the service factor describes any power reserve of the motor. Example: SF 1.1 means that a motor with a rated output of 110 kW is only characterised and operated at 100 kW. Therefore, during normal operation, the motor has a reserve of 10 %. For this case, two currents are usually specified: FLA = full load amps = current at reduced power SFA = service factor amps = current when using the service factor
SSM	Fault signal or collective fault signal
Control input 0 –10 V	analogue input for the external control of functions
U	Voltage (V), rated voltage of the motor for which it is designed. Example: 400 V 3~: With direct activation, the motor must be operated with a 400 V three-phase supply network. With the star-delta version, the motor can be operated with delta with a 400 V supply network and with star with a 690 V supply network.
v	Speed
Y/Δ	Star/delta activation
η	Efficiency eta, the motor efficiency describes the ratio between output mechanical power and supplied electrical power
cos φ	Power factor, the power factor describes the ratio between active power and apparent power

Formulary

Volume flow:

$$Q_2 = Q_1 \cdot \left(\frac{n_2}{n_1}\right)$$

Delivery head:

$$H_2 = H_1 \cdot \left(\frac{n_2}{n_1}\right)^2$$

Power:

$$P_2 = P_1 \cdot \left(\frac{n_2}{n_1}\right)^3$$

Below are formulae that are frequently used for the connection of motors.

Resistance of a line section:

$$R = \frac{L}{\chi \cdot A} [\Omega]$$

Voltage case of a three-phase line

Power known:

$$\Delta U = \frac{L \cdot P}{\chi \cdot A \cdot U} [V]$$

Current known:

$$\Delta U = \sqrt{3} \cdot \frac{L \cdot I}{\chi \cdot A} \cos\varphi \, [V]$$

Power dissipation of a three-phase line:

$$P_{diss} = \frac{L \cdot P \cdot P}{\chi \cdot A \cdot U \cdot U \cdot \cos\varphi \cdot \cos\varphi} [W]$$

Electrical power of three-phase motors

Power output:

$$P_1 = (1.73) \cdot U \cdot L \cdot \cos\varphi \, [W]$$

Current consumption:

$$I = \frac{P_1}{(1.73) \cdot U \cdot \cos\varphi} [A]$$

Efficiency:

$$\eta = \frac{P_1}{P_2} \cdot (100\ \%)$$

Abbreviation	Description
Q	Volume flow
n	Speed
H	Delivery head
P	Power
P_1	Power consumption of the motor
L	Length of the conductor [m]
A	Cross-section of the conductor [mm^2]
χ	Conductivity [$m/\Omega\ mm^2$]

Copper: $\chi = 57 \frac{m}{\Omega\ mm^2}$

Aluminium: $\chi = 33 \frac{m}{\Omega\ mm^2}$

Iron: $\chi = 8.3 \frac{m}{\Omega\ mm^2}$

Zinc: $\chi = 15.5 \frac{m}{\Omega\ mm^2}$

Material tables

Material name	Description
1.4021	Chrome steel X20Cr13
1.4057	Chrome steel X17CrNi16-2
1.4112	Chrome steel X90CrMoV18
1.4122	Chrome steel X39CrMo17-1
1.4301	Chrome-nickel steel X5CrNi18-10
1.4305	Chrome-nickel steel X8CrNiS18-9
1.4306	Chrome-nickel steel X2CrNi19-11
1.4308	Chrome-nickel steel GX5CrNi19-10
1.4401	Chrome-nickel-molybdenum steel X5CrNiMo17-12-2
1.4408	Chrome-nickel-molybdenum steel GX5CrNiMo19-11-2
1.4462	Chrome-nickel-molybdenum steel X2CrNiMoN22-5-3
1.4470	Chrome-nickel-molybdenum steel GX2CrNiMoN22-5-3
1.4517	Chrome-nickel-molybdenum steel with copper addition GX2CrNiMoCuN25-6-3-3
1.4541	Chrome-nickel steel with titanium addition X6CrNiTi18-10
1.4542	Chrome-nickel steel with copper and niobium additions X5CrNiCuNb16-4
1.4571	Chrome-nickel steel with titanium addition X6CrNiMoTi17-12-2
1.4581	Chrome-nickel-molybdenum steel with niobium addition GX5CrNiMoNb19-11-2
Abrasite	chilled cast iron for applications in strongly abrasive fluids
Al	Light metal material (aluminium)
Ceram	Ceramic coating; coating with very high adhesive strength, protection against corrosion and abrasion
Composite	high-strength plastic material
EN-GJL	Grey cast iron (cast iron with lamellar graphite)
EN-GJS	Grey cast iron (cast iron with spheroidal graphite, also called spheroidal cast iron)
G-CuSn10	Zinc-free bronze
GFK	Fibreglass plastic
GG	see EN-GJL
GGG	see EN-GJS
Inox	Stainless steel
NiAl-Bz	Nickel-aluminium-bronze
Noryl	Fibreglass-reinforced plastic
PE-HD	Polyethylene with high density
PP-GF30	Polypropylene, reinforced with 30 % fibreglass
PUR	Polyurethane
SiC	Silicon carbide
St	Steel
St.vz.	Galvanised steel
V2A	(A2) Material group, e.g. 1.4301, 1.4306
V4A	(A2) Material group, e.g. 1.4404, 1.4571

Resistance table Ceram 0

Fluid	Temperature	Factor
Acids		
5 % nitric acid	+20 °C	3
5 % hydrochloric acid	+20 °C	2
10 % hydrochloric acid	+20 °C	2
20 % hydrochloric acid	+20 °C	3
10 % sulphuric acid	+20 °C	2
20 % sulphuric acid	+20 °C	3
Bases and bleaches		
Sewage, alkaline (pH 11)	+20 °C	1
Sewage, alkaline (pH 11)	+40 °C	1
Sewage, slightly acidic (pH 6)	+20 °C	1
Sewage, slightly acidic (pH 6)	+40 °C	1
Sewage, highly acidic (pH 1)	+20 °C	2
Sewage, highly acidic (pH 1)	+40 °C	3
5 % ammonium hydroxide	+40 °C	3
5 % caustic soda	+20 °C	1
5 % caustic soda	+50 °C	2
10 % sodium chloride solution	+20 °C	1
Other compounds		
Decanol (fatty alcohol)	+20 °C	1
Decanol (fatty alcohol)	+50 °C	1
40 % ethanol	+20 °C	1
96 % ethanol	+20 °C	3
Ethylene glycol	+20 °C	1
Heating oil/diesel	+20 °C	1
Compressor oil	+20 °C	1
Methyl ethyl ketone (MEK)	+20 °C	3
Toluene	+20 °C	2
Water (Cooling/industrial water)	+50 °C	1
Xylene	+20 °C	1

1 = stable; 2 = stable, short-term; 3 = overflow-stable, immediate cleaning; 4 = not recommended for direct contact

Resistance table Ceram 1

Fluid	Factor
Acids	
5 % nitric acid	1
10 % nitric acid	3
5 % hydrochloric acid	1
10 % hydrochloric acid	2
20 % hydrochloric acid	3
10 % sulphuric acid	2
20 % sulphuric acid	3
5 % phosphoric acid	1
20 % phosphoric acid	3
Bases and bleaches	
5 % ammonia	2
28 % ammonium hydroxide	1
6 % fixing salt	1
10 % sodium hydroxide	1
50 % sodium hydroxide	1
5 % soap solution	1
Cement mortar/concrete	1
Other compounds	
Sewage	1
Bunker C	1
Diesel oil	1
Isopropanol	1
Kerosene	1
Naphtha	1
Toluene	1
Salt water	1
Xylene	1

1 = stable; 2 = stable, short-term; 3 = overflow-stable, immediate cleaning; 4 = not recommended for direct contact

Tested at 20 °C. Sample hardened for 12 days at 20 °C. Longer hardening improves the chemical resistance.

Resistance table Ceram 2

Fluid	Factor
Acids	
5 % acetic acid	2
20 % acetic acid	4
5 % hydrochloric acid	1
10 % hydrochloric acid	2
20 % hydrochloric acid	3
10 % sulphuric acid	1
20 % sulphuric acid	2
Bases and bleaches	
28 % ammonium hydroxide	1
6 % fixing salt	1
10 % caustic soda	1
30 % caustic soda	1
10 % potassium hydroxide	1
50 % potassium hydroxide	1
Other compounds	
Sewage	1
Bunker C	1
Diesel	1
Isopropanol	1
Kerosene	1
Naphtha	1
Toluene	1
Salt water	1
Xylene	1

1 = stable; 2 = stable, short-term; 3 = overflow-stable, immediate cleaning; 4 = not recommended for direct contact

Tested at 20 °C. Sample hardened for 7 days at 20 °C. Longer hardening improves the chemical resistance.

Resistance table Ceram 3

Fluid	Factor
Acids	
5 % acetic acid	2
20 % acetic acid	4
5 % hydrochloric acid	1
10 % hydrochloric acid	2
20 % hydrochloric acid	3
10 % sulphuric acid	1
20 % sulphuric acid	2
Bases and bleaches	
28 % ammonium hydroxide	1
6 % fixing salt	1
10 % caustic soda	1
30 % caustic soda	1
10 % potassium hydroxide	1
50 % potassium hydroxide	1
Other compounds	
Sewage	1
Bunker C	1
Diesel	1
Isopropanol	1
Kerosene	1
Naphtha	1
Toluene	1
Salt water	1
Xylene	1

1 = stable; 2 = stable, short-term; 3 = overflow-stable, immediate cleaning; 4 = not recommended for direct contact

Tested at 20 °C. Sample hardened for 7 days at 20 °C. Longer hardening improves the chemical resistance.

Fault analysis

	Cause of the fault	Action
Inflow area	The pump's inlet is not free of bubbles	• Air intake due to incoming jet • Air intake due to ventilation • Air intake due to vortex formation • Air intake due to water level falling too much • Air intake due to turbulent inflow • No smooth running, strong vibrations, screwed connections may loosen or break. • Short service life of the pump • In particular the pump's bearing and sealing show signs of damage after a short running time
	Problematic fluid	• Volume flow stalls • Temperature too high, thermal load of the winding gets too high • Aggressive fluid, materials are corroded • Fluid causes severe wear (sand content is very high), wear to impeller and pump housing • Specific weight is higher than 1 kg/dm^3, drive overloaded • Viscosity > 1.5 – 10 – 06 m^2/s, drive overloaded, higher friction losses • Concentration of solids too high, volume flow stalls • Bulky substances, blocking of the impeller
	Unfavourable pump sump	• Water volume too small, switching frequency too high • Water volume too large, sewage fouls – gas formation • Insufficient pump inflow tendency, solids are deposited and not pumped
	Faulty level switching	• Switching difference too low, switching frequency too high • Switching difference too high, formation of deposits and fouling processes • Deactivation contact too low, air intake in pump, possibly cavitation • Contact sensor faulty or not fastened correctly, flutter contact; uncontrolled activation and deactivation of the pump
	Blockage in the suction line	• Suction line too long and with insufficient diameter, high friction losses, possibly cavitation, risk of clogging • Suction line with maximum (not constantly ascending) • Irregular pumping • Risk of dry running • Clogging in suction line or slide valve on suction side, closed dry running of the pump, pump not running smoothly at all; damage to bearings, screws and sealing

	Cause of the fault	Action
Pump	Insufficient submersion in water	• Air intake in pump, possibly cavitation
	The pump is not installed vibration-free and shock-free	• Pump vibrations caused by external components (e.g. vibrating base etc.) • The pump is not fastened or only fastened loosely or hits other components, no smooth running, strong vibrations • Short service life, the pump's bearing and sealing show signs of damage after a short running time
	The pump runs at an unfavourable duty point	• The duty point is in the extreme left range of the pump curve (extremely low volume flow), high risk of clogging, due to insufficient flow rate, possibly cavitation, no smooth running, short service life, poor efficiency. • The duty point is in the extreme right range of the pump curve (very high volume flow), possibly cavitation, no smooth running, short service life, poor efficiency • The duty point is within the cavitation range
	The pump is clogged or blocks	• Flow rate insufficient • Stationary wear ring clearance too narrow • Bulky parts in the fluid
	The electrical connection is faulty	• Incorrect direction of rotation, no smooth running at all • Phase failure, winding damage • Contactor contacts burnt, winding damage • Wires not screwed on firmly, loose contact, possibly winding damage • Motor protection set too low, motor protection triggers • Fuses small, fuses trip • Fuses not screwed in firmly, phase failure • Cable in the water area damaged, water in the motor's terminal compartment • Incorrect connection for star-delta starting • High overvoltage or undervoltage, motor protection triggers
Pressure pipe	Unfavourable arrangement of the return units	• Vertical arrangement, blocking or fluttering of the non-return valve shutter due to deposits • Non-return valve not vented, pump does not pump due to air inclusion
	Pressure pipe not separated from pump in terms of vibrations	• Unfavourable arrangement of the pressure pipe, pressure pipe vibrates severely • Pressure pipe not fastened and supported sufficiently, pressure pipe vibrates severely • Pressure pipe connected directly to pump without compensator
	Unfavourable connection of the pressure pipe to the collection pipe	• Deposits in the collection pipe can enter non-return valve and pump, wear and possible blockage of the non-return valve

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