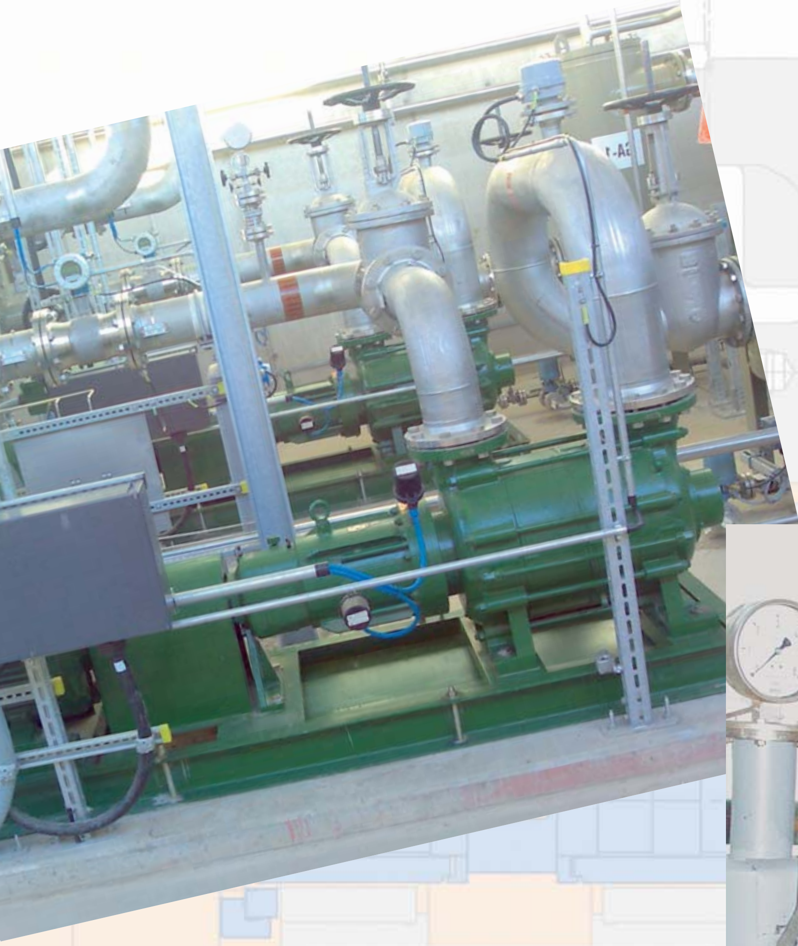
DICKOW PUMPEN



Guidelines for installation and monitoring of centrifugal pumps and side channel pumps

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1. Operating / installation instructions

According to the existing EC-rules, defined by Machinery Directive 2006/42/EC, DICKOW is required to deliver instruction manuals together with the required documentation. The manuals provide instructions for installation, operation and maintenance for the different types of DICKOW pumps. It is essential that the manuals are thoroughly reviewed and that complete comprehension of the matters explained therein is attained before attempting installation and start-up. However, when applying sealless pumps which are different in operation from conventional pumps, the manual should be studied before ordering the pumps. This is to assure that all recommendations regarding installation and monitoring are considered. Modifications after delivery consume time and are expensive.

This guidelines will assist the project engineer who is responsible for the selection of the sealless magnetic coupled pumps. However, this abstract will not substitute the DICKOW-manuals for the supplied pumps. It should only help to avoid pump failures and improve availability of our pumps.

ATTENTION **Never operate or install sealless pumps without having reviewed and understood the specific manual with the design data. This abstract does not give any recommendations for operation, such instuctions are included in the instruction manual only.**

2. Piping

ATTENTION **Pumps are not designed as pipe anchors. Make sure that the piping to the pumps is in exact alignment with the pump flanges and imposes no uncontrolled stress on the pump unit.**

General

1. Both suction and discharge pipe must be supported independently from the pump unit.
2. Allowable forces and moments according to manuals must be considered.
3. No uncontrolled forces must occur when handling hot liquids.
4. Connections must be provided for draining and flushing the pump before disassembly. Consider possible problems when draining jacketed pumps.
5. Flange gaskets must be resistant to the pumped liquid.

2.1 System head curve, pump performance curve

The flow delivered by a positive displacement pump with constant speed is always nearly constant, independent of the pressure in the discharge line, as long as the driver is not overloaded and trips.

Contrary to this, the flow delivered by any installed centrifugal pump with constant speed depends on the pressure in the discharge line because the flow is pressure-related. With a stable performance curve, the maximum capacity is produced at zero differential head and zero flow occurs if the discharge pressure exceeds the pump pressure at shut-off. In other words, the flow delivered on site depends always on the pressure in the discharge pipe. The available pressure at pump discharge flange is determined by the system head. Usually, the system head curve is divided into a static and a dynamic part. The static part is determined by pressure or level difference between suction and discharge vessels and the dynamic part is determined by friction losses.

Figure 1 displays the different performance curves for both types of pump.

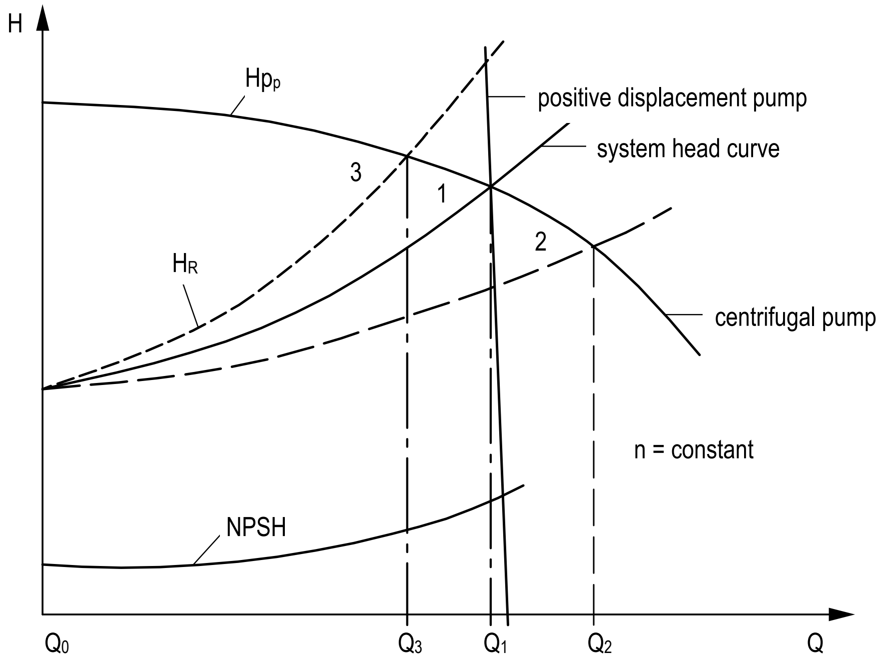


Fig. 1: Pump and system head curve

The capacity of the centrifugal pump is always determined by the intersection point of the pump performance curve and the system head curve. That means, if the actual system head (2, 3) is different from the calculated system head curve (1) when sizing the pump, the pump cannot meet the rated conditions. In most of the cases, the lower capacity (Q_3) can be improved by installing a bigger impeller diameter and will not cause any pump failure. The increased capacity (Q_2) is of critical importance when NPSH-Available is low (handling volatile liquids) as cavitation may occur. This can lead to serious pump damage and/or break down of the flow.

ATTENTION **Only careful calculation of rated conditions, including NPSH-values, and pump sizing can maintain pump availability and avoid serious pump failure.**

2.2 Suction pipe

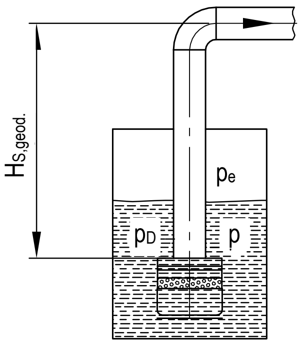
2.2.1 NPSH-values

ATTENTION

When operating sealless pumps with ceramic (SiC) sleeve bearings, cavitation must be avoided at all times. The suction pipe requires careful design for such pumps. The value of NPSH-Available must exactly be determined. The following margin should be applied:

NPSH-Available ≥ NPSH-Required + minimum 0,5 m

NPSH-Available is determined as follows:



Suction lift condition

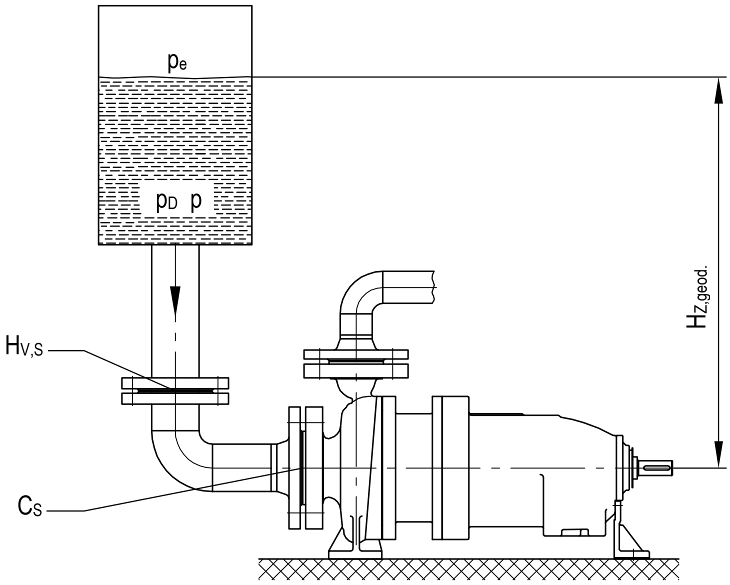


Fig. 2: Arrangement of suction pipe

$$NPSH - Available = NPSH - A = \frac{p_e - p_D}{\rho} \cdot 10{,}2 + H_{Z,\,geod.}{*} - H_{VS} + \frac{C_S^{\,2}}{2g} = vapour\ \ pressure\ reserve$$

The result is given in m, when using the following values:

p_e	Pressure in suction vessel in "bar-abs"	H_{VS}	Friction losses of suction side in "m". Keep as low as possible.
p_D	Vapour pressure of pumped liquid at PT in "bar"	C_S	Liquid velocity in pump suction flange "m/sec"
ρ	Density of pumped liquid at PT in "kg/dm^3"	$H_{S,geod.}$	Maximum suction lift "m"
$H_{Z,\,geod.}$	Minimum liquid level at suction side in "m"	g	Acceleration due to gravity 9,81 m/s^2

*) For operation under suction lift conditions, $H_{s,geod.}$ must be negative "-".

NPSH-Required can be taken from the pump curve.

Examples for calculating NPSH-Available:

a) <u>Handling of non-volatile liquids</u> "$p_e > p_D$"

Available data: Pumped liquid: Acetone; density ρ = 0,77 kg/dm^3
Temperature = 40°C ; vapour pressure p_D = 0,56 bar
Site data: Liquid level $H_{Z, geod.}$ = 1,5 m
Pressure in suction vessel p_e = 1 bar ; abs (atmospheric pressure)
Dia. suction pipe 80 mm, length appr. 10 m
Rated capacity: 70 m^3/h

Wanted: NSPH-A

From the diagram, page 6, we pick the suction velocity C_S = 3,5 m/s, friction losses per 100 m pipe length = 16 m (H_{VS} for 10 m = 1,6 m). With these data, we calculate as follows:

$$NPSH-A = \frac{1{,}0-0{,}56}{0{,}77}\cdot 10{,}2 + 1{,}5 - 1{,}6 + \frac{3{,}5^2}{2\cdot 9{,}81}$$

$$\underline{NPSH-A = 6{,}35\ m}$$

b) <u>Handling of volatile liquids</u> "$p_e = p_D$" ; herewith applies $\frac{p_e - p_D}{\rho} = 0$

Available data: Pumped liquid: Butadiene; density ρ = 0,629 kg/dm^3
Temperature = 20°C ; vapour pressure p_D = 2,3 bar
Site data: Liquid level $H_{Z, geod.}$ = 2,0 m
Pressure in suction vessel p_e = p_D
Dia. suction pipe 80 mm, length appr. 5 m

Wanted: NSPH-A

Friction losses and velocity in suction line as above.

$$NPSH-A = 2{,}0 - 0{,}8 + \frac{3{,}5^2}{2\cdot 9{,}81}$$

$$\underline{NPSH-A = 1{,}82\ m}$$

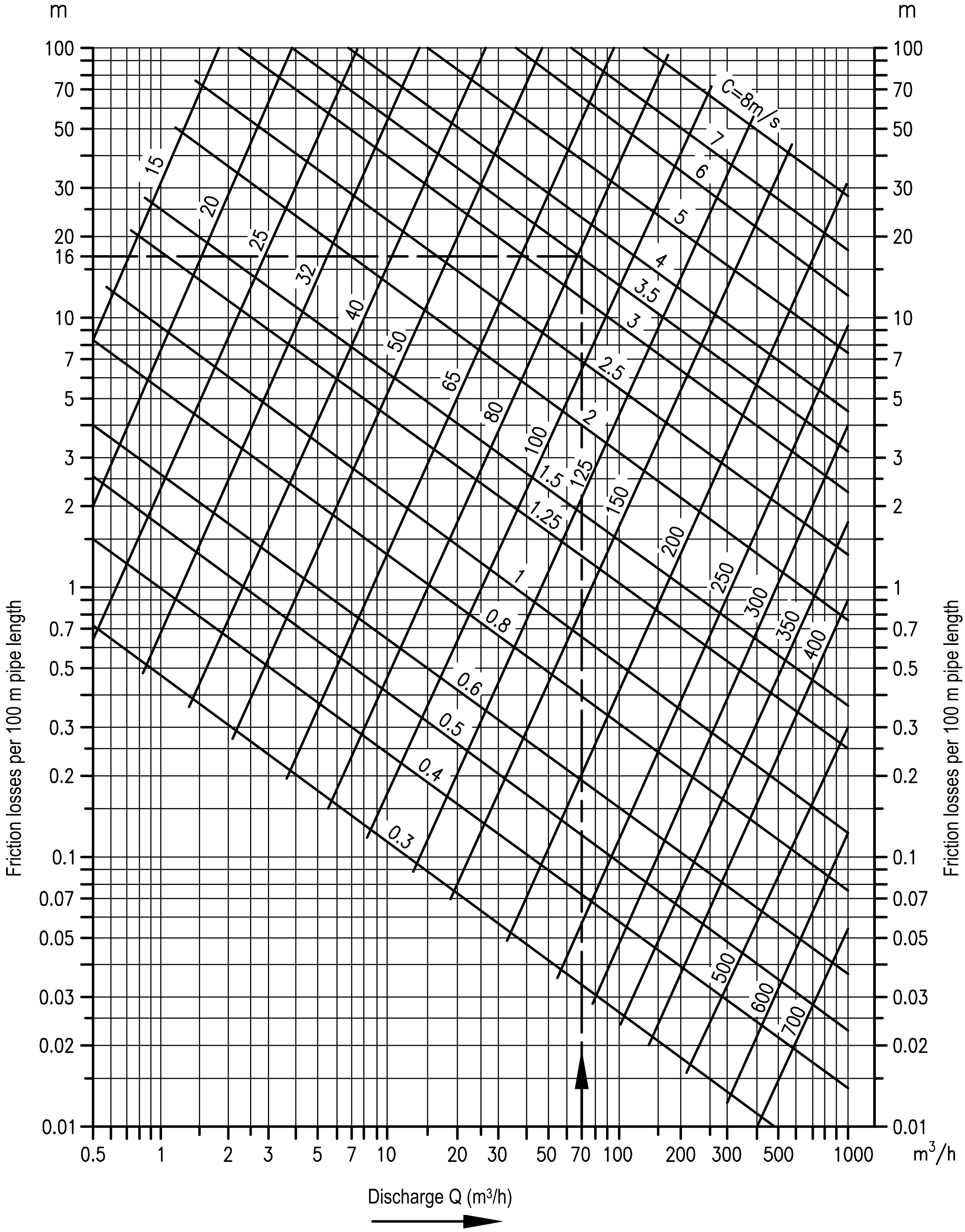


Fig. 3: Velocities and friction losses of pipes

2.2.2 Suction pipe design

1. Use of elbows close to the pump suction flange should be avoided. There should be a minimum of 2 pipe diameters of straight pipe between the elbow and suction inlet. Any elbows used should be of large radius.

2. Size suction pipe should be one or two sizes larger than pump suction, with a reducer at suction flange. Suction pipe must never be of smaller diameter than the pump suction.

3. Reducers, if used, must be eccentric at pump suction flange as shown in figure 4.

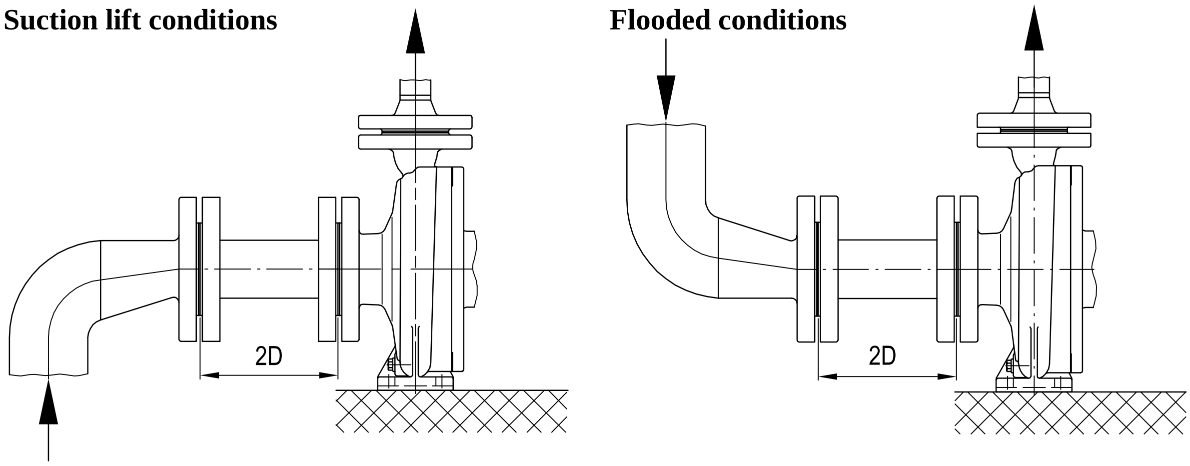


Fig. 4: Suction pipe

4. Suction strainer, if used, must have a net "free area" of at least 3 times the suction pipe area. It is wise to install a differential pressure indicator or switch to avoid cavitation by clogged screen. Screen with a mesh width of 0,5 mm is recommended for centrifugal pumps and 0,2 mm for side channel pumps. Friction loss of suction strainer must be considered when calculating NPSH-A.

ATTENTION **Clogged suction strainers cause cavitation and serious pump damage. Monitoring of differential pressure between strainer inlet and outlet is highly recommended when handling volatile liquids.**

Install a straight pipe (length of at least two pipe diameters) between the strainer and the suction inlet of pump.

5. Separate suction lines are recommended if more than one pump is operating from the same medium source.

Never connect a larger suction pipe direct to the pump suction flange. Fow eddies reduce the free flow area to the pump.
Additional losses reduce the calculated available NPSH, cavitation can occur.

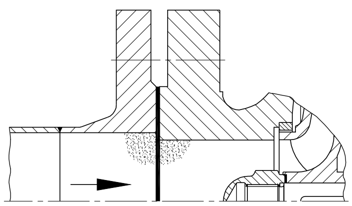


Fig.. 5: Suction flange

6. Max. allowable velocity of liquid in suction pipe is 2 m/s.

Suction lift conditions:

1. The suction pipe must continosly slope upward towards the pump suction to eliminate air pockets.

2. All joints must be air tight.

3. For normal centrifugal pumps, a foot valve should be installed to allow proper filling of the pump and suction line before start-up.

ATTENTION **Consider pressure loss of foot valve when calculating NPSH-A. Easy operation of the foot valve or other non-return flow devices during start-up must be guaranteed. Install any non-return flow devices below the minimum liquid level (during start-up).**

4. Pipe design should allow filling of the pump and suction line for normal centrifugal pumps and filling the pump for selfpriming types, prior to start-up without problems.

5. Place the pump as close as possible to the suction vessel, avoid long suction lines.

Flooded conditions:

1. An isolation valve should be installed in the suction line to permit closing of the line for pump inspection and maintenance.

2. Piping should be level or slope gradually downward from the liquid source to the pump inlet in order to avoid any air pockets during filling the system.

3. The suction pipe inlet should be submerged sufficiently below the liquid surface to prevent vortexes and air or gas entrainment at the inlet. If not possible, provide vortex breaker to avoid vortexes.

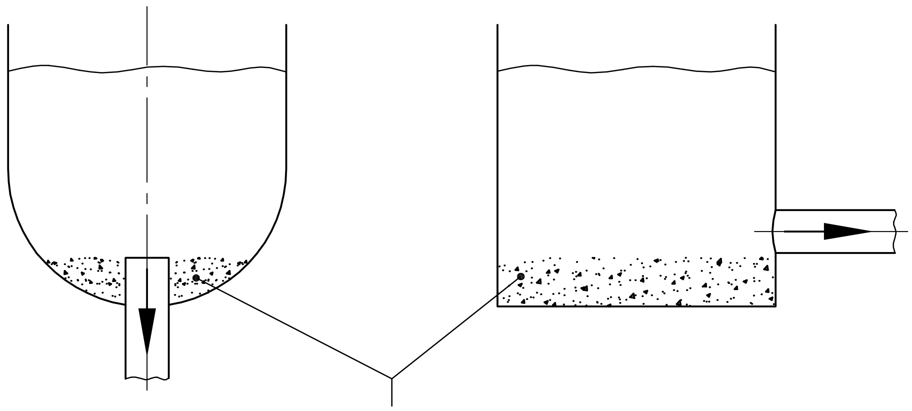


Fig. 6: Suction pipe, inlet

4. Side channel pumps do not tolerate solids or abrasives in the pumped liquid. Such solids as pipe scale or magnetic particles are concentrated on the bottom of the suction vessels or will be collected there during pump shut-off. This fact should be considered when connecting the suction line to suction vessel.

5. If vertical horseshoe bends are available in the suction line, additional vent lines to the expansion vessel will be required. The vent line must be led from the top of the horseshoe to the expansion tank below the minimum level to remove air pockets during filling the system.

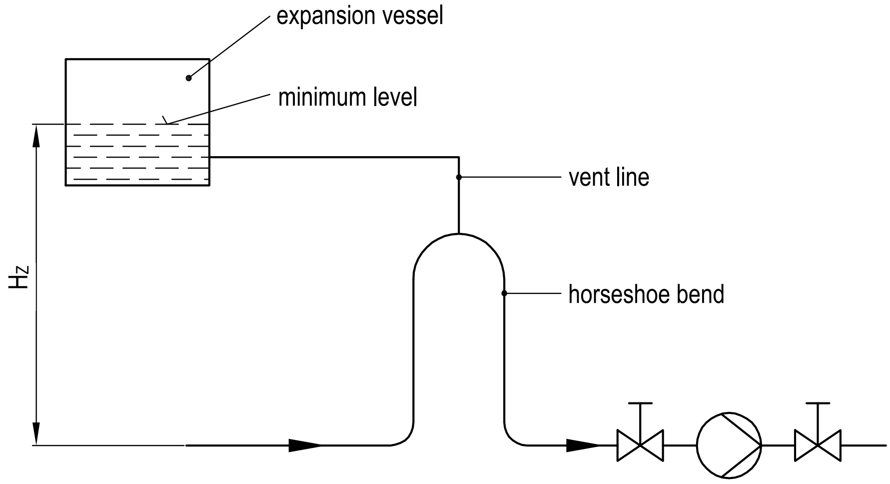


Fig. 7: Vent horseshoe bend

6. Never install non-return valves in suction pipes.

7. When handling volatile liquids, the liquid level H_z on suction side should be higher than the NPSH-Required of the pump:

   H_{Zmin} ≥ NSPH-R + friction losses at suction side

   In this case, it is wise to monitor the liquid level in order to avoid cavitation in any case.

2.3 Discharge pipe

1. Isolation and check valves should be installed in discharge lines. Locate the check valve between the isolation valve and the pump which will allow maintenance of the check valve. An isolation valve is required for isolating, priming, regulation of flow, inspection and maintenance of the pump.

2. Diffusers, if used, should be placed between the pump and check valves. Maximum allowed opening angle is 8°.

3. Pressure compensation devices should be installed to protect the pump from surges and water hammer, if quick-closing valves are installed in the system.

4. If non-return valves are required, install them in the discharge line only.

5. **ATTENTION** **In all cases where more than one pump delivers to a common discharge pipe, every pump should be protected by a non-return valve according to figure 8. This installation is required for parallel operation and for stand-by pumps with automatic start-up.**

ATTENTION **Never try to start reverse spinning pumps as the magnets will decouple.**

6. Parallel operating pumps

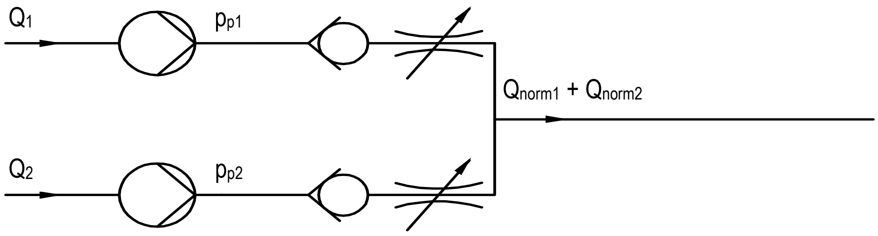


Fig. 8: Parallel operation

The reason why problems can occur when operating pumps in parallel is displayed in figure 9. The problems are caused by the relationship between pump flow and presure as explained in section 2.1. Pump flow rate on site is determined by intersection point of system head curve and pump performance curve.

For the layout of an installation according to figure 8, the pipe designer calculates the rated differential head H for each pump assuming that both pumps deliver the same flow $Q_1 + Q_2$ into the common discharge pipe. Considering the pressure losses of suction side of each pump, the NPSH-Available value is calculated for the flow rate Q_1 of pump p_{p1} and similarly for the flow rate Q_2 of pump p_{p2}. In parallel service, usually $Q_1 = Q_2$. Finally, the pumps are sized such that NPSH-Available exceeds NPSH-Required at Q_1 respectively Q_2 in any case. That means, no cavitation problems will occur if both pumps are operating.

However, if only one pump is operating, for example during start-up or emergency, this pump will operate with flow rate Q_{max} if no partially closed throttle valve or any other flow control device is available in the common discharge line. In this case, the available NPSH-value at Q_{max} must exceed the NPSH-Required at Q_{max}. If this is not the case, a flow limitation device has to be installed in the common discharge line to avoid cavitation.

ATTENTION **Operating of pumps under cavitation - even for short periods - causes serious pump damage.**
Parallel operating pumps must be started always at the same time to avoid cavitation.

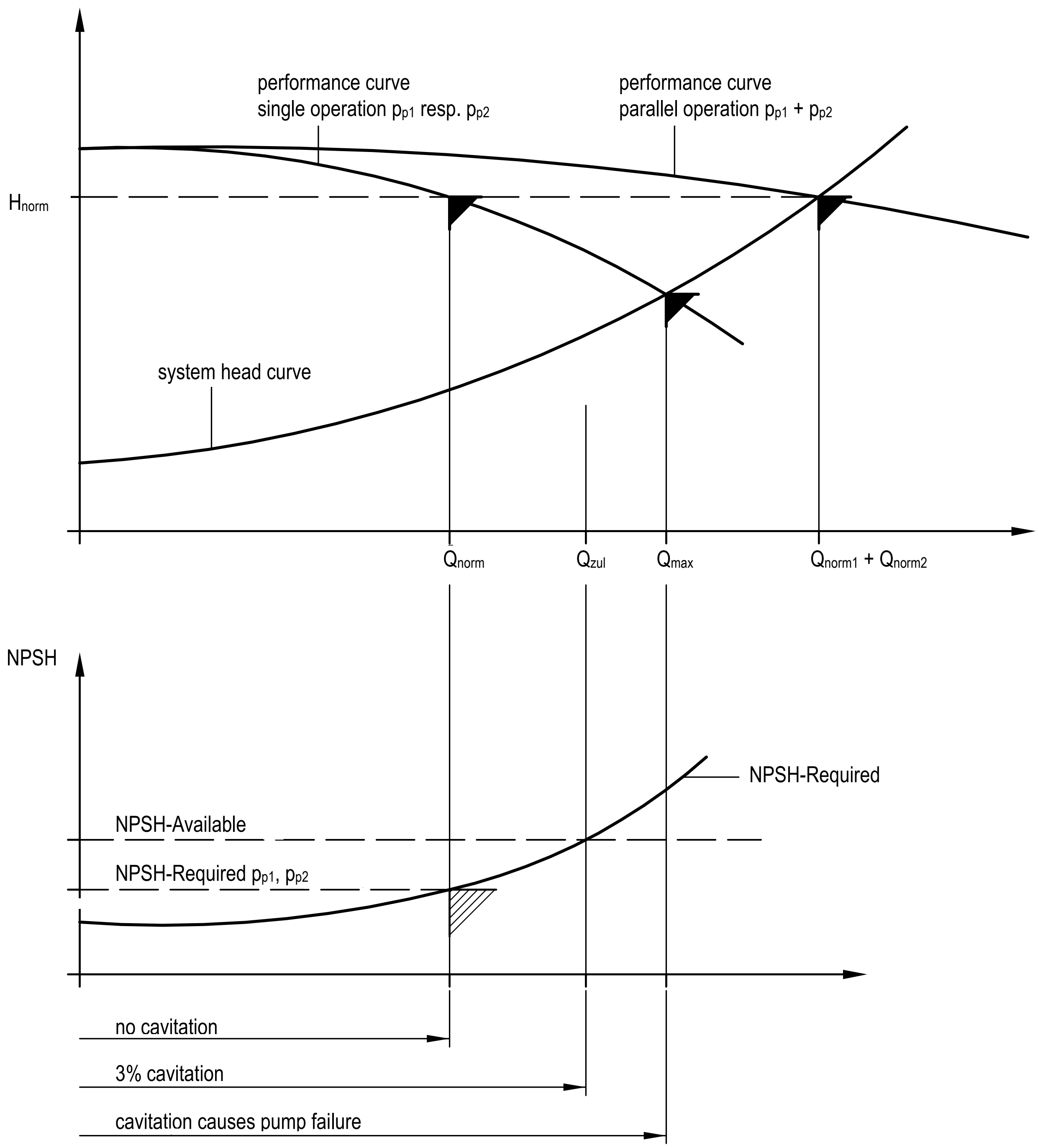


Fig. 9: System head curve and pump curve, parallel operation

2.4 Bypass line, minimum flow

In magnetic coupled pumps, the motor power is transmitted to the pump shaft by the magnetic coupling. The magnetic coupling consists of outer and inner permanent magnets. Outer and inner magnets are connected through the magnetic field lines.

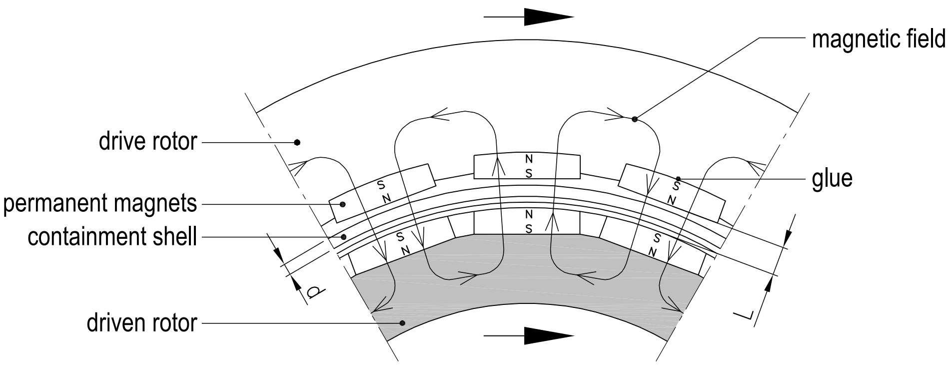


Fig. 10: Magnetic coupling

During operation, the rotating magnetic field lines are cutting the stationary containment shell. Metallic containment shells generate eddy currents which lead to heat and cause temperature rise of the pumped liquid in the containment shell area. In order to prevent inadmissible temperature rise and vaporization of the liquid, this heat must be dissipated through an internal cooling flow. The cooling flow - branched off as a partial flow from the main flow - is led through the gap between internal rotor and containment shell and flows back to the main flow. To keep stable temperature conditions inside the pump, a certain minimum flow must be guaranteed.

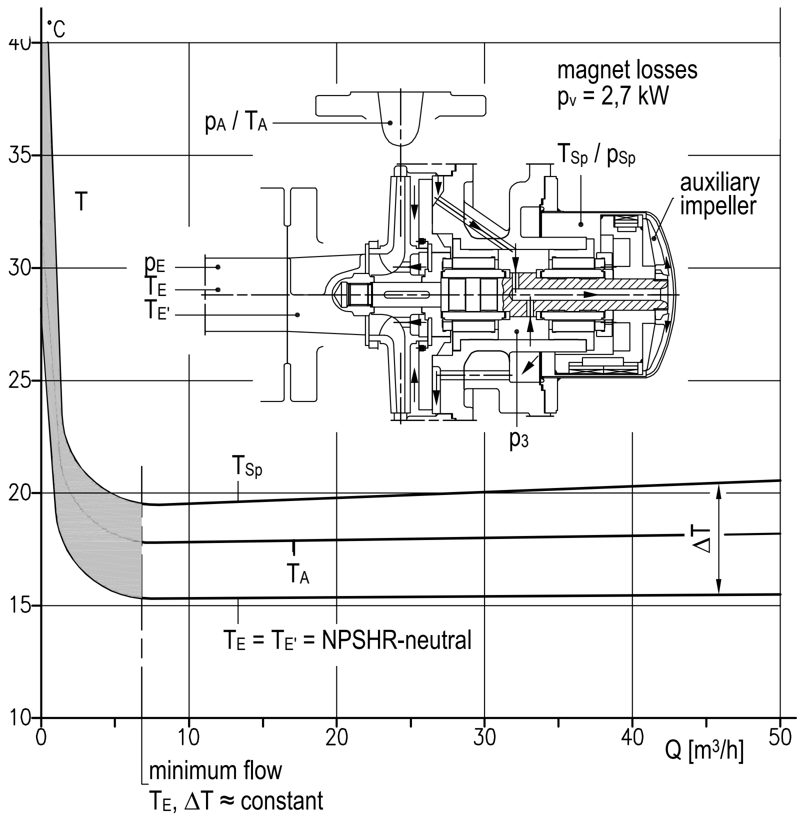


Fig. 11: Temperature behaviour

Right of the thermal stable minimum flow there is a nearly constant temperature rise in the containment shell (T_{Sp}) and at pump discharge (T_A). However, if the minimum flow drops below the thermal stable minimum flow, temperatures will rise rapidly. This is the reason why pumps cannot operate against a closed discharge valve.

ATTENTION **Never operate pumps below minimum flow. Temperature rise causes flashing of the pumped liquid, dry running of the sleeve bearings and serious pump damage.**

If process conditions require operation below min. flow, an additional bypass pipe back to the suction vessel should be installed. Never lead bypass pipe back to pump suction pipe!

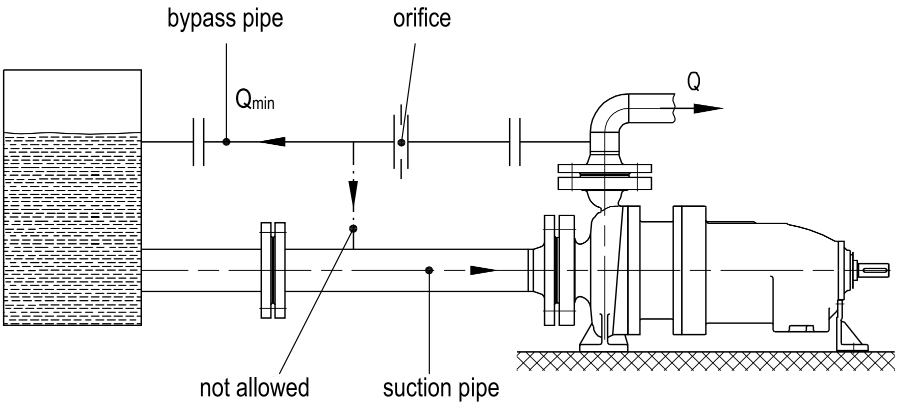


Fig. 12: Bypass arrangement

To adjust the required bypass flow, an orifice should be installed in the bypass pipe. The required diameter d_3 depends on the required flow, the pressure difference H and the ratio $(d_3/D_7)^2$ which determines the throttle factor f_1.

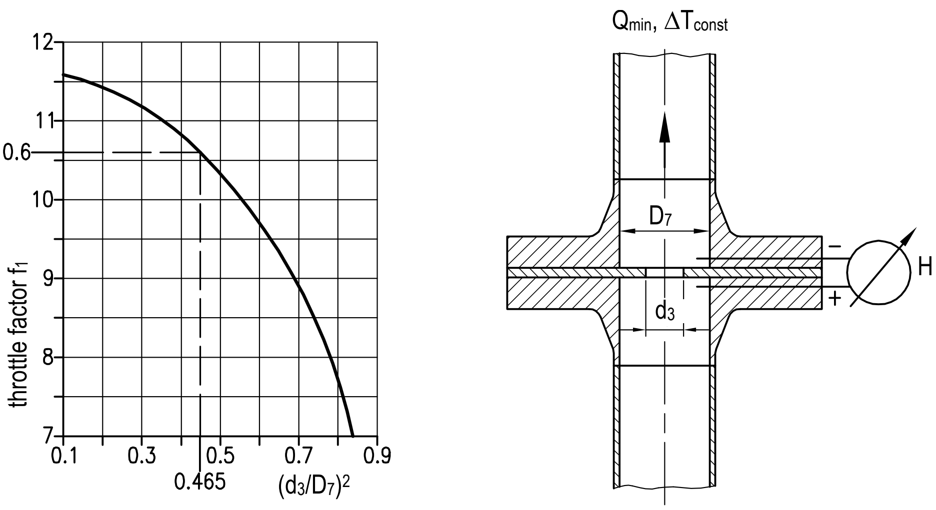


Fig. 13: Throttle factor and orifice

$d_3 = f_1 \cdot \sqrt{\frac{Q\min}{\sqrt{H}}}$ [mm] ; Q_{min} in m^3/h ; H = pressure difference in mFS

For the first step, select throttle factor $f_1 = 10$, because d_3 / D_7 is not known, and repeat calculation with corrected factor if required.

ATTENTION

Operation against closed valve may also occur unexpectedly if upstream control or shut-off valves close automatically during operating troubles. If such valves are available in the discharge pipe, a bypass pipe should generally be foreseen.

3. Application in explosive areas

This chapter outlines the most important informations acc. to directive 94/9/EC concerning the use of pumps in explosive areas.

A pump in operation is to be considered as a potential ignition source. Essential sources are hot surfaces, mechanical sparks, electrostatic charge and discharge. With the design of pumps of category 2, a high level of safety for intended use is guaranteed. That means, expected trouble has been considered during the risk assessment for the pump.
Expected troubles are for example:

- Operation below minimum flow
- Damage on sleeve- and antifriction bearings
- Decoupled magnets for magnetic coupled pumps
- Dry run of mechanical seal for sealed pumps
- Operation against closed valve
- Dry run
- Elevated containment shell temperature for magnetic coupled pumps
- Temperature transmission from pump to explosion proof motor for close coupled pumps

The risk assessment for pumps is based on the intended use of the pump. Therefore, **the pump may only be operated in the application area which is described in the pump data sheet and within the allowable performance range.**

The intended use of the pumps requires that they are **permanently** filled with liquid.

In order to prevent occurrence of expected troubles respectively to recognize them before an ignition source may arise, precautions must be taken by the owner.

3.1 General measures

- Make sure prior to start-up that the pump is vented and suction pipe is completely filled with liquid. If a fluid reservoir for double mechanical seals is available, it must be filled according to the instruction manual.
- Operation against closed discharge valve, respectively below minimum flow is not allowed. Control valves, bypass pipes or similar means can be provided to assure minimum flow. A power monitor is also suitable to recognize operation below minimum flow.

- Dry run must be avoided in any case. Dry run causes inadmissible high temperatures within shortest time in the area of containment shell, sleeve bearing or mechanical seal. Dry run can be recognized in time by temperature monitoring at containment shell or by power monitor.
- Operation against closed suction valve respectively clogged filter or strainer must be avoided in any case.
- The pump must be used only for handling the liquid specified in the pump data sheet. This applies for instance to temperature and specific heat of the liquid, to solids content and viscosity. Other service conditions require consultation with the factory.
- Handling a non-specified liquid may result in clogged circulation holes through solids or polymerisation which leads to temperature increase in the containment shell respectively mechanical seal area.
- The speed specified in the data sheet must not be exceeded, possibly by transmission or frequency converter. The allowable loads can easily be exceeded.
- The wetted parts of the pumps must be regularly inspected.
- Antifriction bearings require regular inspection and maintenance. Statements about maintenance intervals can be found in the operating manual.
  Regular vibration measurements of the bearings give information about the condition of the antifriction bearings. Bearing damage can also be detected through temperature measurements of the bearing bracket.
- Radial shaft seal rings must be checked regularly.
- Insulation of the pump against heat losses is allowed only for the hydraulic part.
- The heating jacket of jacketed pumps must be flushed only with the heating fluid that is specified in the data sheet.

3.2 Special measures for magnetic driven pumps

- In rare cases, decoupling of magnets may be possible at start-up and also during operation. Cooling of magnet coupling in this state is not granted any more, the temperature can inadmissibly rise within short time. This problem can be recognized through a power monitor, a “mag-safe” temperature monitor at the containment shell or on site through monitoring the discharge pressure or capacity in the pump system.
- Decoupling of magnets can also occur if the pump is operated above the maximum allowable capacity. This problem can be recognized through a min-/max-power monitor.
- Condition of sleeve bearing must be checked regularly.

3.3 Special measures for side channel pumps

- During operation of side channel pumps, the side channel impellers may be touching the suction and pressure disks. However, due to the wetted surfaces, no sparks will develop. The short-time touching does also not cause an inadmissible temperature increase. With wear resistant design, rubbing of these parts can almost be excluded.

3.4 Special measures for pumps with mechanical seals

Mechanical seals are machine components put on the market for general purposes and therefore, are no components as defined by the explosion proof directive.

- When using single mechanical seal, dry run or partial insufficient lubrication may cause excessive temperature rise at the seal ring. The **owner** must ensure that the seal chamber is **permanently** filled with liquid.
- The tandem arrangement (= pressureless thermosiphon vessel) has two mechanical seals successive in series with a suitable barrier liquid in between. In case the product side mechanical seal runs dry, the contact with the barrier liquid limits the temperature rise.
  For monitoring, a liquid level controller with high and low level protection and possibly a pressure gauge with limit switch is suitable.
- The back-to-back arrangement (= pressurized thermosiphon vessel) provides lubrication of product side and atmosphere side mechanical seal by the barrier fluid. Therefore, the loss of product does not lead to dry run. For monitoring, a pressure control of barrier fluid and/or liquid level controller with low level protection is suitable.

3.5 Special measures for close coupled pumps

In order to avoid possible ignition risk and excessive temperatures in the electric motor, certain temperature limits must be maintained for direct coupled pumps.

- The design with mechanical seal is always equipped with a vented (resp. open) motor adapter. In this case, no temperature limits must be considered.
- The design with magnet coupling is equipped with a closed motor lantern. The maximum containment shell temperatures which are mentioned in the operating manual of the pump must in no case be exceeded.

3.6 Identification of pumps

A pump of equipment group II, category 2, for application in atmospheres with gas/steam/fog, designed according to standard EN 13463-5 (protection through constructural safety) has the following identification:

The actual maximum surface temperature does not depend on the ignition sources, but on the temperature of the pumped liquid. There is no identification with a temperature class or a temperature. The symbol "X" is integrated in the identification and the operating manual of magnet coupled pumps contains reference to the self-adjusting surface temperature (DIN EN 13463-1; 14.2 g).

3.7 Dust protection

Besides the gas explosion protection, flammable dusts also mean a serious risk, because raised dusts mixed with oxygen are inflammable and explosive. However, ignitable are only dusts of grain size 0,02 – 0,4 mm. The zone concept includes the zones 20, 21 and 22, analog to the gas explosion protection (zone 0, 1 and 2).
The pumps must be defined as per the **actual maximum surface temperatures** and identified accordingly.

A pump of equipment group II, category 2, for application in dust atmosphere of zone 21, designed according to standard EN 13463-5 and a maximum actual surface temperature of e.g. 200°C has the following identification:

Ex II 2 D c 200°C

3.8 Surface temperature

The highest surface temperatures are to be expected at the pump casing, the containment shell and in the area of antifriction bearings. The surface temperature on the pump casing is equal to the temperature of the pumped liquid.
The surface of the bearing bracket must be open to the atmosphere. Insulation of the bearing bracket is not allowed. The containment shell temperature can be determined with figure 14 and the following equation.

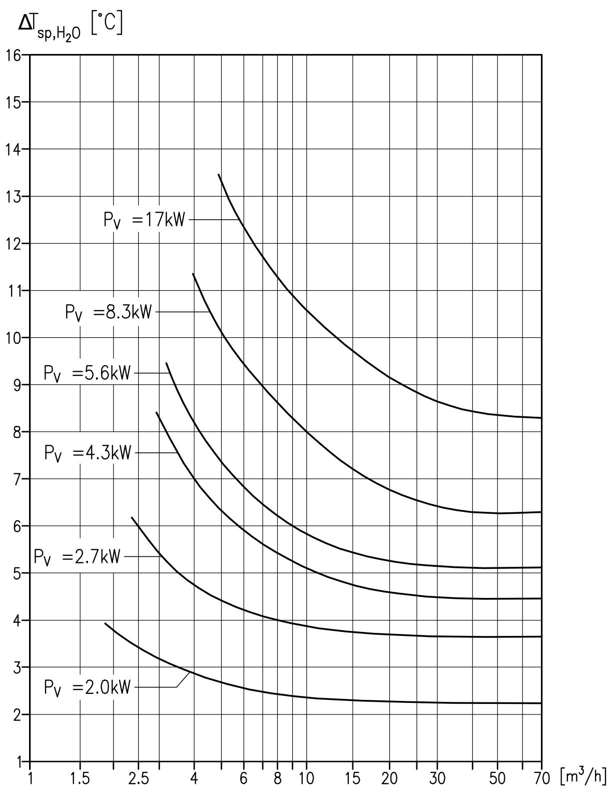


Fig. 14: Containment shell temperature as a function of magnet losses P_v based on water.

$$T_{sp,medium} = T_E + \Delta T_{sp,H_2O} \; x \; \frac{c_{H_2O}}{c_{medium}} \; x \; \frac{\rho_{H_2O}}{\rho_{medium}}$$

T_E	=	inlet temperature of product at suction flange
$\Delta T_{sp,H_2O}$	=	refer to figure 14
c_{H_2O}	=	specific heat capacity of water = 4,187 kJ / kgK
c_{medium}	=	specific heat capacity of product [kJ / kgK]
ρ_{H_2O}	=	density of water = 1 kg / dm^3
ρ_{medium}	=	density of product [kg / dm^3]

4. Monitoring devices

Pumps with magnetic couplings operate generally maintenance-free. However, it should be considered that possible operating upsets can cause serious pump failures if the service conditions are not monitored. The worst possible case is the damage of the containment shell with leakage of pumped liquid to the atmosphere which can endanger maintenance staff and the environment.

This abstract explains possible operating upsets and monitoring devices which can prevent pump failures. The final decision which monitoring devices should be installed, is the responsibility of the customer. Experience with similar applications, references of DICKOW from other customers and the specific properties of the pumped liquid should be considered. For example, when handling volatile liquids, temperature monitoring is more important than for liquids with boiling temperatures far away from boiling point. Pump design and special requirements for the application should also be taken into account.

A very important factor is also the proper installation of the delivered monitoring devices on site. Safety regulations, vendor manuals and wiring diagrams for connection to the motor circuit must be considered in any case.

4.1 Power monitor, load detector

The idea of monitoring the motor power is based on the fact that the power consumption at all sorts of centrifugal and side-channel pumps is flow related. That means that all changes in the flowrate at constant speed generate also changes in the motor power consumption.

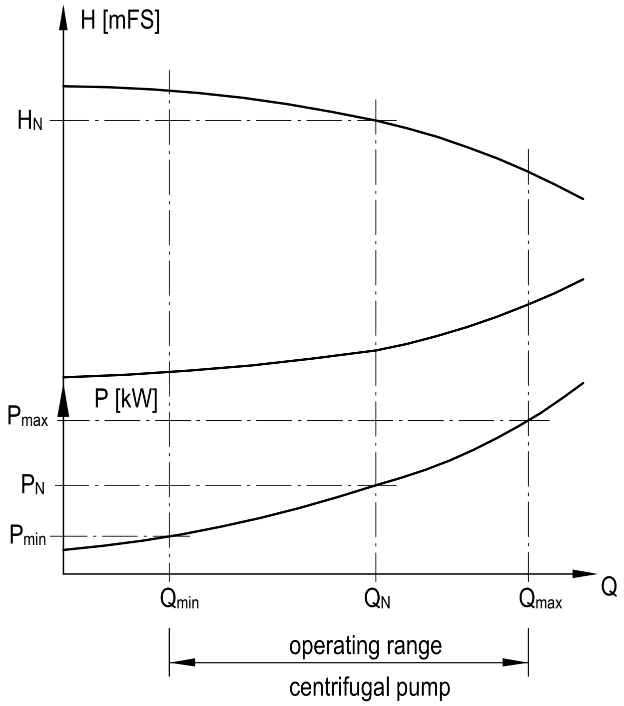


Fig. 15: Load detector, measuring range

The power monitor measures the motor power consumption during pump operation electronically. The amplifier will trip the pump if P_{max} is exceeded or if power consumption drops below P_{min}. Power monitoring is the most economic protection device. No additional sensors and no expensive wiring to the pump itself are required. The power monitor is installed outside the hazardous area (if any) direct into the motor control panel.

Installation after the pump has been installed is also possible. Power monitoring is recommended for all kinds of non-volatile liquids. For volatile liquids, additional temperature monitoring is recommended.
Contrary to the "power factor" monitoring, the values of P_{min} and P_{max} can be precalculated according to the pump performance curve and the motor efficiency, and the trip points can be set when the monitor is delivered.

Protection against the following operating upsets will be achieved:

- **Dry run, decoupled magnets**
  Non self-priming DICKOW-magnetic coupled pumps, types NM, KM, PRM, HZM have SiC-sleeve bearings with diamondlike carbon coating. These bearings can tolerate dry run when empty because no hydraulic loads are acting. In this case, the power monitor is protecting the magnets against demagnetization because no internal cooling flow is available (consider 2.4) during dry run and if magnets are decoupled. In both cases, the motor operates with the amount of the magnetic losses far below minimum load P_{min}. The motor will trip after the set tripping delay has passed.

- **Dead end operation, flow rate drops below thermal stable flow**
  If operating below minimum thermal stable flow, the temperature will rise remarkably. The temperature rise can generate flashing of the pumped liquid and dry running sleeve bearings, that causes serious pump failure. The power monitor trips the motor if the motor power consumption drops below P_{min}. The preselected P_{min} value should reach at least 25% of the rated motor power, precalculation for lower values is not possible.

- **Operation above Q_{max}**
  Operation of centrifugal pumps above Qmax leads to increased vibrations and reduces the life time of pumps. If centrifugal pumps are operated under such conditions, the motor power will exceed the set maximum power P_{max}.
  The motor will trip after the set tripping delay has passed.

The load detector is not suitable for the following service conditions:

- Low capacity and minor difference between P_{min} and P_{max}.
- Temperature fluctuations and related to that varying viscosities and densities of the pumped liquid. This applies for thermal oil plants where high viscosities and densities occur during start-up of a plant.
- When pumping different liquids (batch-operation).

4.2 Level monitoring, dry run protection

4.2.1 Selfpriming pumps - optoelectronic level detector

ATTENTION **Side channel pumps or centrifugal pumps with integrated side-channel stage can in no case accept dry run due to the tight clearances between impeller and stage discs. Pumps must be filled before first start-up.**

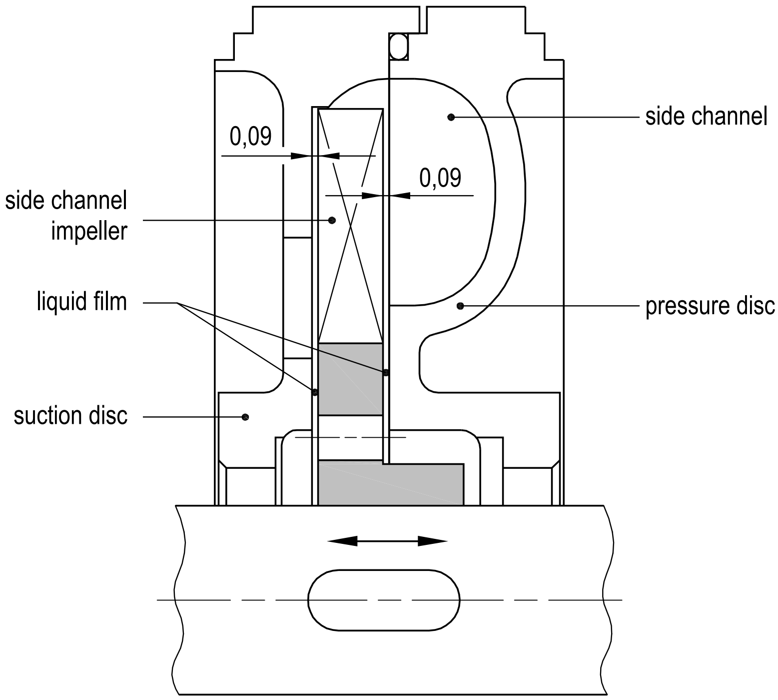
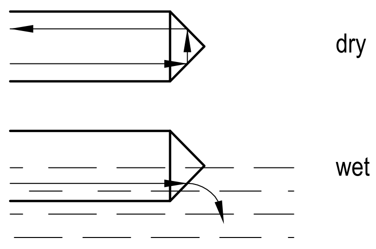


Fig. 16: Side channel stage

If such pumps are operating under suction lift conditions, level monitoring by optoelectronic sensor is recommended.

Function



A light ray which is led into the sensor tip will be reflected in dry condition and diverted in wet state. The transducer detects the divertion and transforms it into a signal to the switch amplifier. The switch amplifier is connected to the motor circuit such that no power supply exists for wet condition.

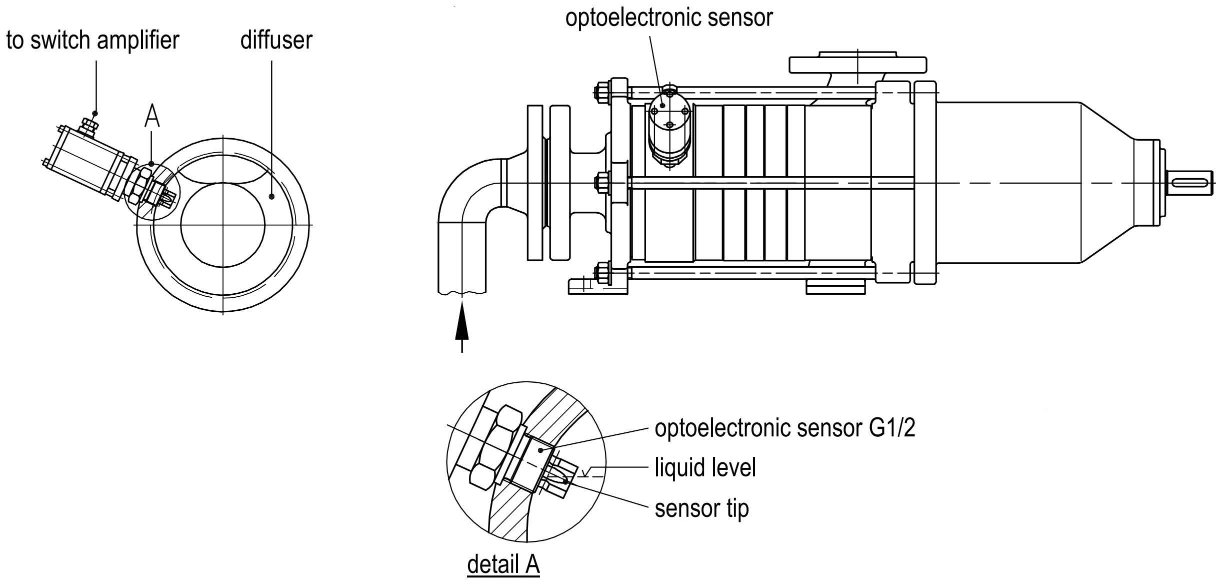


Fig. 17: Optoelectronic level detector

4.2.2 Standard centrifugal pumps, floating switch

Start-up of standard centrifugal pumps requires a completely primed suction line and pump casing. Several devices for level monitoring are available.

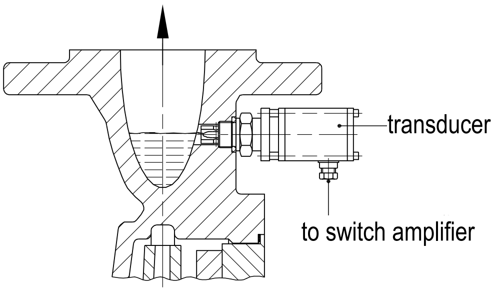
a) Optoelectronic sensor, fitted to the pump casing, see chapter 4.2.1.

b) Floating bypass level switch, acc. to EN 50020, fitted to the pump discharge line.

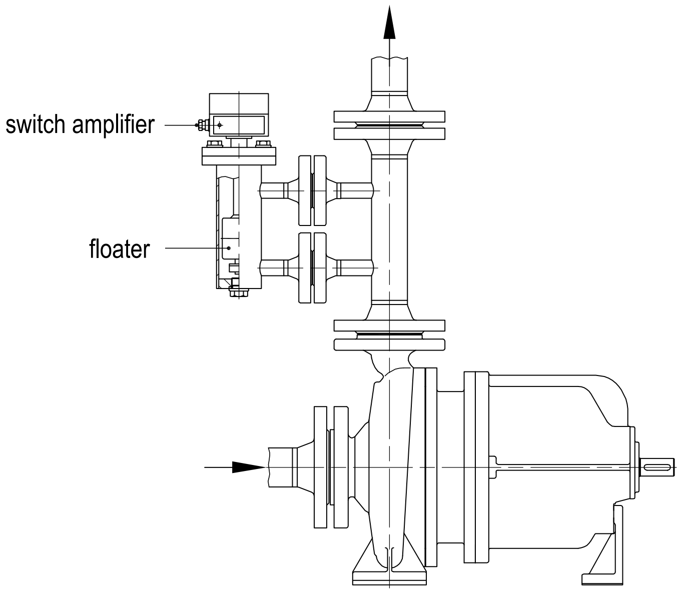
c) Fill level switch LIQUIPHANT

The sensor in the form of a tuning fork is made to vibrate at its resonant frequency by a piezocrystal drive unit. Its resonant frequency changes when the sensor is immersed in the liquid. This frequency change is detected and then converted into a switching signal by a switch amplifier.

a) Optoelectronic sensor



b) Floating switch acc. to EN 50020



c) Fill level switch LIQUIPHANT

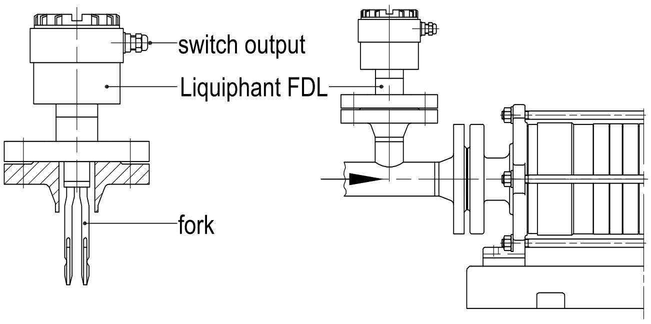


Fig. 18: Monitoring devices, dry run

Level monitoring for side-channel pumps with floating switch or Liquiphant is also possible if these pumps operate under flooded conditions with primed suction line.

4.3 Temperature monitoring, PT100-probe

4.3.1 Containment shell surface

Beside the power monitor, the PT100-temperature probe on the containment shell surface is the most common monitoring device.

Function

The PT100-temperature probes are equipped with a resistance element of platinum, showing a resistance of 100 Ohm at 0°C. Temperature changes at the measuring point lead to a change of the resistance and thus, of the output voltage. The voltage change is processed in the trip amplifier such that - if the set temperature limit is exceeded - the drive motor is tripped, initiating an alarm. The probe should protect the pump against flashing of liquid in the containment shell. When applying PT100-probes for containment shell surface temperature monitoring, make sure that these probes are correctly designed for this application.

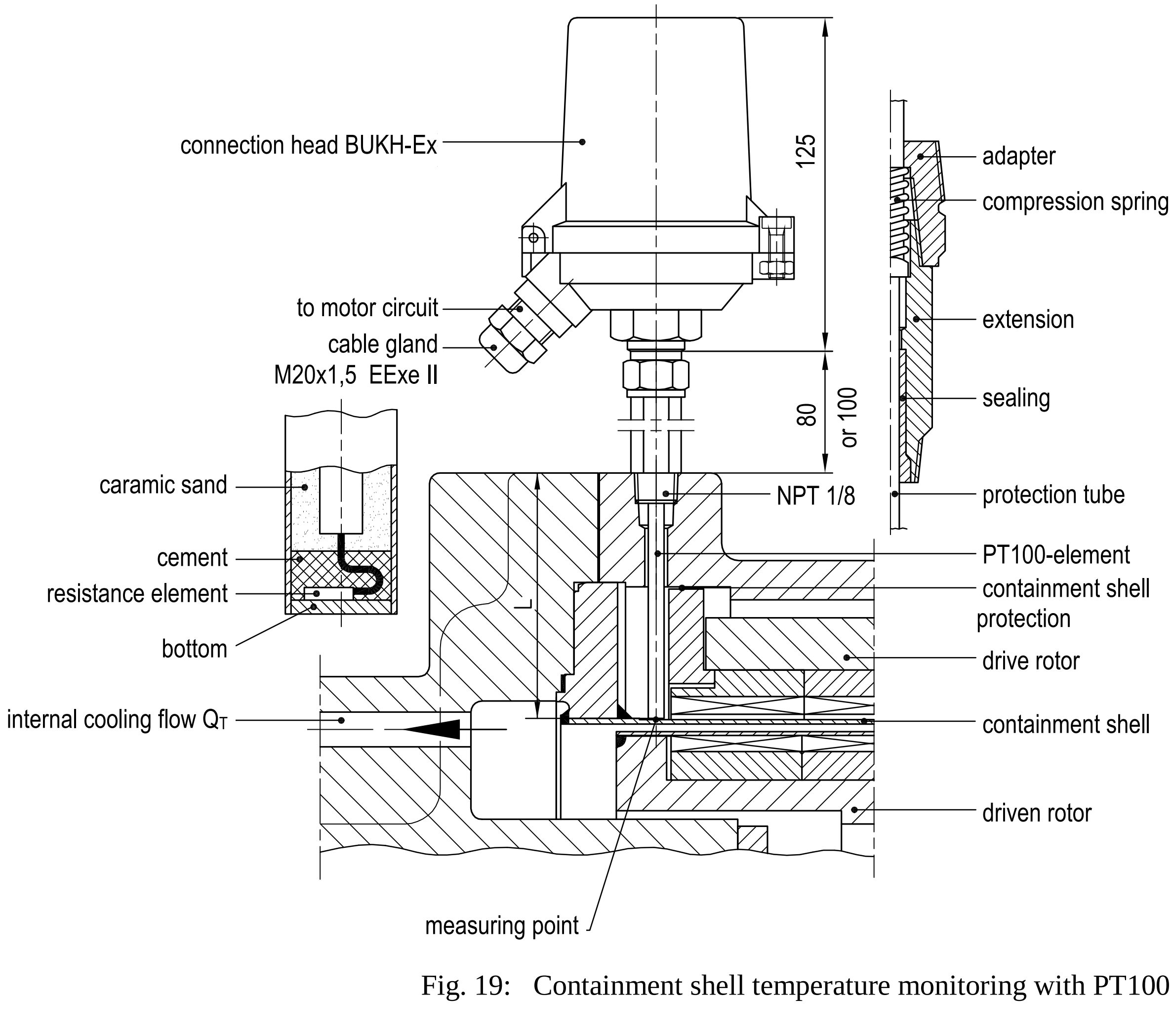


Fig. 19: Containment shell temperature monitoring with PT100

Figure 19 shows a standard PT100 probe with the design features for proper surface temperature detection. A flat bottom is required with sufficient contact to the containment shell surface. The PT100-element is located directly at the bottom. Continuous contact between bottom and containment shell surface is provided by compression spring.

A reliable function of the PT100 is given only if the pump is properly filled with pumped liquid. When handling volatile liquids, the direction of the internal cooling flow is also decisive for the reliability. The measuring point should be located such that the PT100 can read the elevated flow temperature after passing the magnet area. This is the case for DICKOW NM / NMW series with auxiliary impeller only, see figure 20.

Temperature rise can be caused by operation below min. flow, closed discharge without bypass line, clogged internal circulation and decoupled magnetic coupling.

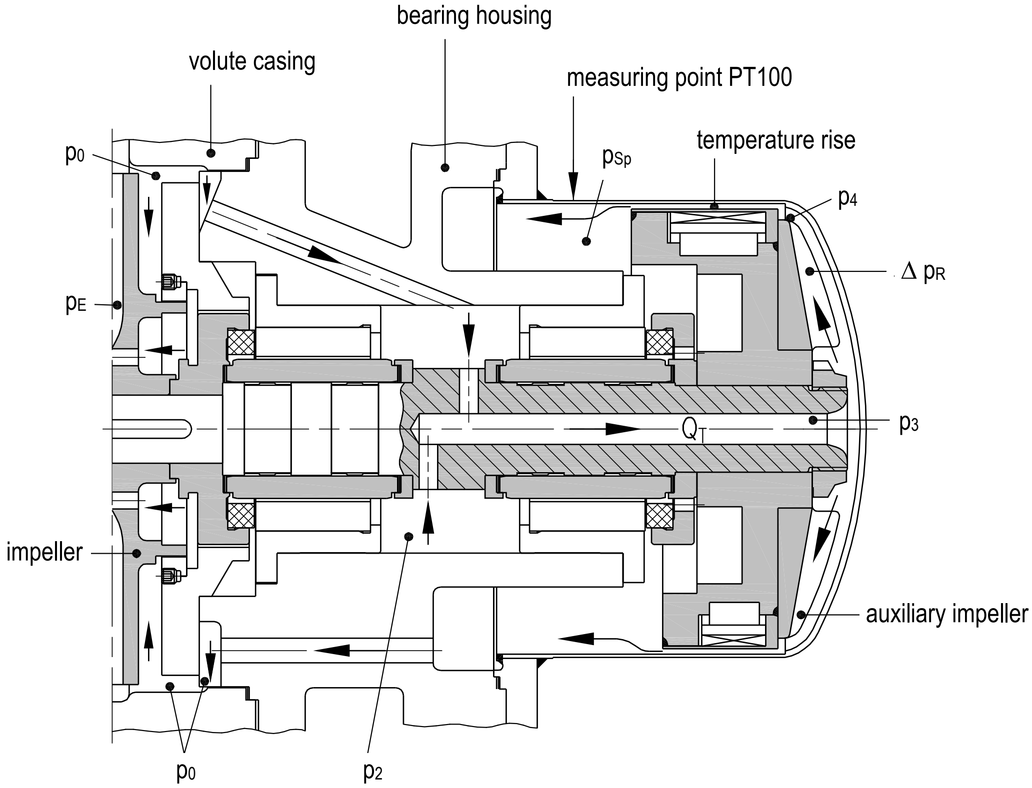


Fig. 20: Magnet coupling with auxiliary impeller

ATTENTION	**PT100 only protects magnet coupling against overheating if pump is filled completely with liquid.**
ATTENTION	**If the measuring point reads the temperature of the circulation flow before it has entered the magnet area, pumps without auxiliary impeller according to figure 21, problems can occur when handling volatile liquids because the PT100 reacts too slow. DICKOW uses the flow pattern according to figure 21 for small pumps with low magnetic losses and low temperature rise only.**
ATTENTION	**PT100 acc. to figure 19 can not be used as dry run protection. Consider chapter 4.6 "mag-safe".**

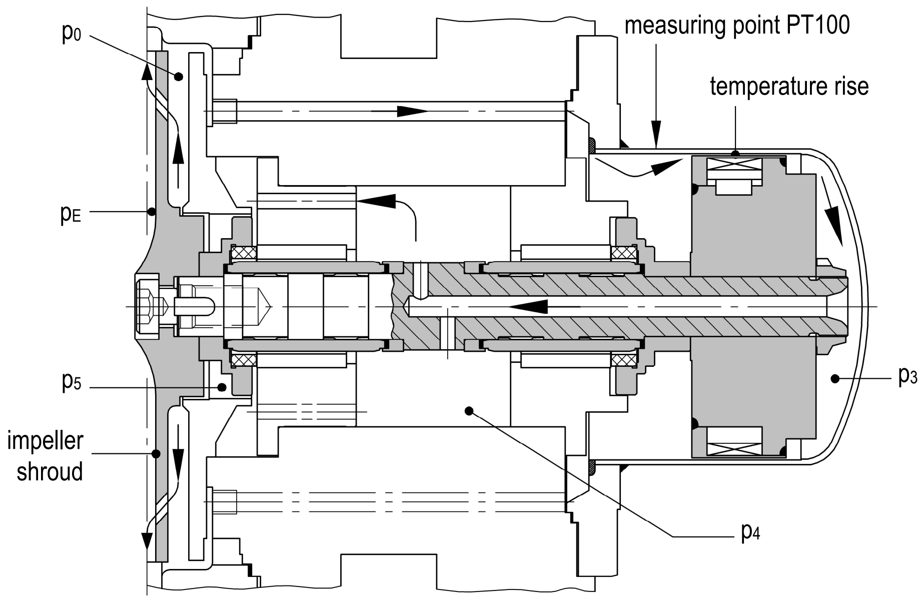


Fig. 21: Magnet coupling without auxiliary impeller

4.3.2 Liquid temperature in the magnet coupling

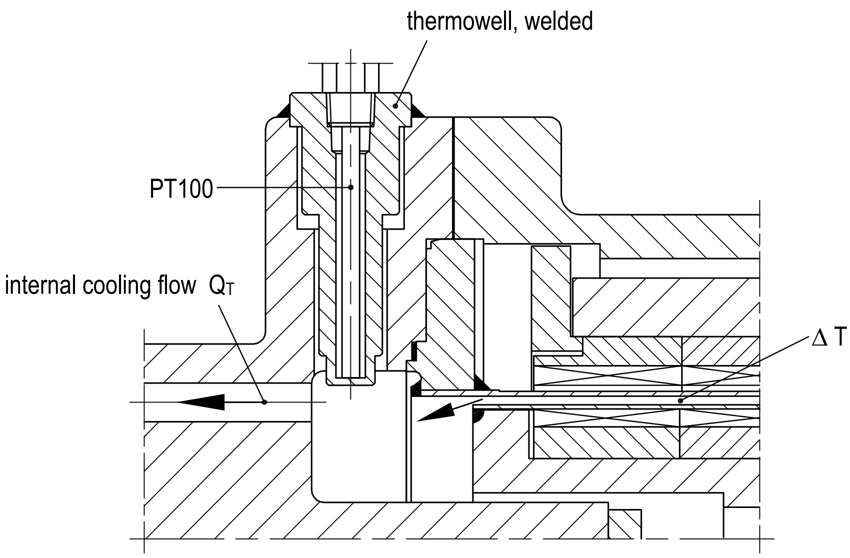


Fig. 22: PT100 with thermowell

Function

For design and function of the PT100, see chapter 4.3.1.

Due to safety, the PT100 is located at the bottom of a welded thermowell. Direction of cooling flow should be considered (auxiliary impeller). Liquid temperature monitoring is applied for handling volatile liquids, typically in addition to temperature monitoring of containment shell surface.

ATTENTION **PT100 acc. to figure 22 can not be used as dry run protection. Consider chapter 4.6 "mag-safe".**

4.3.3 Sleeve bearing temperature, jacketed pumps

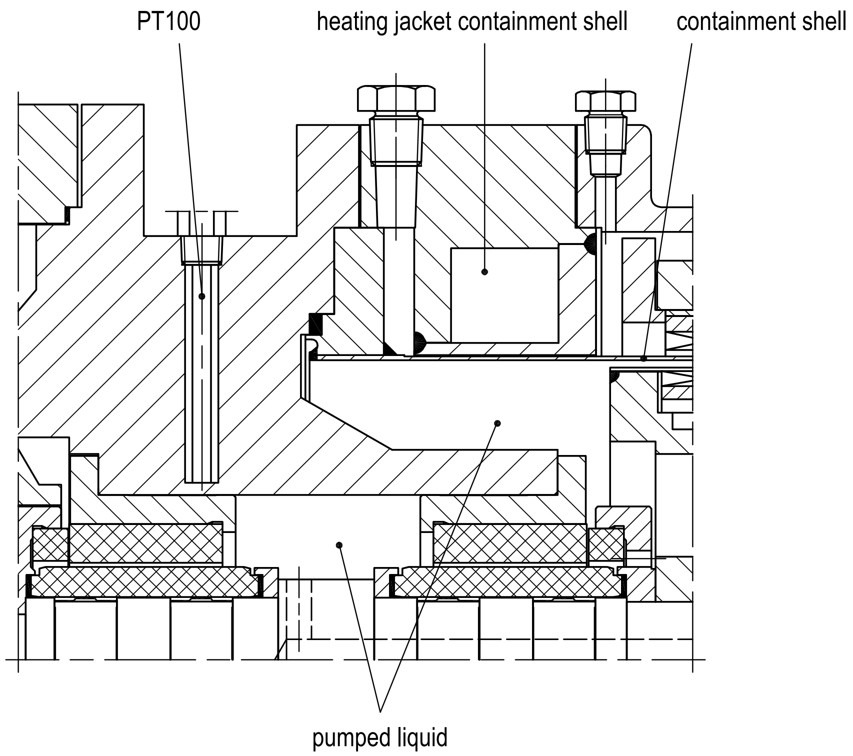


Fig. 23: PT100 for jacketed pumps

Function

For design and function of the PT100, see chapter 4.3.1.

PT100-arrangements as shown in figures 19 and 22 are installed to protect the pump against over-heating and vaporization of the liquid in the magnet coupling. This is not required for jacketed pumps because the pumping temperature is well below boiling point and the heating fluid keeps the temperature stable in the magnet end.

Problems resulting in serious failure can occur if the pumped liquid inside the pump is not completely melted at start-up. It is recommended to monitor the temperature inside the pump in the area of the front sleeve bearing using the PT100-arrangement according to figure 23. In this case, the pump cannot be started before the temperature at the PT100 exceeds the melting temperature.

ATTENTION **If no temperature monitoring is applied, an automatic pump start is not possible. In this case - after sufficient preheating - disconnect the motor, remove coupling guard and rotate the pump shaft by hand before start-up. If the pump shaft is tight, continue preheating.**

4.4 Containment shell protection, ball bearing monitoring

Contrary to the wear resistant SiC-sleeve bearings inside the pump, the outer ball bearings should be considered as wear parts. When the ball bearing wears significantly, the outer magnetic coupling will run eccentrically.

To avoid rubbing of the outer magnets on the containment shell surface, all DICKOW-magnetic coupled pumps are fitted with a mechanical shell protection device. The different clearances S_1 and S_2 ensure that the cover of the outer magnets touches the stationary bearing bracket before the magnets will touch the containment shell. Operators can recognize such upset conditions by increased noise, vibration and power consumption and switch off the driver before serious trouble occurs.

ATTENTION **However, if this condition is undetected, wear between cover and bearing bracket can cause cutting of containment shell through outer magnets. As a result, liquid would leak to the atmosphere. When handling dangerous liquids, additional monitoring devices are recommended. Consider also chapter 4.6 "mag-safe" and 4.5 "leakage monitoring".**

4.4.1 Monitoring with PT100

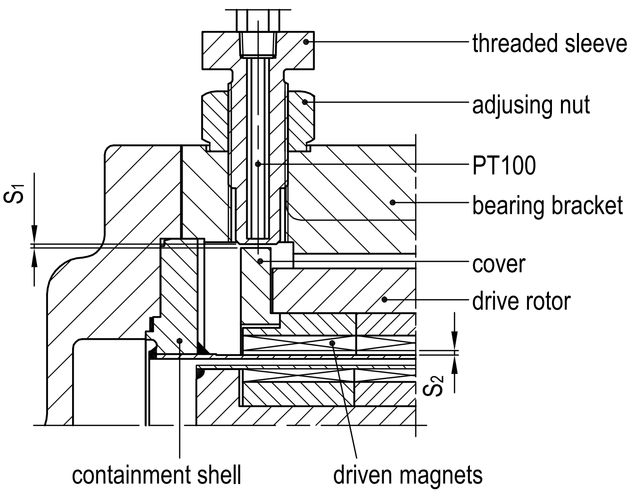


Fig. 24: PT100 to monitor antifriction bearings

Function

For design and function of the PT100, see chapter 4.3.1.

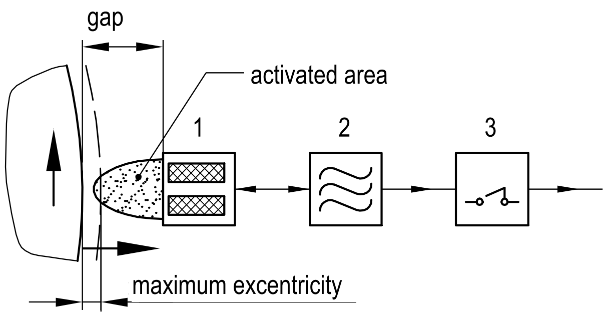
An eccentric running cover will touch the complete inner diameter of the bearing bracket. If the PT100-arrangement as shown in figure 24 is installed, the cover will touch the bottom of the sleeve. Friction heats up the PT100 immediately and the trip amplifier switches off the motor.

4.4.2 Monitoring with proximity switch

The arrangement shown in figure 25 monitors the gap between cover and bearing bracket and trips the drive motor if the eccentricity of the cover exceeds a certain limit. The advantage of this system is the avoidance of any contact between metallic parts respectively between cover and bearing bracket.

Function

For a better understanding of the monitoring principle, the unit can be divided into three separate elements:



1 Sensor with activated area
2 Oscillator
3 Trip amplifier with relay

Fig. 25: Proximity switch

The oscillator is fed by the amplifier with a certain voltage. With this voltage and a fixed ampere consumption, the oscillator builds up a resonant circuit. With the ferrit core in the sensor, the resonant circuit is concentrated to the activated area. If any metallic part touches the activated area, the resonant circuit breaks down and generates a change of ampere consumption in the oscillator. The trip amplifier reads this change and trips the motor by activating the relay.

4.5 Leakage monitoring, secondary mechanical seal

Sealless DICKOW-pumps with heavy duty oil lubricated bearing bracket can be supplied with a mechanical seal as an option in lieu of the inboard labyrinth seal. This mechanical seal separates the magnet area from the oil bath and atmosphere and forms, together with the closed bearing bracket, a secondary containment behind the containment shell. During normal operation, stationary and rotating seal ring are running contactless and wear free with unlimited lifetime. At a pressure rise in the bearing bracket of 50 kPa, the mechanical seal will be activated and the seal faces close.

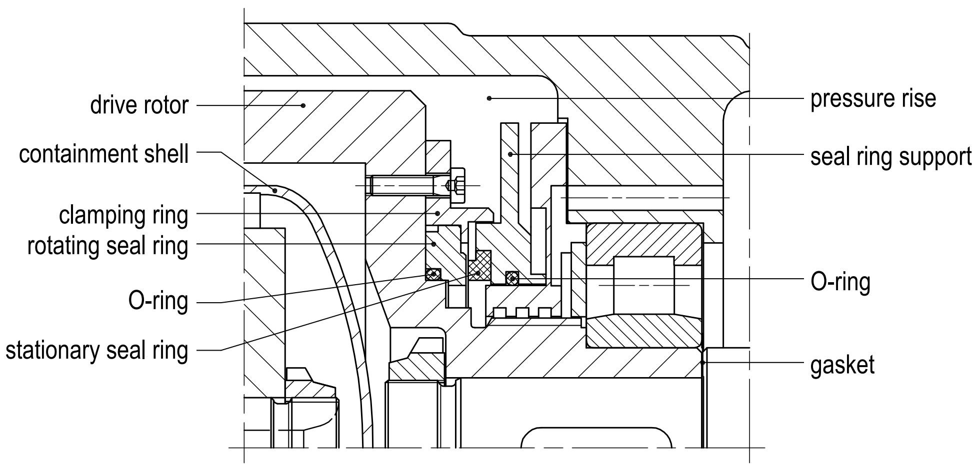


Fig. 26: Secondary mechanical seal

4.5.1 Leakage monitoring with optoelectronic level detector

A optoelectronic level detector can be fitted to the bearing bracket to monitor the secondary containment.

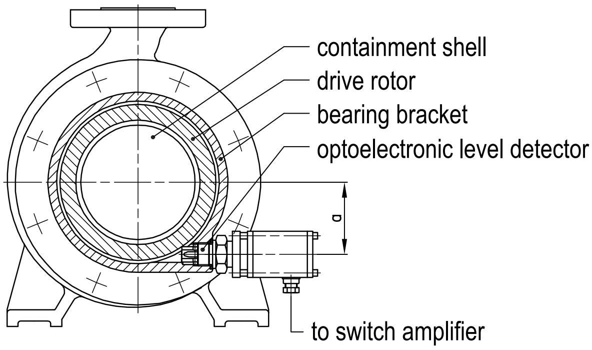


Fig. 27: Optoelectronic level detector

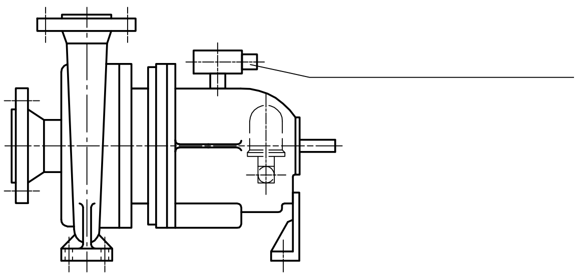
Function

For monitoring principle of the optoelectronic level detector, see chapter 4.2.1. Any leakage from the containment shell is collected at the bottom of the bearing bracket and will activate the level detector.

4.5.2 Leakage monitoring with pressure switch

Function

When handling volatile liquids (if vapour pressure of liquid at operating temperature is above atmospheric pressure) leakage from containment shell will be steam or gas. This leakage does not collect at the bottom, but will lead to a pressure increase in the bearing bracket.



The pressure switch is located at the highest point of the bearing bracket and shall be connected to the motor control (fig. 28).

Fig. 28: Pressure switch

4.6 "mag-safe" monitoring device for pumps

The most common temperature monitoring systems are PT100 elements.
The disadvantage of these elements is the location outside of the magnets.

This is proved by the test results shown in the graph below. Fig. 29 shows the temperature rise (T_2) at the PT100 and the temperature rise (T_1) in the center of the magnets during dry running of a pump over a period of 4 minutes.

In the center of the magnets the temperature rises very fast and can reach, depending on the magnetic losses, 350 - 500°C (660 - 930°F) already after 30 seconds. The temperature reading at the PT100 after 4 minutes is 40°C (105°F) only. These results prove that the PT100-probe cannot act as a dry running protection.

To obtain reliable readings from the PT100-probe, the pump must be vented respectively properly filled with pumped liquid and the internal circulation flow must transport the heat from the magnet center to the measuring spot of the PT100. This is provided in our NM-pumps with circulation from discharge to discharge by auxiliary impeller and the PT100 located at the return of the internal cooling flow (after passing the magnet area).

Problems with temperature rise can also occur through unreliable temperature reading of the PT100 in pumps with cooling flow circulation from discharge to suction, or in case of decoupled magnets and starved cooling flow.

The mag-safe is developed and designed for monitoring DICKOW-sealless pumps with metallic containment shells and preventing serious pump failures.
The mag-safe system is patented, Pat.No. 0610562. The Ni-thermocouple wire is spot-welded to the containment shell surface and forms a thermocouple. Contrary to the PT100, the mag-safe reads the temperature in the center of the magnets, between shell and magnets direct at the heat source. Temperature changes in the thermocouple generate voltage changes. The transducer converts these changes into a linear output signal of 4 to 20 mA. This gives the possibility to set any shut-off temperature within the range of -50 to +300°C (-60 to +570°F).

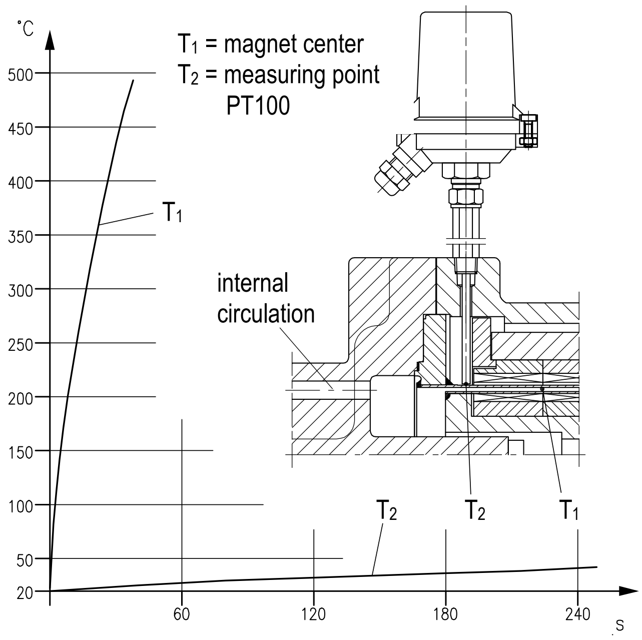


Fig. 29: Temperature during dry running

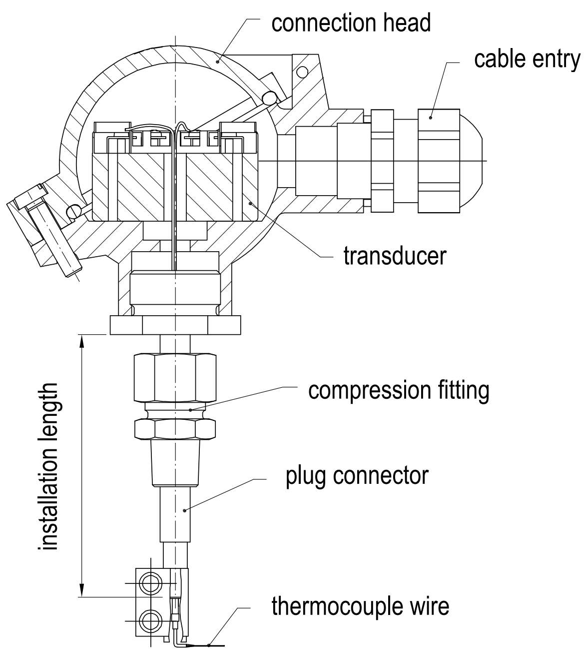


Fig. 30: Design mag-safe

Advantages / protective function

problem	symptoms	possible affects	protection through mag-safe
dry running	temperature rise, hot containment shell surface	damage of sleeve bearings, demagnetization of the magnets	alarm or immediate shut-off if the allowable temperature limit is exceeded
closed discharge valve, clogged circulation channels, operation below minimum flow		volatile liquids: vaporization of liquid in sleeve bearing area, failure of bearings through dry run non-volatile liquids: demagnetization of magnets through overheat	
decoupled magnets			
dry running through exceeded boiling point in containment shell area		vaporization of liquid in sleeve bearing area, failure of bearings through dry run	
solids/sediments between rotor and containment shell		rupture of the containment shell, leakage	
worn out antifriction bearings	increased vibrations and noise level	rupture of the containment shell through rubbing of drive rotor	shut-off when connection wire is cut

The mag-safe is highly recommended for handling boiling liquids, for liquids which tend to polymerize if a certain temperature is exceeded and for service conditions where no monitoring of antifriction bearings is provided.

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