Manual for the Design of Pipe Systems and Pumps

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1 GENERAL

Preface

Archimedes – the ingenious scientist of the ancient world – recognized the functionality of pumps as early as in the middle of the 3rd cent. B.C. Through the invention of the Archimedean screw, the irrigation of the fields became much more effective. 2200 years later GEA Hilge is building high-tech pumps for hygienic process technology giving the process lines the optimal impetus.

Selecting the right pump to serve the purpose is not always that easy and requires special knowledge. GEA Hilge has set up this manual for giving support in finding out the optimal pump design. Special attention was given to produce a manual that is interesting and informative for everybody, from the competent engineer to the layman.

The content is self-explanatory and built up one after the other. Simplifications were partly accepted and profound theories dispensed with. We hope that this manual will give you an extended comprehension of this subject and will help you solving any problems that might occur.

Explanation

Formula	Explanation	SI – Unit
B	Operating Point	–
D	Impeller diameter	mm
DN or d	Nominal width of the pipe or pump port	mm
g	Acceleration of the fall = 9.81 m/s^2	m/s^2
H	Flow head	m
H_A	Flow head of the system	m
H_{geo}	Geodetic flow head	m
$H_{s,geo}$	Geodetic suction head	m
$H_{d,geo}$	Geodetic pressure head	m
$H_{z,geo}$	Static suction head	m
H_z	Flow head viscous medium	m
H_v	Pressure drops	m
$H_{v,s}$	Pressure drops, suction side	m
$H_{v,d}$	Pressure drops, delivery side	m
K_H	Correction factor for the flow head	–
K_Q	Correction factor for the flow rate	–
K_h	Correction factor for the efficiency	–
k	Pipe roughness	mm
l	Pipe length	m
n	Speed	rpm.
$NPSH_{req.}$	NPSH (pump)	m
$NPSH_{avl}$	NPSH (system)	m
P	Power consumption	kW
P_z	Power consumption viscous medium	kW
p	Pressure	bar
p_a	Pressure at the outlet cross section of a system	bar
p_b	Air pressure / ambient pressure	bar
p_D	Vapour pressure of pumped liquids	bar
p_e	Pressure at the inlet cross section of a system	bar
Q	Flow rate	m^3/h
Q_z	Flow rate viscous medium	m^3/h
Re	Reynolds number	–
v	Flow speed	m/s
v_a	Flow speed at the outlet cross section of a system	m/s
v_e	Flow speed at the inlet cross section of a system	m/s
ζ (Zeta)	Loss value	–
η (Eta)	Efficiency of the pump	–
η_z (Eta)	Efficiency of the pump for viscous medium	–
λ (Lambda)	Efficiency value	–
ν (Ny)	Kinematic viscosity	mPas
η (Eta)	Dynamic viscosity	Pa s
ρ (Rho)	Density	t/m^3

2 INTRODUCTION

The requirements made on process plants steadily increase, both regarding the quality of the products and the profitability of the processes. Making liquids flow solely due to the earth's gravitational force is today unthinkable. Liquids are forced through pipes, valves, heat exchangers, filters and other components, and all of them cause an increased resistance of flow and thus pressure drops.

Pumps are therefore installed in different sections of a plant. The choice of the right pump at the right place is crucial and will be responsible for the success or failure of the process.

The following factors should be taken into consideration:
1. Installation of the pump
2. Suction and delivery pipes
3. The pump type chosen must correspond to product viscosity, product density, temperature, system pressure, material of the pump, shearing tendency of the product etc.
4. The pump size must conform to the flow rate, pressure, speed, suction conditons etc.

As a manufacturer and supplier of centrifugal pumps and positive displacement pumps we offer the optimum for both applications.

Generally spoken, the pump is a device that conveys a certain volume of a specific liquid from point A to point B within a unit of time.

For optimal pumping, it is essential before selecting the pump to have examined the pipe system very carefully as well as the liquid to be conveyed.

2.1 Pipe systems

Pipe systems have always special characterstics and must be closely inspected for the choice of the appropriate pump. Details as to considerations of pipe systems are given in Chapter 6, "Design of Centrifugal Pumps".

2.2 Liquids

Each liquid possesses diverse characteristics that may influence not only the choice of the pump, but also its configuration such as the type of the mechanical seal or the motor. Fundamental characteristics in this respect are:
- Viscosity (friction losses)
- Corrodibility (corrosion)
- Abrasion
- Temperature (cavitation)
- Density
- Chemical reaction (gasket material)

Besides these fundamental criteria, some liquids need special care during the transport. The main reasons are:
- The product is sensitive to shearing and could get damaged, such as yoghurt or yoghurt with fruit pulp
- The liquid must be processed under highest hygienic conditions as practised in the pharmaceutical industry or food industry
- The product is very expensive or toxic and requires hermetically closed transport paths as used in the chemical or pharmaceutical industry.

2.3 Centrifugal or positive displacement pump

Experience of many years in research and development of pumps enables GEA Hilge today to offer a wide range of hygienic pumps for the food and beverage industry as well as the pharmaceutical and dairy industry.

We offer efficient, operationally safe, low-noise pumps for your processes and this manual shall help you to make the right choice.

The first step on the way to the optimal pump is the selection between a centrifugal pump or a positive displacement pump. The difference lies on one hand in the principle of transporting the liquid and on the other hand in the pumping characteristic. There are two types of centrifugal pumps: “non-self priming” and “selfpriming”.

Centrifugal pumps are for most of the cases the right choice, because they are easily installed, adapted to different operating parameters and easily cleaned. Competitive purchase costs and reliable transport for most of the liquids are the reasons for their steady presence in process plants.

Restrictions must be expected in the following cases:

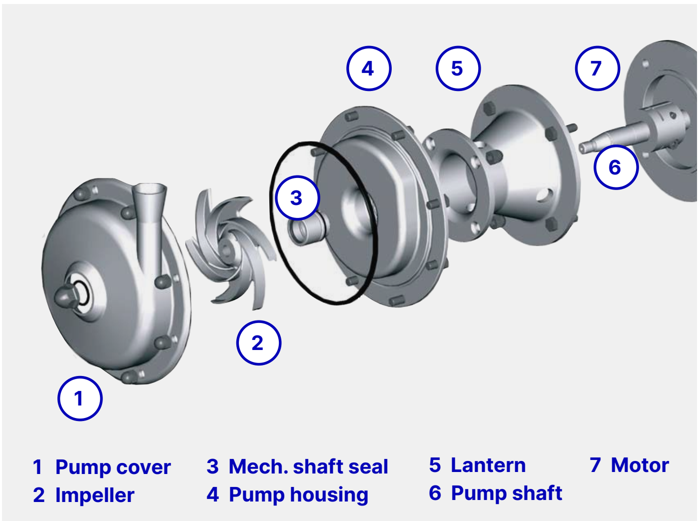
- with viscous media the capacity limit is quickly reached,
- the use is also restricted with media being sensitive to shearing,
- with abrasive liquids the service life of the centrifugal pump is reduced because of earlier wear.

2.4 GEA Hilge pump program

The GEA Hilge pump program conforms to today’s requirements made on cleanability, gentle product handling, efficiency and ease of maintenance. Various technical innovations made to the pumps ensure that the cleanability is optimized according to 3-A and EHEDG guidelines.

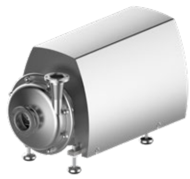
2.5 Applications

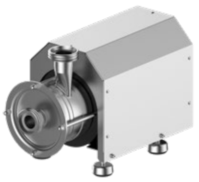
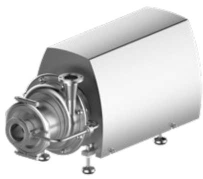
GEA Hilge pumps are preferably used in the brewing and beverage industry as well as in dairies and in process plants for pharmaceutical and health care products where highest hygienic standards are set. They are used in these industries mainly as transfer pumps, CIP supply pumps and booster pumps.

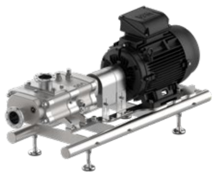


Main components (GEA Hilge TP; centrifugal pump)
Pump cover, impeller, pump housing, lantern, shaft and motor

2.6 Program overview

		GEA VARIPUMP		**GEA SMARTPUMP**	**GEA VARIPUMP**
		Centrifugal pumps			
					
		Single-stage			Multi-stage
		GEA Hilge HYGIA/HYGIA H	**GEA Hilge MAXA**	**GEA Hilge TP**	**GEA Hilge CONTRA**
2-pole, 50 Hz	Max. flow rate [m^3/h]	220	320	210	100
	Max. pump head [m]	77	100	90	200
	Motor rating [kW]	up to 45.0	up to 90.0	up to 45.0	up to 45.0
4-pole, 50 Hz	Max. flow rate [m^3/h]	110	1.450	100	–
	Max. pump head [m]	18	62	23	–
	Motor rating [kW]	up to 7.5	up to 160.0	up to 7.5	–
2-pole, 60 Hz	Max. flow rate [m^3/h]	175	300	240	100
	Max. pump head [m]	110	100	130	230
	Motor rating [kW]	up to 45.0	up to 90.0	up to 45.0	up to 45.0
4-pole, 60 Hz	Max. flow rate [m^3/h]	110	480	120	–
	Max. pump head [m]	26	88	34	–
	Motor rating [kW]	up to 7.5	up to 160.0	up to 7.5	–
	Surface roughness R_a [µm]	≤ 0.4 / ≤ 0.8 / ≤ 3.2	≤ 0.8 / ≤ 3.2	<=0.8 / ≤ 3.2	≤ 0.4 / ≤ 0.8 / ≤ 3.2
	Max. viscosity [mPas]	500, temporarily 1,000	500	500, temporarily 1,000	500
	System pressure [bar]	15 / 25 / 64	10	16	25

GEA SMARTPUMP	GEA VARIPUMP	GEA SMARTPUMP
		
	Self-priming	
GEA Hilge DURIETTA	**GEA Hilge SIPLA**	**GEA Hilge TPS**
8	–	125
72	–	95
up to 2.2	–	up to 45.0
5	78	–
3	47	–
0.25	up to 22.0	–
8	–	155
41	–	138
up to 2.2	–	up to 45.0
3	64	–
3	60	–
0.25	up to 22.0	–
≤ 3.2	≤ 3.2	≤ 3.2
500	1,000	500
8	10	16

GEA VARIPUMP		
Positive displacement pumps		
		
Rotary lobe	Twin-screw	
GEA Hilge NOVALOBE	**GEA Hilge NOVATWIN+**	
up to 2,1 l/rev	up to 330 m³/h	Displacement/ Flow rate
up to 16	up to 25	Max. differential pressure [bar]
up to 95 150 (SIP)	up to 180 135 (SIP)	Max. media temperature [°C]
bi-wing multilobe	4 Screw pitches per size	Rotor/Screw design
up to 41	up to 53	Max. particle size [mm] (non-abrasive)
1,000,000	1,000,000	Max. viscosity [mPas]
≤ 0.4 / ≤ 0.8	≤ 0.4 / ≤ 0.8	Surface roughness R_a [µm]
16	30	System pressure [bar]

3 PHYSICAL FUNDAMENTALS

Fluids – a subject matter of this manual – include liquids, gases and mixtures of liquids, solids and gases. All these fluids have specific characteristics that will be explained in this chapter.

3.1 Density

Density (ρ = Rho) – former specific weight – of a fluid is its weight per unit volume, usually expressed in units of grams per cubic centimeter (g/cm³).

Example: If weight is 80 g in a cube of one cubic centimeter, the density of the medium is 80 g/cm³. The density of a fluid changes with the temperature.

3.2 Temperature

Temperature (t) is usually expressed in units of degrees centigrade (°C) or Kelvin (K). The temperature of a fluid at the pump inlet is of great importance, because it has a strong effect on the suction characteristic of a pump.

3.3 Vapour pressure

The vapour pressure (pD) of a liquid is the absolute pressure at a given temperature at which the liquid will change to vapour. Each liquid has its own specific point where it starts to evaporate. Vapour pressure is expressed in bar (absolute).

3.4 Viscosity

Viscosity of a medium is a measure of its tendency to resist shearing force. Media of high viscosity require a greater force to shear at a given rate than fluids of low viscositiy.

3.5 Dynamic and kinematic viscosity

One has to distinguish between kinematic viscosity (ν = Ny) and dynamic viscosity (η = Eta). Centipoise (cP) is the traditional unit for expressing dynamic viscosity.

Centistokes (cSt) or Millipascal (mPa) express the kinematic viscosity.

$$\text{Ratio: kinematic viscosity} = \frac{\text{dynamic viscosity}}{\text{density}}$$

Viscosity is not constant and thus depending on external factors. The viscous behaviour of media is more clearly expresed in effective viscosity or shearing force. The behaviour of viscous fluids varies.

One distinguishes between Newtonian and Non-Newtonian fluids.

3.6 Fluid behaviour

The flow curve is a diagram which shows the correlation between viscosity (η) and the shear rate (D). The shear rate is calculated from the ratio between the difference in flow velocity of two adjacent fluid layers and their distance to eachother.

The flow curve for an ideal fluid is a straight line. This means constant viscosity at all shear rates. All fluids of this characteristic are "Newtonian fluids". Examples are water, mineral oils, syrup, resins.

Fluids that change their viscosity in dependence of the shear rate are called "Non-Newtonian fluids". In practice, a very high percentage of fluids pumped are non-Newtonian and can be differentiated as follows:

Intrinsically viscous fluids

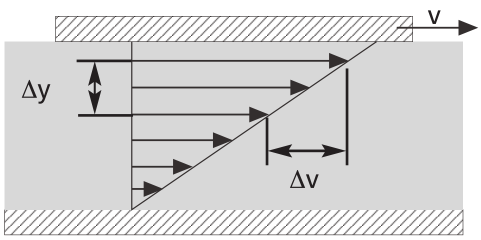
Viscosity decreases as the shear rate increases at high initial force. This means from the technical point of view that the energy after the initial force needed for the flow rate can be reduced. Typical fluids with above described characteristics are a.o. gels, Latex, lotions.

Dilatent fluids

Viscosity increases as the shear rate increases. Example: pulp, sugar mixture

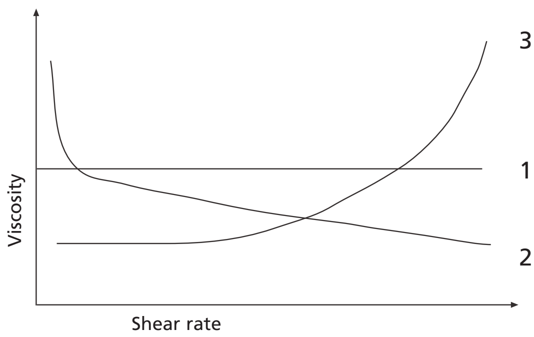
Thixotropic fluids

Viscosity decreases with strong shear rate (I) and increases again as the shear rate decreases (II). The ascending curve is however not identical to the descending curve. Typical fluids are a.o. soap, ketchup, glue, peanut butter.



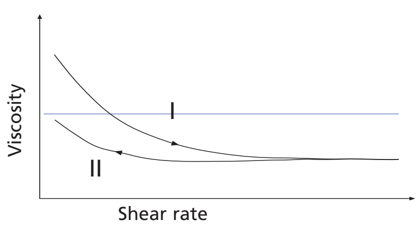
$$D = \frac{\Delta v}{\Delta y}$$

Shear rate



1 Newtonian fluids
2 Intrinsically viscous fluids
3 Dilatent fluids

Flow curves



Thixotropic fluids

4 HYDRAULIC FUNDAMENTALS

Pumps shall produce pressure. Fluids are conveyed over a certain distance by kinetic energy produced by the pump.

4.1 Pressure

The basic definition of pressure (p) is the force per unit area. It is expressed in this Manual in Newton per square meter ($N/m^2 = Pa$).

$$1 \text{ bar} = 10^5 \frac{N}{m^2} = 10^5 \text{ Pa}$$

4.2 Atmospheric pressure

Atmospheric pressure is the force exerted on a unit area by the weight of the atmosphere. It depends on the height above sea level (see Fig. 1). At sea level the absolute pressure is approximately 1 bar = 105 N / m². Gage pressure uses atmospheric pressure as a zero reference and is then measured in relation to atmospheric pressure. Absolute pressure is the atmospheric pressure plus the relative pressure.

Height above sea level m	Air pressure p_b bar	Boiling temperature °C
0	1,013	100
200	989	99
500	955	98
1,000	899	97
2,000	795	93

Fig. 1 – Influcence of the topographic height

4.3 Relation of pressure to elevation

In a static liquid the pressure difference between any two points is in direct proportion to the vertical distance between the two points only.

The pressure difference is calculated by multiplying the vertical distance by density.

In this manual different pressures or pressure relevant terms are used. Here below are listed the main terms and their definitions:

- Static pressure
  Hydraulic pressure at a point in a fluid at rest.
- Friction loss
  Loss in pressure or energy due to friction losses in flow.
- Dynamic pressure
  Energy in a fluid that occurs due to the flow velocity.
- Delivery pressure
  Sum of static and dynamic pressure increase.
- Delivery head
  Delivery pressure converted into m liquid column.
- Differential pressure
  Pressure between the initial and end point of the plant.

4.4 Friction losses

The occurance of friction losses in a pipe system is very complex and of essential importance when selecting the pump. Friction losses in components caused by the flow in the pipe system (laminar flow and turbulent flow) are specified by the pump manufacturer.

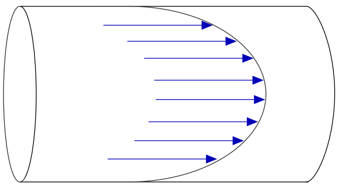


Fig. 2 – Laminar flow

There are two different types of flow Laminar flow is characterized by concentric layers moving in parallel down the length of the pipe, whereby highest velocity is found in the centre of the pipe, decreasing along the pipe wall (see Fig. 2). Directly at the wall the velocity decreases down to zero. There is virtually no mixing between the layers. The friction loss is proportional to the length of the pipe, flow rate, pipe diameter and viscosity.

In case of turbulent flow strong mixing takes place between the layers whereby the the velocity of the turbulences is extremely high.

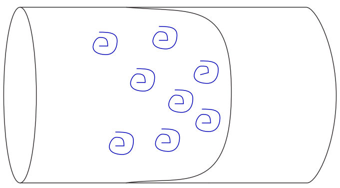


Fig. 2 – Laminar flow

Turbulent flow occurs mainly in low viscous fluids and is characterised by higher friction losses. The friction losses behave proportional to the length of the pipe, square flow rate, pipe diameter and viscosity.

4.5 Reynolds number

In transition between laminar flow and turbulent flow there is a multitude of so called „mixed flows“. They are characterised by a combination of properties of the turbulent flow and the laminar flow. For determination and simple computing of the specific characteristics the Reynolds number was introduced. This dimensionless number is the ratio of fluid velocity multiplied by pipe diameter, divided by kinematic fluid viscosity.

$$Re = v \times DN / \nu$$

Re = Reynolds number
v = Fluid velocity (m/s)
DN = Pipe diameter
ν = Kinematic fluid viscosity

General:
Laminar flow - if $Re < 2320$
Turbulent flow - if $Re \geq 2320$

5 TECHNICAL FUNDAMENTALS

This manual helps carrying out the optimal design of centrifugal pumps. We show you how to proceed to find the right pump.

5.1 Installation

Install the pump in close vicinity to the tank or to another source from which the liquid will be pumped. Make sure that as few as possible valves and bends are integrated in the pump's suction pipe, in order to keep the pressure drop as low as possible. Sufficient space around the pump provides for easy maintenance work and inspection. Pumps equipped with a conventional base plate and motor base should be mounted on a steady foundation and be precisely aligned prior commissioning.

5.2 Pipe connection

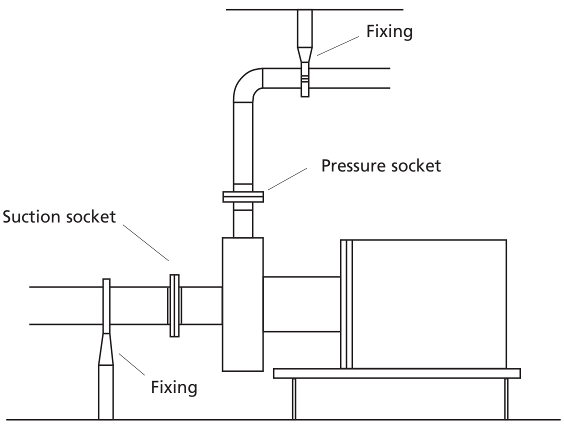
GEA Hilge pumps are equipped with pipe connections that are adaped to the flow rate. Very small pipe dimensions result in low cost on one hand, but on the other hand put the safe, reliable and cavitation-free operation of the pump at risk.

Practical experience has shown that identical connection diameters on a short suction pipe are beneficial, however, always keep an eye on the fluid velocity. Excepted thereof are long suction pipes with integrated valves and bends. In this case the suction pipe should be by one size larger, in order to reduce the pressure drop.

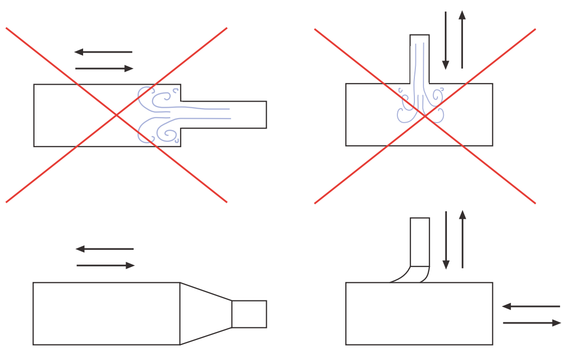
The pipes connected to the pump should always be supported in a way that no forces can act on the pump sockets. Attention must be paid to thermal expanson of the pipe system. In such a case, expansion compensators are recommended.

As long as the pump is mounted on adjustable calotte-type feet, the pump will be able to compensate slight pipe length expansions.

If the pump is rigid mounted on to a base plate, compensation must be ensured by the pipe system itself, using pipe bends or suitable compensators.



Pipe support



Right and wrong connection of a pipe

5.3 Suction pipe
It is important for most of the pumps – but especially for non-selfpriming centrifugal pumps that no air is drawn into the pump – as otherwise this would impair the pump performance. In the worst case the pump would stop pumping. Therefore the tanks should be designed and constructed in a way that no air-drawing turbulences occur. This can be avoided by installing a vortex breaker into the tank outlet. The locaton of the pump as well as the connection of the suction pipe must not cause the formation of air bubbles. When planning the suction pipe, sufficient length must be provided upstream the pump. This section should be in length at least five times the diameter of the inlet socket (Fig. 4).

5.4 Delivery pipe
Normally valves, heat exchangers, filters und other components are installed in the delivery pipe. The flow head results from the resistance of the components, the pipe and the geodetic difference. Flow rate and flow head can be influenced via the control fittings installed in the delivery pipe.

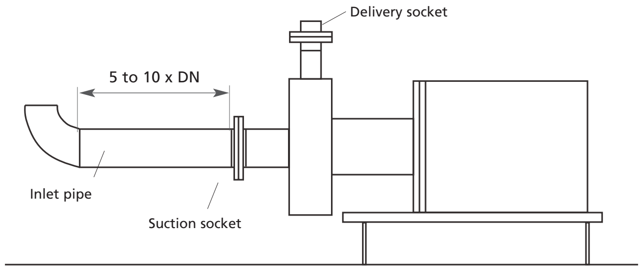


Fig. 4 – Distance to the inlet socket

5.5 NPSH
NPSH (Net Positive Suction Head) is the international dimension for the calculation of the supply conditions.

For pumps the static pressure in the suction socket must be above the vapour pressure of the medium to be pumped. The NPSH of the pump is determined by measurements carried out on the suction and delivery side of the pump. This value is to be read from the pump characteristic curve and is indicated in meter (m). The NPSH is in the end a dimension of the evaporation hazard in the pump inlet socket and is influenced by the vapour pressure and the pumped liquid. The NPSH of the pump is called NPSH required, and that of the system is called NPSH av(ai)lable. The $NPSH_{avl}$ should be greater than the $NPSH_{req}$ in order to avoid cavitation.

$NPSH_{avl} > NPSH_{req}$

For safety reasons another 0.5 m should be integrated into the calculation, i.e.:

$NPSH_{avl} > NPSH_{req} + 0.5$ m

5.6 Suction and supply conditions
Troublefree operation of centrifugal pumps is given as long as steam cannot form inside the pump; in other words: if cavitation does not occur. Therefore, the pressure at the reference point for the NPSH must be at least above the vapour pressure of the pumped liquid. The reference level for the NPSH is the centre of the impeller so that for calculating the $NPSH_{avl}$ according to the equation below, the geodetic flow head in the supply mode ($H_{z,geo}$) must be set to positive and in the suction mode (H) to negative.

$$NPSH_{avl} = \frac{p_e + p_b}{\rho \times g} - \frac{p_D}{\rho \times g} + \frac{v_e^2}{2g} - H_{v,s} + H_{s,geo}$$

p_e = Pressure at the inlet cross section of the system
p_b = Air pressure in N/m2 (consider influence of height)
p_D = Vapour pressure
ρ = Density
g = Acceleration of the fall
v_e = Flow speed
$H_{v,s}$ = Sum of pressure drops
$H_{s,geo}$ = Height difference between liquid level in the suction tank and centre of the pump suction socket

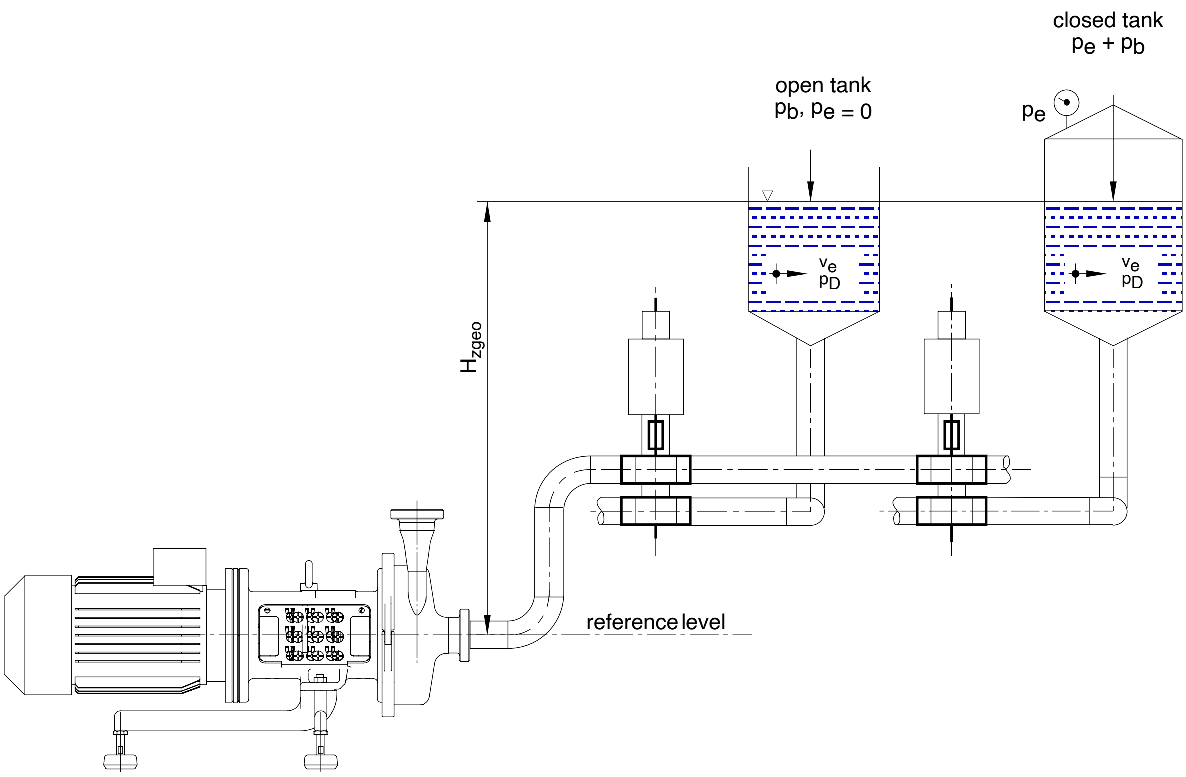
At a water temperature of 20 °C and with an open tank the formula is simplified:
$NPSH_{avl} = 10 - H_{v,s} + H_{z,geo}$

5.7 Cavitation

Cavitation produces a crackling sound in the pump. Generally spoken is cavitation the formation and collapse of vapour bubbles in the liquid. Cavitation may occur in pipes, valves and in pumps. First the static pressure in the pump falls below the vapour pressure associated to the temperature of a fluid at the impeller intake vane channel. The reason is in most of the cases a too low static suction head. Vapour bubbles form at the intake vane channel. The pressure increases in the impeller channel and causes an implosion of the vapour bubbles. The result is pitting corrosion at the impeller, pressure drops and unsteady running of the pump. Finally cavitation causes damage to the pumped product.

Cavitation can be prevented by:

1. Reducing the pressure drop in the suction pipe by a larger suction pipe diameter, shorter suction pipe length and less valves or bends
2. Increasing the static suction head and/or supply pressure, e.g. by an upstream impeller (Inducer)
3. Lowering the temperature of the pumped liquid



Pumping system

5.8 Q-H characteristic diagram

Before designing a pump, it is important to ascertain the characteristic curve of the plant that allows you to select the right pump by help of the pump characteristic curve.

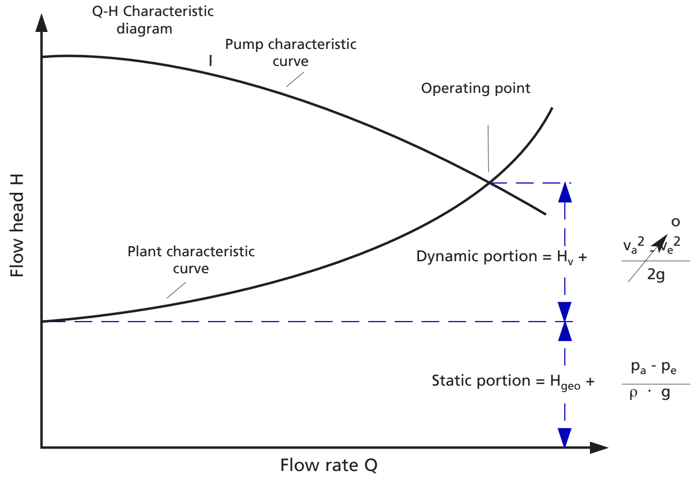


Fig 5 – Q-H Characteristic diagram

The operating performance of centrifugal pumps is rarely represented in the form of tables, but mainly in the form of characteristic curves (Fig. 5). These pump characteristic curves are measured at line machines at constant speed and show the flow rate (Q in m^3/h) and the flow head (liquid column in m) of the pump. The flow head H of a pump is the effective mechanical energy transferred by the pump to the pumped liquid, as a function of the weight force of the pumped liquid (in m liquid column). It is independent of the density (r) of the pumped liquid; that means a centrifugal pump transfers liquids regardless of the density up to the same flow head. However, the density must be taken into account for the determination of the power consumption P of a pump.

The actual flow head of the pump is determined by the flow rate H_A of the plant, which consists of the following components:

$$H_A = H_{geo} + \frac{p_a - p_e}{\rho \times g} + \frac{v_a^2 - \cancelto{0}{v_e^2}}{2g} + \Sigma H_v$$

H_{geo}	geodetic flow head = the difference in height to overcome between the liquid level of the suction and the delivery side
$\frac{p_a - p_e}{\rho \times g}$	difference of pressure heights between liquid level of the suction and delivery side with closed tanks
$\frac{v_a^2 - \cancelto{0}{v_e^2}}{2g}$	speed difference (can be neglected in practice)
Σ	H_v sum of pressure drops (pipe resistances, resistance in fittings and formed parts in suction and delivery pipes)

5.9 Flow rate

The flow rate (Q) accrues from the requirements of the process plant and is expressed in m^3/h or GPM (Gallons per minute).

5.10 Flow head

A decisive factor in designing a pump is the flow head (H), that depends on:

- the required flow head (for instance of a spray ball of 10 to 15 m; equal to 1.0 to 1.5 bar),
- difference in the pressure height of a liquid level on the delivery side and suction side,
- the sum of pressure drops caused by pipe resistance, resistance in components, fittings in the suction and delivery pipe.

5.11 Plant characteristic curve

The graphical representation of the flow head of a plant (H_A) in dependance of the flow rate (Q) is the characteristic curve of a pipe or plant. It consists of a static portion that is is independent of the flow rate and a dynamic portion in square with rising flow rate.

5.12 Operating point

The operating point of a pump is the intersection of a pump characteristic curve with the plant characteristic curve.

5.13 Pressure drops

Essential for the design of a pump are not only the NPSH, flow head and flow rate, but also pressure drops.

Pressure drops of a plant may be caused by pressure drops in:

- the pipe system,
- installed components (valves, bends, inline measurement instruments),
- installed process units (heat exchangers, spray balls).

Pressure drops H_v of the plant can be determined by help of tables and diagrams. Basis are the equations for pressure drops in pipes used for fluid mechanics that will not be handled any further.

In view of extensive and time-consuming calculation work, it is recommended to proceed on the example shown in Chapter 6.1. The tables in Chapter 8.2 and 8.3 help calculating the equivalent pipe length.

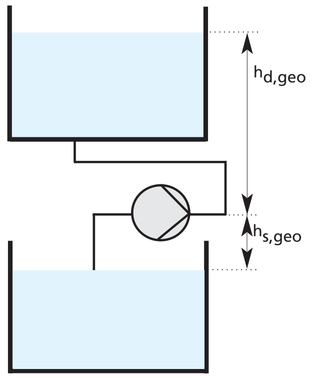
The data is based on a medium with a viscosity ν = 1 mPas (equal to water). Pressure drops for media with a higher viscosity can be converted using the diagrams in the annexed Chapter 8.5.

5.14 Theoretical calculation example

Various parmeters of the pipe system determine the pump design. Essential for the design of the pump is the required flow head. In the following, the three simplified theoritical calculation examples shall illustrate the complexity of this subject before in Chapter 6 the practical design of a pump is handled.

H_v = Pressure drop
$H_{v,s}$ = Total pressure drop – suction pipe
$H_{v,d}$ = Total pressure drop – delivery pipe
$H_{s,geo}$ = Geodetic head – suction pipe
$H_{z,geo}$ = Geodetic head – supply pipe
$H_{d,geo}$ = Geodetic head – delivery pipe
$H_{v,s}$ = Pressure drop – suction pipe
$H_{v,d}$ = Pressure drop – delivery pipe
p = Static pressure in the tank

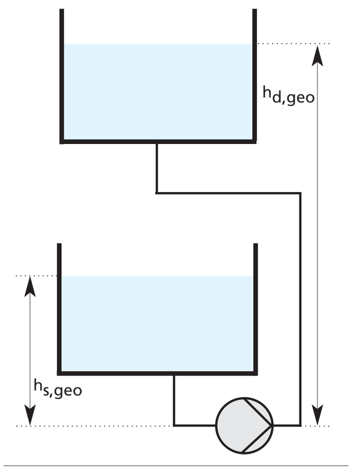
Attention:
Pressure in the tank or supplies in the suction pipe are negative because they must be deducted from the pressure drop. They intensify the flow.



Negative supply

Example 1 – Negative supply

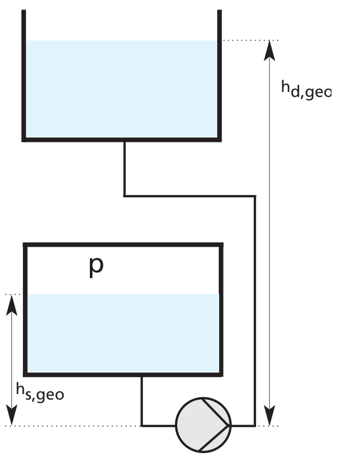
$H_{d,geo}$ = 25 m
$H_{v,d}$ = 10 m
$H_{s,geo}$ = 6 m (suction pressure)
$H_{v,s}$ = 3 m
$H_{v,d}$ = $H_{d,geo} + H_{v,d}$ = 25 m + 10 m = 35 m
$H_{v,s}$ = $H_{s,geo} + H_{v,s}$ + p = 6 m + 3 m + 0 m = 9 m
H_v = $H_{v,d} + H_{v,s}$ = 35 m + 9 m = 44 m



Supply under atmospheric pressure

Example 2 – Supply under atmospheric pressure

$H_{d,geo}$ = 10 m
$H_{v,d}$ = 5 m
$H_{z,geo}$ = −3 m (supply pressure)
$H_{v,s}$ = 2 m
$H_{v,d}$ = $H_{d,geo} + H_{v,d}$ = 10 m + 5 m = 15 m
$H_{v,s}$ = $H_{z,geo} + H_{v,s}$ + p = −3 m + 2 m + 0 m = −1 m
H_v = $H_{v,d} + H_{v,s}$ = 15 m −1 m = 14 m



Supply from pressure tank

Example 3 – Supply from pressure tank

$H_{d,geo}$ = 5 m
$H_{v,d}$ = 3 m
$H_{z,geo}$ = −2 m
$H_{v,s}$ = 1 m
p = 8 m
$H_{v,d}$ = $H_{d,geo} + H_{v,d}$ = 15 m + 3 m = 18 m
$H_{v,s}$ = $H_{z,geo} + H_{v,s}$ + p = −2 m + 1 m + (−8 m) = −9 m
H_v = $H_{v,d} + H_{v,s}$ = 18 m + (−9 m) = 9 m

5.15 CIP / SIP

In industries where hygiene and product quality are paramount, such as food and pharmaceuticals, the cleanliness of pump systems is non-negotiable. To ensure the safe transfer of high-quality products, thorough cleaning procedures are essential. This is where Cleaning in Place (CIP) comes into play.

CIP is a standard cleaning process designed to eliminate all traces of product from the pump system without the need for dismantling. This efficient method utilizes specialized CIP fluids to cleanse the system, maintaining hygiene standards and preparing the equipment for the next production cycle.

The CIP process typically involves several key steps:

1. Preliminary Rinsing: The system is rinsed with water to remove initial debris and contaminants.
2. Flushing with Alkaline Solution: An alkaline solution is circulated through the system to dissolve and remove organic residues.
3. Intermediate Rinsing: A thorough rinse with water to remove any remaining cleaning agents.
4. Flushing with Acid: Acid is circulated to neutralize alkaline residues and sanitize the system.
5. Final Rinse: The system is rinsed with clean water to ensure all cleaning agents are completely removed.

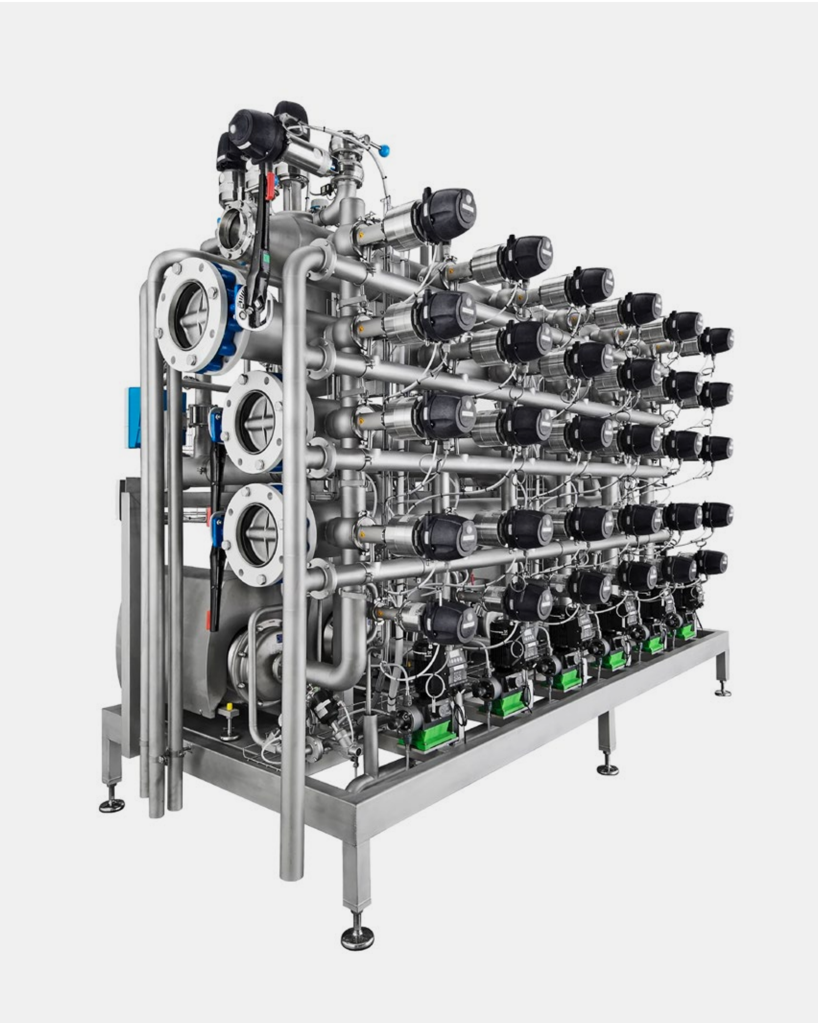
For effective CIP, a turbulent flow of the cleaning fluid is crucial. In pipes, a minimum flow velocity of 2 m/s is typically required to achieve thorough cleaning. However, when transferring viscous fluids with positive displacement pumps at low flow velocities, additional cleaning pumps, such as centrifugal pumps, may be necessary to meet the flow rate requirements for CIP.

Our pumps are specifically designed to meet the demands of CIP cleaning. They boast features such as welded and ground joints, smooth internal surfaces, and O-rings immersed in the pump housing to minimize the risk of contamination. With rounded edges, no narrow gaps or dead ends, and high surface finishes, our pumps ensure thorough cleaning and maintain hygienic standards with ease.

In some industries, such as pharmaceuticals and highly sensitive food production, an additional Sterilization in Place (SIP) process may be required after CIP cleaning. SIP effectively eliminates any remaining microorganisms that may pose a risk to product integrity.

Sterilization methods can vary, including chemical treatments, hot water, or steam. In the dairy industry, for instance, sterilization temperatures may reach approximately 145°C to ensure complete microbial inactivation.

By incorporating CIP and SIP processes into our pump systems, we ensure not only the highest standards of cleanliness but also the integrity and safety of your products. Trust in our pumps for reliable, hygienic performance every time.



6 DESIGN OF CENTRIFUGAL PUMPS

By help of the example below and the annexed summarised diagrams and tables all the centrifugal pumps can be designed. The tables contain GEA specific valves and pipe fittings. For the calculation of pressure drops in a plant, the conversion principle of the measured friction factor (ζ) of valves and fittings in metre equivalent pipe length is applied.

6.1 Practical calculation example (Fig. 6)

6.1.1 Calculation

Pressure drop of the plant

$$H_A = H_{geo} + \frac{p_a - \overset{0}{p_e}}{\rho \times g} + \frac{v_a^2 - \overset{0}{v_e^2}}{2 \times g} + \Sigma H_v$$

$H_{geo} = H_{d,geo} - H_{z,geo} = 10\ m - 4\ m = \underline{6\ m}$

$\Sigma H_v = H_{v,s} + H_{v,d}$

$H_{v,s}$

1 Tank outlet	= 0.8 m eqv.pipe"
1 Double seat valve DN 65 flow through (seat)	= 22.5 m "
1 Double seat valve DN 65 flow through (housing).	= 2.9 "
1 Reducer DN 65	= 0.2 m
5 Bends 90° DN 65	= 5 x 0.6 m
10 m pipe DN 65	<u>10.0 m</u>
	Σ = 40.2 m

see Page 37 Page 36 (and 40 - 44)

Pressure drop H_v at 24 m³/h DN 65

$$40{,}2 \times \frac{6.5\ m}{100\ m} = 2{,}62$$

$H_{v,s} = \underline{2.6\ m}$

$H_{v,d}$

1 Double seat valve DN 50 flow through (seat)	=10.5 m eqv. pipe
1 Normal valve DN 50 flow through (seat)	= 2.2 m "
10 Bends 90° DN 50	= 10 x 0.45 m "
20 m pipe DN 50	<u>20.0 m</u>
	Σ = 37.2 m

see Page 37 Page 36 (and 40 - 44)

Pressure drop H_v at 24 m³/h DN 50

$$37{,}2 \times \frac{25.0\ m}{100\ m} = 7{,}44$$

Heat exchanger at 24 m³/h	= 12.0 m
Spray ball at 24 m³/h	= <u>5.0 m</u>
	24.4 m =>

$H_{v,d} = \underline{24.4\ m}$

$H_A = H_{geo} + H_{v,s} + H_{v,d}$
$= 6\ m + 2.6\ m + 24.4\ m$
$H_A = \underline{33\ m}$

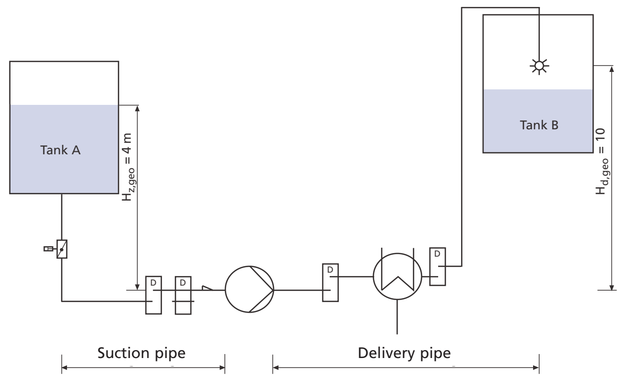


Fig. 6 – Pressure drop in a plant

6.1.2 Explanations

The flow rate is 24 m^3/h. Components and process units are installed in the pipe between Tank A to be emptied and Tank B to be filled. As already mentioned before, it is essential to install the pump as close as possible to the tank to be emptied.

Between Tank A and the pump are located a butterfly valve and two double seat valves as well as one reducer and 5 bends and finally 10 m pipe in DN 65.

In the pipe from the pump up to Tank B (20 m in DN 50) are installed a double seat valve, a single seat valve, one heat exchanger and one spray ball. The difference in elevation of the liquid level in Tank A to Tank B is 6 m. Now the metre equivalent pipe length must be determined for each component installed. For this purpose see the standard tables for pressure drops on page 36 and 37. The outcome is in total 40.18 m on the suction side. This value is converted into the corresponding pressure drop (H) of the pipe, cross section DN 65.

According to the table, the pressure drop is 6.5 m per 100 m at a flow rate of 24 m^3/h and with a pipe DN 65. Based on 40.18 m, the pressure drop ($H_{v,s}$) is 2.61 m. Downstream the pump, the liquid must be conveyed in length equivalent pipe of 37.2 m in total. The pressure drop of a pipe in DN 50 is according to the table 25 m per 100 m. Based on 37.2 m, the pressure drop is 7.4 m. In addition, on the delivery side there is a heat exchanger with a pressure drop of 12 m (at 24 m^3) as well as a spray ball at the end of the pipe with a pressure drop of 5 m. In total the pressure drop on the delivery side ($H_{v,d}$) is 24.4 m. The sum of pressure drops on the suction side ($H_{v,s}$), on the delivery side ($H_{v,d}$) and the geodetic flow head (H_{geo}), result in a total pressure drop (H_A) of 33.0 m that must be compensated by the pump.

6.1.3 Calculation of the NPSH

The next step is the calculation of the NPSH of the plant that finally complete the parameters needed for the design of your pump.

The calculation of the NPSH takes only the suction pipe into consideration.

The calculated NPSH of the plant is 9.4 m and must be above that of the pump. Using this data now available, the plant characteristic curve can be ascertained.

$$NPSH_{avl} = \frac{p_e + p_b}{\rho \times g} - \frac{p_D}{\rho \times g} + \overbrace{\cancel{\frac{v_e^2}{2g}}}^{0} - H_{v,s} + H_{z,geo}$$

$$= \underset{}{10\ m} \; - \underset{\text{Vapour pressure at 60°C from page 38}}{2.0\ m} \; - \underset{\text{Flow head}}{2.6\ m} \; + \underset{\text{static suction head}}{4\ m} \; = \underset{NPSH_{avl}}{9.4\ m}$$

$NPSH_{avl}$ = 9.4 m must be above the $NPSH_{pump}$

6.2 Characteristic curve interpretation

The flow rate, flow head, the required motor power, the NPSH and efficiency of the pump are indicated in the pump characteristic.

On the example shown on the right it is explained how a pump characteristic is to interprete.

Values ascertained so far (from Chapter 6.1):
Flow rate = 24.0 m³/h
Req. flow head = 33.0 m
$NPSH_{avl}$ = 9.4 m

These are the relevant values for finding out the optimal pump by use of diagrams.

<u>Step 1</u>
The first diagram to be used is the Q/H Diagram (Fig. 7 – the diagram of a TP 2030). First the intersection point of the flow rate (24 m³/h) with flow head (33 m) should be made out. The intersection point is located in the area of the impeller of 160 mm in diameter.

<u>Step 2</u>
The pump efficiency (η) is read in Fig. 7 and amounts to approximately 57 %.

<u>Step 3</u>
The NPSH/Q Diagram (Fig. 8) shows the $NPSH_{req}$, that amounts to 1.9 m.

<u>Step 4</u>
The impeller diameter of 160 mm is required in order to read out the required motor power in the Q/P Diagram (Fig. 9). Accordingly, at a flow rate of 24 m³/h the motor power is 3.7 kW. Fluctuations in volume and pressure must be expected in the plant and consequently fluctuations of the operating point, that causes variation of the power consumption P of the pump. This is the reason why in principle an increased factor of 5 % is fixed.

The result is that the motor size should be at least to 4 kW (the required 3.7 kW plus increased safety). The next larger sized standard motor has 4 kW and should therefore be selected.

The power consumption of a pump can also be calculated using the formula

$$P = \frac{\rho \times Q \times H}{\eta \times 367}$$

and using the diagrams, the missing parameters for the optimal pump design are made available.

The required flow rate of 24 m³/h and the specified flow head of 33 m require the use of the pump TP 2030 with an impeller diameter 160 mm and 4 kW motor capacity at n = 2,900 rpm and 50 Hz.

The efficiency of this pump is about 57 % and the NPSH of the pump (1.9 m) does not exceed the NPSH of the plant (9.4 m > 1.9 + 0.5 m) so that cavitation does not occur. Accordingly, the pump is suitable for the application in question.

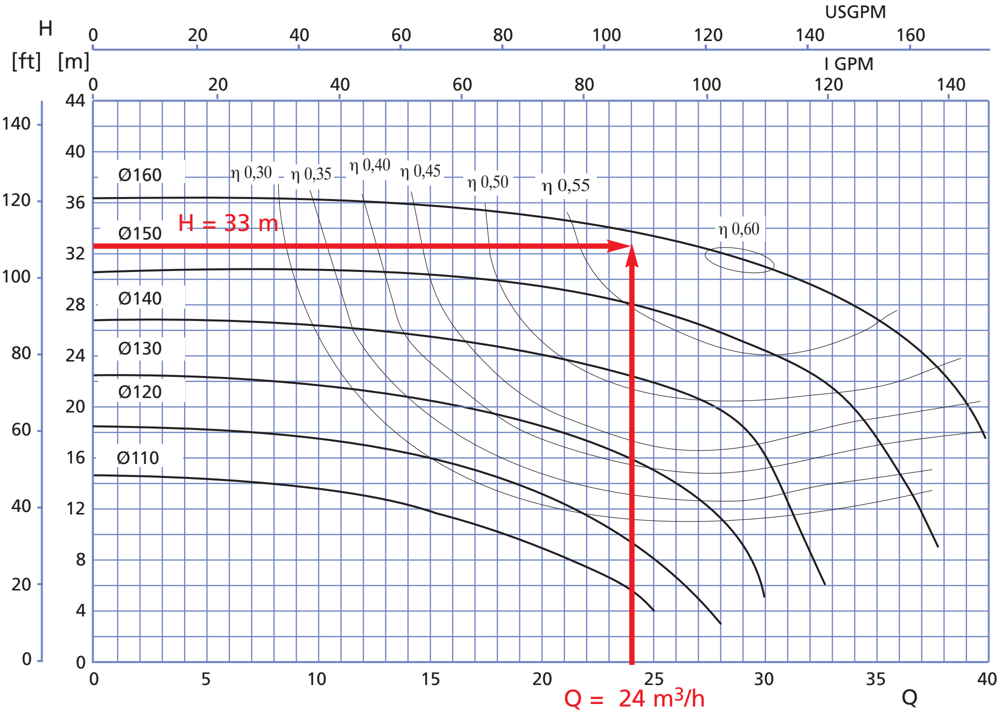


Fig. 7

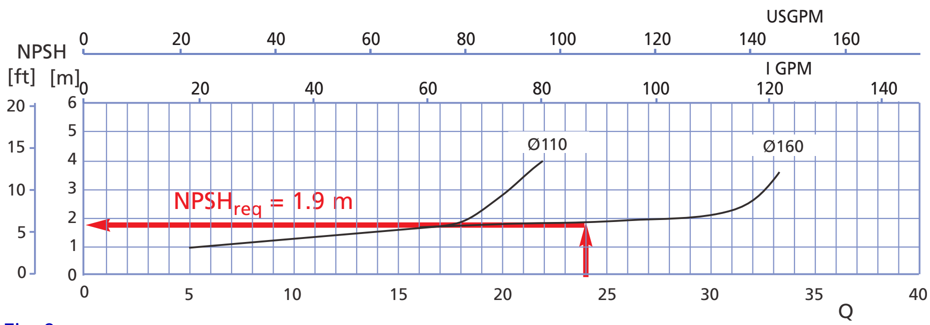


Fig. 8

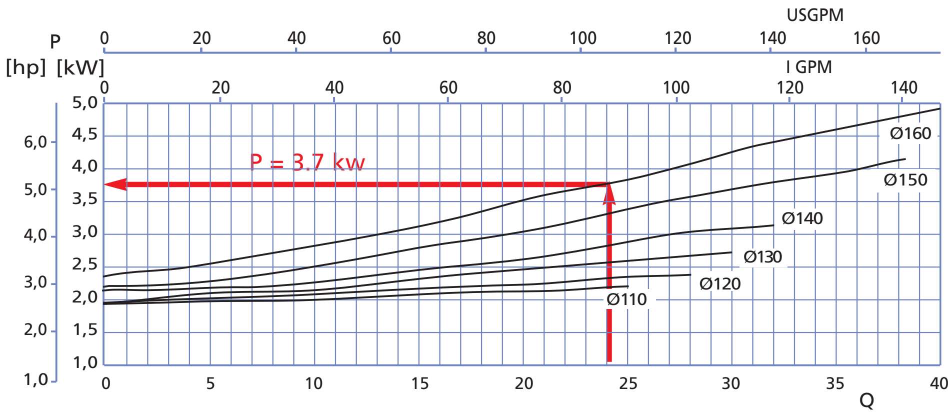


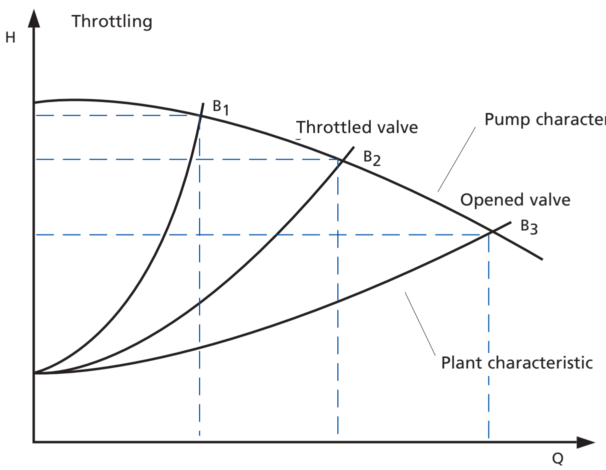
Fig. 9

6.3 Modification

In the previous example the pump design took place in four steps. In practice, however, pumps are used at different operating points. These may be pumping of viscous media, temperature changes or systems with integratation of pressurised tanks.

6.3.1 Throttling

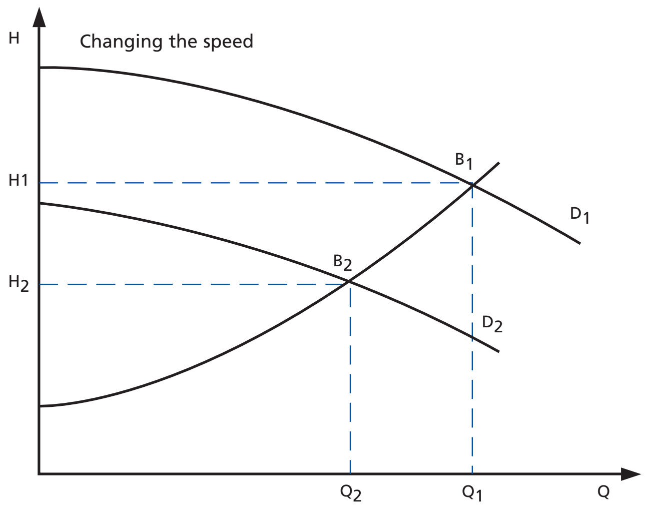
Changes in the flow head of a system H_A (throttling) are realised in practice by increasing or reducing the resistance on the delivery side of the pump, e.g. by installing a throttling valve. In this case the operating point is always located on the intersection of the plant characterstic curve with the pump characteristic curve.



Throttling

6.3.2 Changing the speed

Changing the speed (n) causes a change of the operating point and thus of the flow rate (Q) and the flow head (H). For this purpose a frequency converter or a pole changing motor is needed. In spite of the high purchase costs for a frequency converter, its use is in view of the operating costs the clearly more favourable alternative to the throttling process with a throttling valve. Speed control is used, if different operating points shall be achieved, e.g. for product and cleaning liquid.

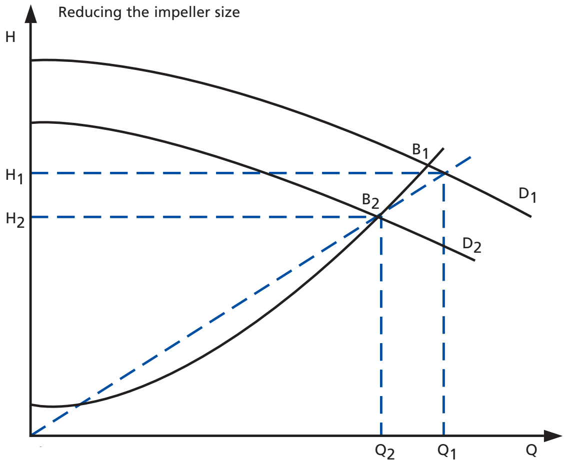


$$Q_2 = \frac{n_2}{n_1} \times Q_1 \qquad H_2 = \left[\frac{n_2}{n_1}\right]^2 \times H_1 \qquad P_2 = \left[\frac{n_2}{n_1}\right]^3 \times P_1$$

Changing the speed

6.3.3 Reducing the impeller size

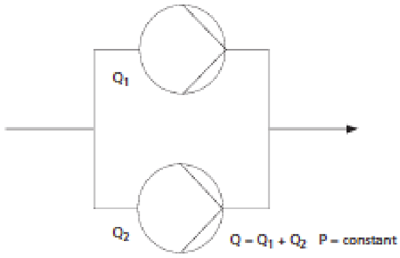
GEA Hilge offers for each pump different impeller sizes. It may happen that the best efficiency point of the impeller is located between two characteristic curves. The impeller will then be turned to size in order to obtain the required diameter. This is both the most simple and favourable method.



Reducing the impeller size

6.3.4 Operation in parallel

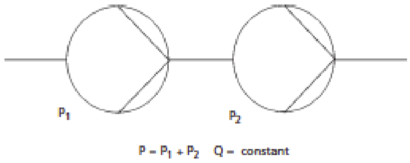
Two pumps can be operated in parallel, if the desired operating point cannot be reached with only one pump. In such a case the flow of the two pumps are added while the flow head remains unchanged.



Operation in parallel

6.3.5 Operation in series

If the required flow head cannot be achieved by one pump only, two pumps are connected in series. Thus the flow head is doubled at constant flow rate.



Operation in series

6.4 Pumping of viscous media

In the previous example (Chapter 6.1) water served as pumping medium. In practice media other than water are conveyed. In this respect viscosity is a factor that must be taken into account for the calculation and design of the pump.

Conveying liquids of higher viscosity (ν) at constant speed (n), reduce the flow rate (Q), flow head (H) and the efficiency (η) of the pump, while power consumption Pz of the pump (see Fig. 10) increases tt the same time. According to the method of approximation, (6.4.2) the suitable pump size can be determined, starting from the operating point for viscous liquids via the operating point for water. The pump's power consumption depends on the efficiency of the complete unit.

Annexed are tables used for the determination of pressure drops in dependence of viscosity and pipe diameter. In this connection it is worthwhile to mention that the pressure drop in dependence of viscosity is irrelevant for centrifugal pumps and can therefore be neglected. Centrifugal pumps are suitable for liquids up to a viscosity of 500 mPas.

If it is the question of pumping viscous media such as quarg, butter or syrup, positive displacement pumps will be used due to their higher efficiency in this respect.

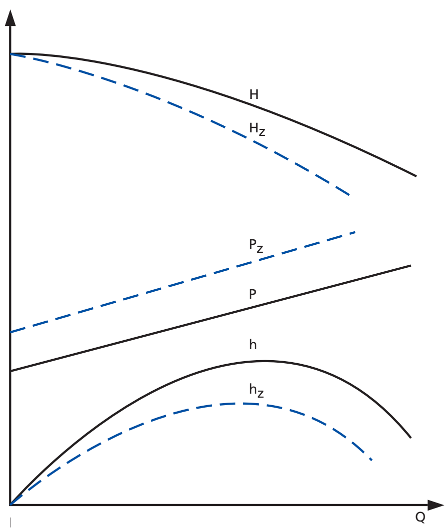


Fig. 10

<u>6.4.1 Correction for high viscosities</u>

The following page shows an example that explains the calculation and design of a pump used for viscous media. Decisive in this connection are the correction factors for the flow head (KH), flow rate (KQ) and the pump efficiency (Kη).

The correction factors are found in the diagram on page 29, by proceeding in the following steps:

1. Find out the kinematic viscosity of the medium in mPas
2. Determine product of Q x √H (m^3/h √m)
3. Set up a vertical at the intersection of Q x √H with the corresponding viscosity
4. Reading the intersections with the three correction lines at the vertical
5. Enter these values into the equations and calculate the corrected value

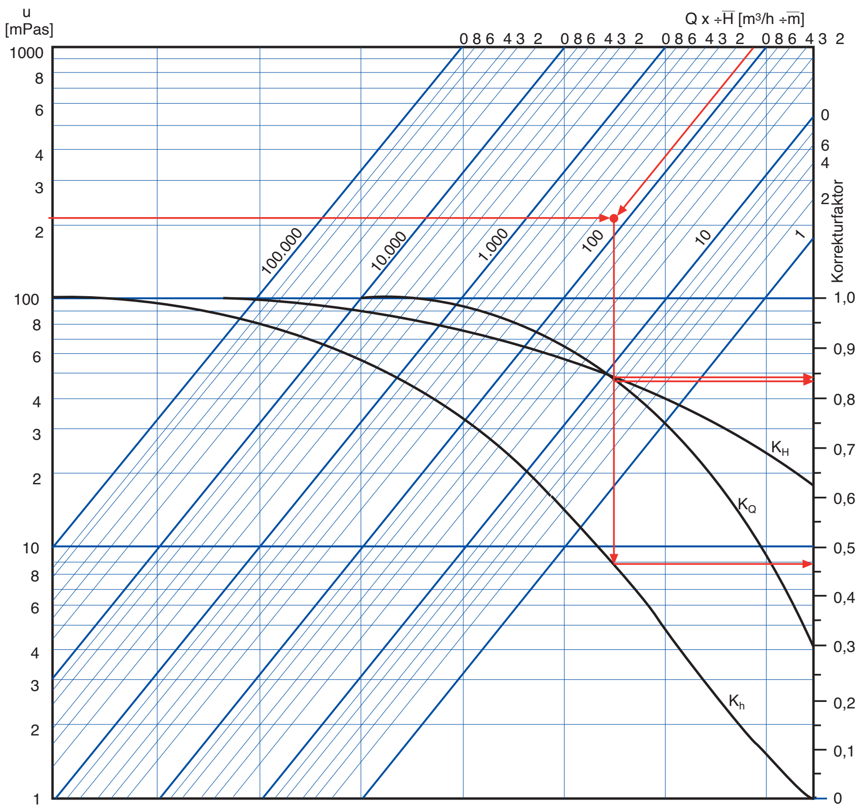
On the basis of the obtained values, the pump can be desigend by means of the pump characteristic for water (see Chapter 6.2).

<u>6.4.2 Calculation of correction factors</u>

Pumping medium: Oil
Flow rate: Q = 24 m^3/h
Flow head: H = 33 m
Viscosity: ν = 228 mPas
Density: ρ = 0.9 t/m^3
Efficiency: η = 0.55 %

A vertical is set up cutting KH, KQ and Kη at the intersection of the horizontal viscosity line coming from the left side with the diagonal Q x √H line.

From each of the newly created intersections, a horizontal leads to the right hand side, on to the correction factors. The reading is: KQ = 0.83, KH = 0.84, Kη = 0.47



The pump should be designed for the following pump data based on water:

$$Q = \frac{Q_z}{K_Q} = \frac{24}{0.83} = 28.9 \text{ m}^3/\text{h}; \quad H = \frac{H_z}{K_H} = \frac{33}{0.84} = 39.29 \text{ m}$$

Fill into the formula for the power consumption (P_z), the efficiency (η) from the „water flow head diagram".

$$\text{power consumpt. } P_z = \frac{Q_z \times H_z \times \rho}{367 \times K_\eta \times \eta}$$

$$= \frac{24 \times 33 \times 0{,}9}{367 \times 0.47 \times 0.55} = 7.52 \text{ kW}$$

Higher accuracy is achieved by repeating the procedure with the data obtained.

Result: After correction using the factors K_Q, K_H and K_η, a pump must be selected for pumping oil and a flow head of 24 m³/h that is capapable of achieving 29 m³/h and 39 m flow head. The required motor power is at least 7.5 kW.

6.5 Inquiry Sheet

Inquiry Sheet · Centrifugal Pumps 1/2

GEA Engineering for a better world.

GEA Hygienic Pumps

Contact Data

Company: ______________________ E-mail: ______________________

Contact Person: ______________________ Country: ______________________

Phone: ______________________ Country of Installation: ______________________

Preferred Range

☐ VARIPUMP ☐ SMARTPUMP ☐ No preference

Liquid Data

*Liquid: ______________________ Solids: ☐ No ☐ Yes:

*Liquid temperature [°C / °F]: ______________________ Kind of solids: ______________________

*Density [kg/dm³]: ______________________ Size of solids [mm]: ______________________

*Viscosity [mPas]: ______________________ Abrasive: ☐ No ☐ Yes

Concentration [%]: ______________________

Operating Conditions

*Duty point 1 *Flow [m³/h / gpm]: ______________________ *Head [m lc]: ______________________

Duty point 2 Flow [m³/h / gpm]: ______________________ Head [m lc]: ______________________

☐ End-suction pump: ☐ Self-priming pump:

Inlet pressure (NPSHa) [m]: ______________________ Suction head [m]: ______________________

Vacuum at inlet: ☐ No ☐ Yes: Gas content: ☐ No ☐ < 5 % ☐ > 5 %

Vacuum, abs. [mbar]: ______________________

System pressure [bar]: ______________________

Cleaning / Sterilization

CIP: ☐ No ☐ Yes: SIP: ☐ No ☐ Yes:

CIP Temperature [°C / °F]: ______________________ SIP Temperature [°C / °F]: ______________________

CIP Flow [m³/h / gpm]: ______________________

CIP Head [m Fls]: ______________________ SIP Duration [min]: ______________________

Pump execution

***Connection Type**

☐ Tri Clamp (DIN 32676) ☐ ANSI Flange ☐ DIN 11851

☐ DIN 11853-2 / 11864-2 ☐ Other: ______________________

Connection Size DN_I/DN_O: ______________________

Other: ______________________

Drainable: ☐ No ☐ Yes

Execution and Design

☐ Pump in Bloc version with motor ☐ Combi foot ☐ Motor foot

☐ Pump in long coupled version with base plate and standard motor ☐ On Trolley ☐ Horizontal

☐ With stainless steel motor shroud ☐ Cast iron foot ☐ Vertical

☐ 3-A stainless steel adjustable feet ☐ Stainless steel foot ☐ Vertical w. stainless steel stand

Engineering for a better world.

GEA Hygienic Pumps

Surface Roughness
- Not specified
- $R_a \leq 3.2$ µm
- $R_a \leq 0.8$ µm
- $R_a \leq 0.4$ µm

Ferrite Content
- Not specified
- Fe < 1%

Shaft Seal
- Single mechanical seal
- Flushed mechanical seal

Material Shaft Seal
- Carbon / Stainless Steel
- SiC / SiC
- Carbon / SiC
- Other: ______

Elastomer
- EPDM
- FKM (Viton)
- Other: ______

Motor Data

*Power supply:
- 3~ 400 V / 50 Hz
- 3~ 200 V / 50 Hz
- Other: ______
- 3~ 460 V / 60 Hz
- 3~ 200 V / 60 Hz
- 3~ 380 V / 60 Hz

Motor speed [1/min]: ______

PTC-Thermistors: No Yes

2 wire-Thermistors: No Yes

Variable speed drive No Yes:
- External frequency converter (not on motor)
- Integrated frequency converter (on motor)

Explosion protection No Yes

ATEX No Yes:

Ex-Zone: ______

Temperature class: ______

Ambient temperature [°C / °F]: ______

EXP Motor No Yes:

Temperature class: ______

Ambient temperature [°C / °F]: ______

Class: ______

Division: ______

Group: ______

Certificates / Documentation

- 3-A Sanitary Standard certification
- Inspection certificate 3.1 acc. to DIN EN 10204
- Test report 2.2 acc. to DIN EN 10204
- EHEDG certification
- Further certificates and documentation: ______
- FDA declaration of conformity
- Surface roughness test report
- Delta ferrite test report

Further Information

* Fields marked with an asterisk are mandatory for a pump selection

Selected options subject to confirmation by our offered portfolio

09/2022

7 DESIGN OF POSITIVE DISPLACEMENT PUMPS

7.1 Fundamentals

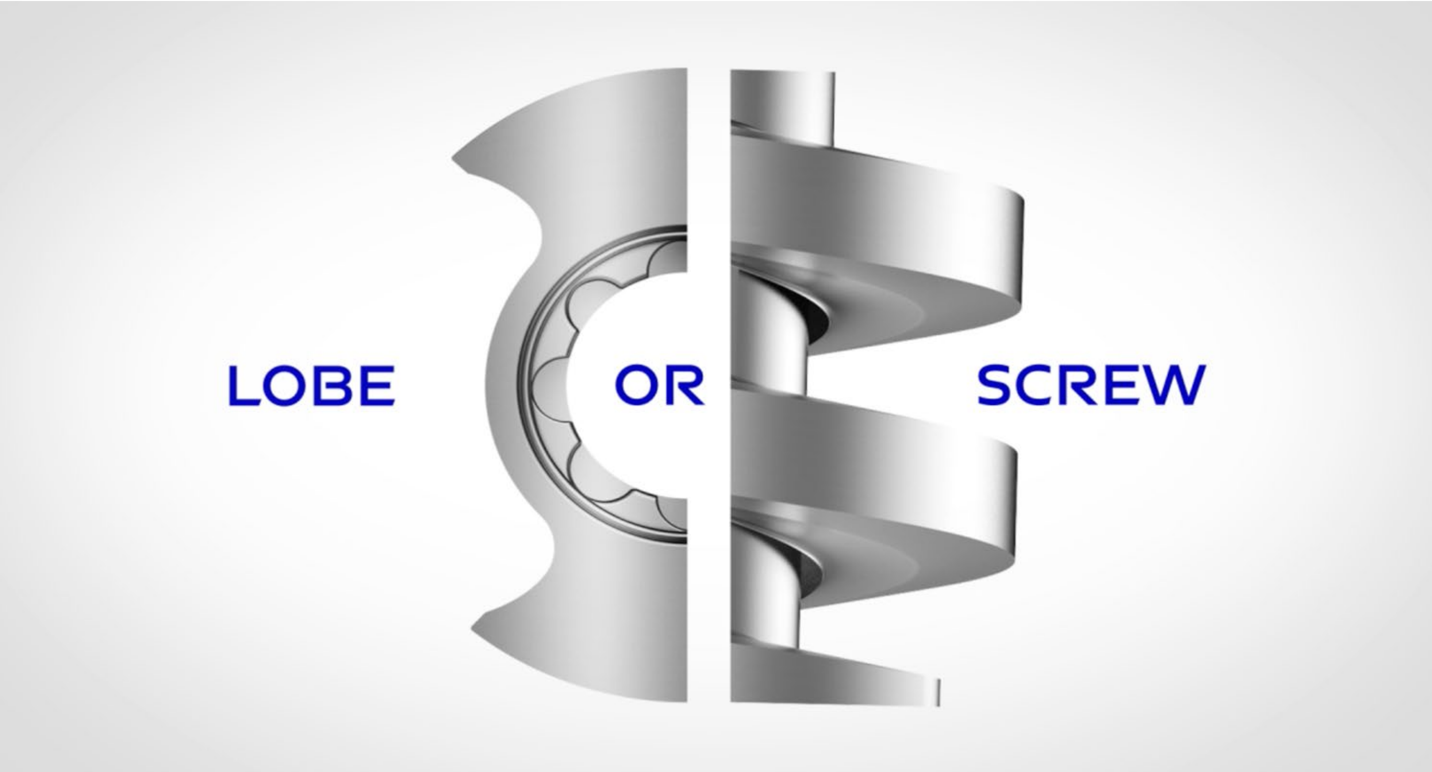
GEA Hilge rotory lobe NOVALOBE and twin screw pumps NOVATWIN are rotating positive displacement pumps. Two rotors or two screws rotate in the pump housing in opposite direction creating a fluid movement through the pump. The rotors or screws do neither come in contact with each other nor with the pump housing.

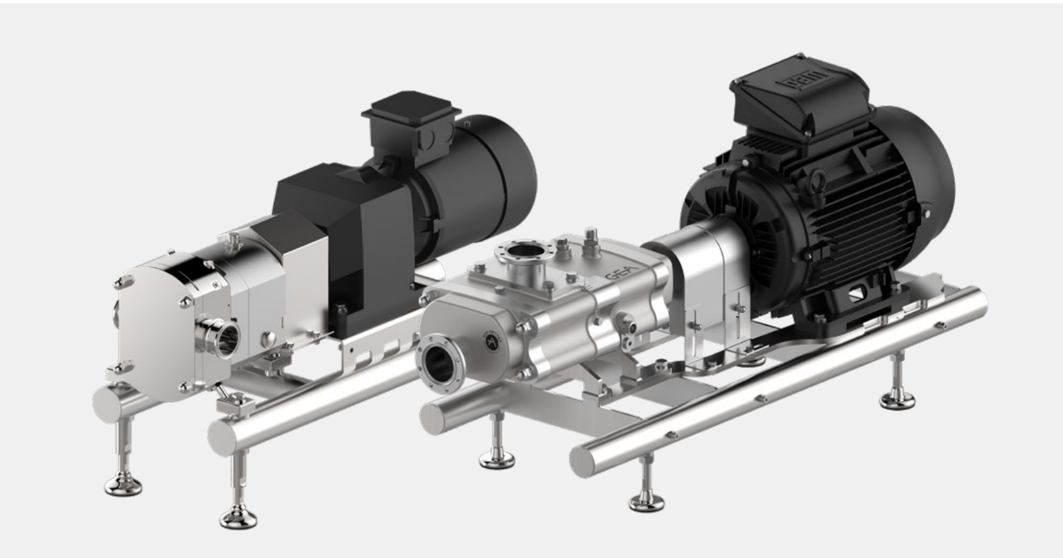
A positive pressure difference is generated between the pump's delivery and suction sockets when the liquid is conveyed. A part of the pumped medium flows back from the delivery side to the suction side through the gap between the two rotors and the pump housing. The flow rate – theoretically resulting from the volume of the working areas and the pump speed – is reduced by the volume of the back flow. The back flow portion rises with increasing delivery pressure and decreases as the product viscosity rises.

The capacity limits of rotary lobe pumps or twin screw pumps are usually revealed when rating the pump. They are reached, if one of the parameters needed for the pump design cannot be determined (e.g. speed), or if the NPSH of the pump is above or equal to that of the plant. In such a case the next bigger pump size should be selected for safety reasons.

Pumping against a closed delivery side will result in an intolerable rise of pressure that can destroy the pump or other parts of the plant. If pumping against a closed delivery side cannot be excluded to the full extent, safety measures are to be taken either by suitable flow path control or by the provision of safety or overflow valves.

With the new design of the NOVATWIN+, the volume has been increased and thus a smaller size can be used in ⅔ of all cases. This leads to energy savings of 13 % on average, as a result of which the pump was awarded the GEA Add Better label.





GEA Hilge NOVALOBE and GEA Hilge NOVATWIN+

ADD BETTER
Resource efficient solution

The Add Better label relates to the serial product GEA Hilge NOVATWIN+, released in July 2023. The comparison refers to its predecessor model, the GEA Hilge NOVATWIN.

7.2 Inquiry Sheet

Inquiry Sheet · Positive Displacement Pumps 1/2

Engineering for a better world.

GEA Hygienic Pumps

Contact Data

Company: ______________ E-mail: ______________

Contact Person: ______________ Country: ______________

Phone: ______________ Country of Installation: ______________

Liquid Data

*Liquid: ______________ Solids: ☐ No ☐ Yes:

*Liquid temperature [°C / °F]: ______________ Kind of solids: ______________

*Density [kg/dm³]: ______________ Size of solids [mm]: ______________

*Viscosity [mPas]: ______________ Abrasive: ☐ No ☐ Yes

Concentration [%]: ______________ Shear sensitive: ☐ No ☐ Yes

Maximum allowed media speed: ______________

Operating Conditions

*Duty point 1 *Flow [m³/h / gpm]: ______________ *Diff. Pressure [bar]: ______________

Inlet pressure [bar]: ______________ Vacuum at inlet: ☐ No ☐ Yes

Vacuum, abs. [mbar]: ______________

CIP / SIP Conditions

CIP with another pump: ☐ No: ☐ Yes SIP (Pump stopped): ☐ No ☐ Yes:

CIP Temperature [°C / °F]: ______________ SIP Temperature [°C / °F]: ______________

CIP Flow [m³/h / gpm]: ______________

CIP differential pressure [bar]: ______________ SIP Duration [min]: ______________

Pump execution

***Connection Type**

☐ Tri Clamp (DIN 32676) ☐ SMS ☐ DIN 11851

☐ DIN 11853-2 / 11864-2 ☐ Other: ______________

Connection Size

Standard: ☐ No: ☐ Yes

Special ($DN_s/DN_{d)}$): ______________

Drainable: ☐ No ☐ Yes

Execution

☐ Pump with bare shaft end

☐ Pump on stainless steel base with motor and coupling

☐ Pump in stainless steel trolley with motor and coupling

☐ With stainless steel motor shroud

Connection Position

GEA Hilge NOVALOBE:

☐ Horizontal port orientation

☐ Vertical port orientation

GEA Hilge NOVATWIN:

☐ Axial in, top out

☐ Axial in, bottom out

☐ Top in, axial out

☐ Bottom in, axial out

☐ Other: ______________

Surface Roughness

☐ $R_a \leq 0.8$ µm

☐ Other: ______________

Ferrite Content

☐ Not specified

☐ Fe < 1%

Options

☐ Thermal jacket

☐ Other: ______________

GEA Engineering for a better world.

GEA Hygienic Pumps

Shaft Seal

- ☐ Single mechanical seal
- ☐ Flushed mechanical seal
- ☐ Double mechanical seal
- ☐ Single O-ring shaft seal
- ☐ Double O-ring shaft seal

Material Shaft Seal

- ☐ Carbon / SiC
- ☐ SiC / SiC
- ☐ TuC / TuC

Elastomer

- ☐ EPDM
- ☐ FKM (Viton)
- ☐ Other: ______________

Motor Data

*Power supply:

- ☐ 3~ 400 V / 50 Hz
- ☐ 3~ 200 V / 50 Hz
- ☐ Other: ______________
- ☐ 3~ 460 V / 60 Hz
- ☐ 3~ 200 V / 60 Hz
- ☐ 3~ 380 V / 60 Hz

Variable speed drive ☐ No ☐ Yes:

- ☐ External frequency converter (not on motor)
- ☐ Integrated frequency converter (on motor)

Motor Certificates: ______________________________

Explosion protection ☐ No ☐ Yes

ATEX ☐ No ☐ Yes:

Temperature class: ______________________________

Ambient temperature [°C / °F]: ______________________________

Class: ______________________________

Division: ______________________________

Group: ______________________________

Certificates / Documentation

- ☐ Inspection certificate 3.1 acc. to DIN EN 10204
- ☐ Test report 2.2 acc. to DIN EN 10204
- ☐ FDA declaration of conformity
- ☐ Surface roughness test report
- ☐ Delta ferrite test report
- ☐ Further certificates and documentation: ______________

Further Information

* Fields marked with an asterisk are mandatory for a pump selection

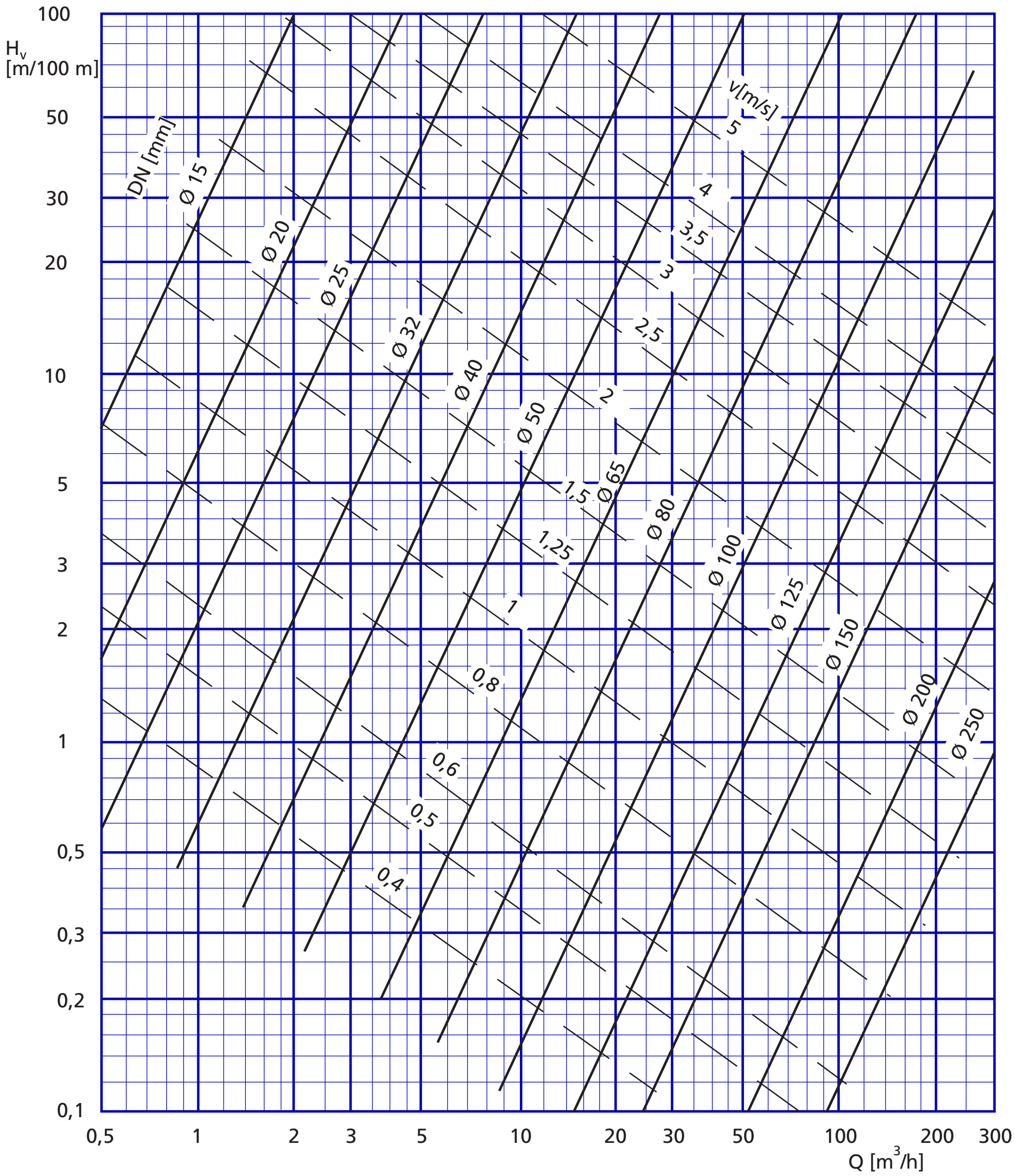
Selected options subject to confirmation by our offered portfolio

09/2022

8 ANNEX

8.1 Diagram for the calculation of pressure drops

Pressure drops H_v per 100 m pipe length for stainless steel pipes with a surface roughness of k = 0.05 and media with 1 mPas viscosity (= water) (accuracy ± 5 %)



Pipe diameter (beverage pipe)

Metric

DN	25	32	40	50	65	80	100	125
inside Ø [mm]	26	32	38	50	66	81	100	125

	Inch OD							Inch IPS			
DN	1"	1 1/2"	2"	2 1/2"	3"	4"		2"	3"	4"	6"
inside Ø [mm]	22	35	47,5	60	73	97,5		57	85	110	162

8.2 Pressure drops of fittings in metre equivalent pipe length

Fitting	**Nominal Diameter in mm**								
	25	32	40	50	65	80	100	125	150
ζ = 0.05 Reducer Tee	0.05	0.07	0.09	0.12	0.17	0.20	0.28	0.40	0.48
ζ = 0.15 Bend 45°	0.14	0.20	0.27	0.35	0.50	0.60	0.85	1.20	1.40
ζ = 0.25 Bend 90° Expansion Butterfly valve Inlet (Tank outlet)	0.25	0.35	0.45	0.60	0.80	1.00	1.35	1.90	2.4
ζ = 0.90 Tee	0.90	1.20	1.60	2.00	3.00	3.70	5.20	7.00	8.80
ζ = 1.30 Tee	1.20	1.80	2.30	3.00	4.30	5.40	7.40	10.00	12.50
ζ = 1.5 Reflux valve	1.40	2.10	2.70	3.50	5.00	6.30	8.50	11.50	14.50

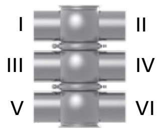
Applies to: Pipe roughness k = 0.05 mm
Flow speed v = 1-3 m/s (error >10% deviation in speed)
(Accuracy ± 5%)

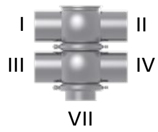
8.3 Pressure drops of valves in metre equivalent pipe length

Valve	DN								Inch OD						
	25	40	50	65	80	100	125	150	1	1 ½	2	2 ½	3	4	6
D-tec® Type N															
I to II	0.92	1.64	2.21	3.34	2.22	2.72			0.77	1.46	1.42	1.86	2.43	2.38	
I to III	2.01	3.90	6.26	10.06	15.96	19.27			1.57	2.74	4.79	5.85	11.68	17.78	
III to I	5.04	11.03	22.02	28.73	36.46	25.95			3.08	5.38	19.14	19.73	29.71	26.21	
III to IV	0.67	0.86	1.65	2.57	1.47	2.13			0.53	0.90	0.78	1.19	1.32	1.80	
I to VII	2.01	2.42	5.68	6.49	10.25	11.75			1.82	3.09	4.79	5.02	6.86	10.00	
VII to I	2.01	2.42	4.60	5.23	10.25	11.75			1.37	2.33	3.52	4.22	6.12	10.22	
D-tec® Type W															
I to II	1.07	1.15	1.93	2.42	2.19	2.94			0.95	0.97	1.40	1.95	2.14	2.30	
I to III	3.22	3.90	10.21	10.71	35.65	20.83			2.14	5.38	13.29	15.53	26.07	30.80	
III to I		3.70	7.19	9.47	23.77	25.11				2.33	5.49	5.85	13.69	21.85	
III to VII		3.51	4.35	7.99	15.04	13.93				2.21	3.32	4.93	8.67	12.13	
VII to III	2.24	2.64	6.06	6.49	12.55	16.21			1.57	2.21	4.79	4.93	7.43	14.36	
ECOVENT® Type N															
I to II	0.92	1.64	1.86	3.34	2.22	2.72			0.77	1.46	1.72	1.86	2.43	2.38	
I to III	2.01	3.90	6.26	10.06	15.96	19.27			1.57	2.74	4.79	5.85	11.68	17.78	
III to I	5.04	11.03	22.02	28.73	36.46	25.95			3.08	5.38	19.14	19.73	29.71	26.21	
III to IV	0.67	0.86	1.65	2.57	1.47	2.13			0.53	0.90	0.78	1.19	1.32	1.80	
I to VII	1.81	3.34	4.23	7.18	10.50	11.92			1.37	2.21	3.62	5.31	8.30	10.70	
VII to I	1.64	2.76	3.61	6.49	11.91	14.28			0.85	1.66	3.23	3.64	9.48	13.87	
ECOVENT® Type W															
I to II	1.07	1.48	1.57	2.37	4.15	3.16			1.37	1.74	1.87	2.07	2.32	2.52	
I to III	1.26	9.27	15.62	23.60	20.63	41.57			3.80	5.84	21.98	19.73	35.18	39.42	
III to I	1.16	3.51	6.94	9.29	23.77	25.11			2.54	3.74	8.51	8.26	18.81	23.35	
III to V	2.24	3.34	4.23	7.84	14.83	13.93			2.54	2.91	5.30	7.21	12.52	13.51	
V to VI	0.67	0.86	1.65	2.57	1.47	2.13			0.53	0.90	0.78	1.19	1.32	1.80	
III to VII	2.24	3.34	4.23	7.84	14.83	13.93			2.54	2.91	5.30	7.21	12.52	13.51	
VII to III	2.24	2.76	5.18	6.29	15.27	17.56			1.82	2.21	5.12	4.29	12.09	17.10	
VARIVENT® Type PMO 2.0															
I to II										1.34	3.32	5.85	6.43	6.75	7.52
III to IV										1.20	2.83	3.76	4.51	6.92	14.14
III to I										19.89	10.77	12.18	14.21	16.78	32.93
I to III										23.35	8.90	11.20	12.97	16.62	34.86

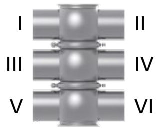
Valve	DN								Inch OD						
	25	40	50	65	80	100	125	150	1	1 ½	2	2 ½	3	4	6
VARIVENT® Type B															
I to II				2.92	3.63	2.58	5.08	4.07				1.57	1.81	2.16	
I to III				15.10	40.02	41.57	26.63	36.48				9.56	23.06	37.21	
III to IV				3.64	4.74	3.75	6.24	4.10				4.36	2.69	3.34	
III to I				14.37	34.86	44.63	27.14	35.35				9.56	21.01	40.60	
VARIVENT® Type B_L and B_C															
I to II				2.92	3.63	2.58	5.08	4.07				1.57	1.81	2.16	
I to III				15.10	40.02	41.57	26.63	36.48				9.56	23.06	37.21	
III to IV				3.64	4.74	3.75	6.24	4.10				4.36	2.69	3.34	
III to I				14.37	34.86	44.63	27.14	35.35				9.56	21.01	40.60	
VARIVENT® Type C															
I to II	1.16	1.30	1.49	2.92	3.65	2.59	4.72	4.47	0.49	0.82	1.14	1.80	2.10	2.25	
I to VII	3.22	3.51	4.12	8.29	11.91	10.84	11.27	15.64	1.37	2.21	3.15	5.12	6.86	9.44	
VII to I	2.01	2.64	4.88	4.53	11.03	12.01	11.13	17.24	0.85	1.66	3.37	2.80	6.35	10.46	
VARIVENT® Type D															
I to II	1.16	1.30	1.49	2.92	3.63	2.58	5.08	3.81	0.28	0.97	1.24	1.57	1.81	2.17	
I to III	4.29	5.55	10.66	13.70	33.36	48.05	24.89	34.42	1.39	4.00	10.25	8.66	19.64	37.21	
III to IV	0.86	1.23	1.31	2.85	3.55	2.80	4.95	3.77	0.35	1.00	1.10	1.51	1.80	2.37	
III to I	3.70	8.54	18.41	25.14	30.01	58.06	24.30	30.91	1.39	5.84	9.77	16.04	32.27	48.90	
VARIVENT® Type D_L and D_C															
I to II	1.16	1.30	1.49	2.92	3.63	2.58	5.08	3.81	0.28	0.97	1.24	1.57	1.81	2.17	
I to III	4.29	5.55	10.66	13.70	33.36	48.05	24.89	34.42	1.39	4.00	10.25	8.66	19.64	37.21	
III to IV	0.86	1.23	1.31	2.85	3.55	2.80	4.95	3.77	0.35	1.00	1.10	1.51	1.80	2.37	
III to I	3.70	8.54	18.41	25.14	30.01	58.06	24.30	30.91	1.39	5.84	9.77	16.04	32.27	48.90	
VARIVENT® Type K															
I to II	1.16	1.30	1.49	2.92	3.65	2.59	5.09	3.94	0.49	0.82	1.14	1.80	2.10	2.25	
I to III	4.29	5.55	10.66	13.70	33.36	48.05	24.89	38.38	1.82	3.50	8.14	8.46	19.22	41.83	
III to IV	0.67	0.86	1.65	2.59	1.48	2.13	2.68	3.68	0.28	0.54	1.26	1.60	0.85	1.86	
III to I	3.70	8.54	18.41	25.14	30.01	58.06	24.30	34.27	1.57	5.38	14.06	15.53	17.29	50.53	
VARIVENT® Type L_H, L_S, L_HL, L_HC, L_SL and L_SC															
I to II		1.76	2.98	5.23	6.11	6.52				1.40	2.13	5.85	5.25	5.97	
III to IV		0.77	1.52	1.45	1.94	2.08				0.82	0.85	1.24	1.31	1.74	
III to I		10.09	18.41	41.95	33.36	28.40				7.62	16.83	19.03	26.74	25.01	
I to III		4.62	10.21	29.75	19.29	23.80				3.74	8.14	10.07	12.30	20.07	
VARIVENT® Type N															
I to II	0.91	1.61	2.19	3.34	2.21	2.72	3.36	4.58	0.75	1.47	1.43	1.86	2.43	2.39	
I to III	2.03	3.86	6.35	10.15	15.03	19.26	19.43	30.13	1.55	2.71	4.82	5.90	11.74	17.74	
III to I	5.39	10.93	22.58	28.53	34.48	25.92	37.00	37.48	3.41	5.56	19.02	19.66	29.63	26.09	
III to IV	0.67	0.85	1.64	2.58	1.38	2.13	2.68	3.68	0.52	0.90	0.78	1.19	1.32	1.80	
I to VII	1.76	3.30	3.75	7.02	9.48	11.41	11.60	15.87	1.32	2.19	3.16	5.10	6.96	9.46	
VII to I	1.60	2.72	4.41	6.16	10.37	12.79	11.54	17.73	0.88	1.65	3.78	2.73	6.59	10.45	

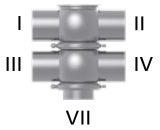
8.3 Pressure drops of valves in metre equivalent pipe length (continued)





Valve	DN								Inch OD						
	25	40	50	65	80	100	125	150	1	1½	2	2½	3	4	6
VARIVENT® Type N_V															
I to II	0.91	1.61	2.19	3.34	2.21	2.72	3.36	4.58	0.75	1.47	1.43	1.86	2.43	2.39	
I to III				6.71	14.20	13.49						5.74	11.30	9.17	
III to I				22.88	40.99	29.76						18.37	30.53	16.94	
III to IV	0.67	0.85	1.64	2.58	1.38	2.13	2.68	3.68	0.52	0.90	0.78	1.19	1.32	1.80	
I to VII				3.97	7.28	6.63						2.62	7.13	4.42	
VII to I				4.47	12.72	10.18						3.64	7.33	7.50	
VARIVENT® Type R															
I to II	0.99	1.30	1.49	2.92	3.73	2.58	4.56	3.62		0.97	1.24	1.57	1.81	2.17	
I to III	7.25	10.09	17.40	16.73	25.61	22.13	23.45	34.88		19.89	11.93	11.51	15.95	43.78	
III to IV	0.92	1.59	1.86	4.41	4.78	3.61	6.49	8.33		1.11	1.45	2.45	2.78	3.15	
III to I	7.25	10.09	15.62	19.17	24.66	22.13	25.50	35.67		17.15	11.33	12.54	15.04	43.11	
VARIVENT® Type R_L and R_C															
I to II	0.99	1.30	1.49	2.92	3.73	2.58	5.08			0.97	1.24	1.57	1.81	2.17	
I to III	3.22	10.09	18.41	15.49	25.61	18.22	23.45			33.62	11.33	9.81	15.04	26.21	
III to IV	0.92	1.59	1.86	4.41	4.78	3.61	6.49			1.11	1.45	2.45	2.78	3.15	
III to I	3.22	10.09	17.40	34.41	24.66	18.91	25.98			27.79	11.33	10.61	14.48	25.01	
VARIVENT® Type T_R															
I to II		1.76	2.98	5.23	6.11	6.52	6.24	7.89		1.40	2.13	5.85	5.25	5.97	
III to I		10.09	18.41	41.95	33.36	28.40	28.38	43.27		7.62	16.83	19.03	26.74	25.01	
I to III		4.62	10.21	29.75	19.29	23.80	23.73	39.66		3.74	8.14	10.07	12.30	20.07	
VARIVENT® Type T_RL and T_RC															
I to II		1.76	2.98	5.23	6.11	6.52	6.24	7.89		1.40	2.13	5.85	5.25	5.97	
III to I		10.09	18.41	41.95	33.36	28.40	28.38	43.27		7.62	16.83	19.03	26.74	25.01	
I to III		4.62	10.21	29.75	19.29	23.80	23.73	39.66		3.74	8.14	10.07	12.30	20.07	
VARIVENT® Type U															
I to II	3.22	2.76	2.45	3.34	4.02	2.89			1.37	1.74	1.87	2.07	2.32	2.52	
I to III	8.95	9.27	28.76	31.95	61.07	45.29			3.80	5.84	21.98	19.73	35.18	39.42	
III to I	5.99	5.93	11.14	13.38	32.65	26.83			2.54	3.74	8.51	8.26	18.81	23.35	
III to IV	1.07	1.19	1.13	2.03	2.25	1.82			0.46	0.75	0.87	1.26	1.30	1.58	
VARIVENT® Type W															
I to II	1.05	1.48	1.59	2.37	4.15	3.16	4.53	5.15	0.93	1.22	1.46	2.39	2.75	3.96	
I to III	1.23	10.09	16.47	24.35	20.98	41.57	21.35	31.11	3.36	12.59	15.04	12.09	36.18	25.45	
III to I	1.19	3.70	7.19	9.47	23.77	25.11	19.65	29.40	2.33	5.49	5.85	13.69	21.85	25.94	
III to V	2.29	3.51	4.35	7.99	15.04	13.93	12.05	14.68	2.21	3.32	4.93	8.67	12.13	30.82	
V to VI	0.67	0.85	1.64	2.58	1.38	2.13	2.68	3.68	0.52	0.90	0.78	1.19	1.32	1.80	
III to VII	2.29	3.51	4.35	7.99	15.04	13.93	12.05	14.68	2.21	3.32	4.93	8.67	12.13	30.82	
VII to III	2.24	2.76	5.18	6.29	15.27	17.72	11.90	18.83	2.19	3.96	3.88	8.80	15.43	31.02	
VARIVENT® Type W_R															
I to II		1.48	1.59	2.37	4.15	3.16				0.93	1.22	1.46	2.39	2.75	
I to III		10.09	16.47	24.35	20.98	41.57				6.36	12.59	15.04	12.09	36.18	
III to I		3.70	7.19	9.47	23.77	25.11				2.33	5.49	5.85	13.69	21.85	
III to V		3.51	4.35	7.99	15.04	13.93				2.21	3.32	4.93	8.67	12.13	
V to VI		1.19	1.13	2.03	2.25	1.82				0.75	0.87	1.26	1.30	1.58	
III to VII		3.51	4.35	7.99	15.04	13.93				2.21	3.32	4.93	8.67	12.13	
VII to III		2.76	5.18	6.29	15.27	17.72				1.74	3.96	3.88	8.80	15.43	





Valve	DN								Inch OD						
	25	40	50	65	80	100	125	150	1	1 ½	2	2 ½	3	4	6
VARIVENT® Type W_V															
I to III				26.85	44.12	43.37						16.58	25.42	37.75	
III to I				11.93	28.24	22.82						7.37	16.27	19.86	
III to VII				4.24	12.38	5.08						2.62	7.13	4.42	
VII to III				5.90	12.72	8.62						3.64	7.33	7.50	
V to III				29.75	52.99	19.46						18.37	30.53	16.94	
VARIVENT® Type X															
I to II	0.86	1.73	1.29	1.86	3.53	2.28	4.36		0.82	0.83	1.11	1.47	2.08	1.99	
I to III	2.76	3.11	8.77	7.40	17.93	19.31	18.49		1.88	1.95	5.38	5.01	12.76	15.09	
III to I	2.94	3.86	9.28	13.07	34.78	29.62	35.21		1.94	2.96	6.20	8.50	18.49	22.63	
III to V	2.94	4.65	9.55	11.30	23.34	28.90	35.75		1.88	2.94	6.25	8.73	16.30	25.07	
V to III	2.60	3.06	8.12	12.48	18.48	20.41	19.44		1.94	1.92	4.82	5.05	13.28	16.01	
V to VI	0.73	1.48	1.00	2.26	3.06	1.99	2.57		0.44	0.75	0.87	1.25	1.30	1.58	
VARIVENT® Type X_V															
I to II												1.46	2.07	1.99	
III to IV												5.02	12.74	15.15	
III to I												8.46	18.41	22.58	
I to III												8.66	16.27	25.01	
I to VII												5.12	13.20	16.01	
III to VII												1.26	1.30	1.58	
VARIVENT® Type Y															
I to II	0.75	1.19	1.26	1.81	3.53	2.21	4.17	4.68	0.58	0.85	1.18	1.49	2.10	2.02	
I to III	3.70	12.10	10.66	7.44	35.65	60.02	23.05	38.20	3.80	7.62	7.80	8.66	21.49	58.98	
III to I	4.29	10.09	10.66	13.07	18.36	57.11	37.41	52.44	3.80	7.62	8.14	11.84	28.92	54.98	
III to V	3.70	5.55	6.26	11.42	17.51	35.84	20.36	32.25	2.54	2.74	6.13	11.20	23.06	32.45	
V to III	2.24	2.42	5.34	7.06	18.07	20.83	19.60	32.25	1.57	1.82	3.84	11.20	10.09	18.31	
V to VI	0.92	1.30	1.36	1.88	3.58	2.35	3.88	4.36	0.77	0.82	1.16	1.99	2.23	2.46	
VARIVENT® Type Y_L and Y_C															
I to II	0.75	1.19	1.26	1.81	3.53	2.21	4.17	4.68	0.58	0.85	1.18	1.49	2.10	2.02	
I to III	3.70	12.10	10.66	7.44	35.65	60.02	23.05	38.20	3.80	7.62	7.80	8.66	21.49	58.98	
III to I	4.29	10.09	10.66	13.07	18.36	57.11	37.41	52.44	3.80	7.62	8.14	11.84	28.92	54.98	
III to V	3.70	5.55	6.26	11.42	17.51	35.84	20.36	32.25	2.54	2.74	6.13	11.20	23.06	32.45	
V to III	2.24	2.42	5.34	7.06	18.07	20.83	19.60	32.25	1.57	1.82	3.84	11.20	10.09	18.31	
V to VI	0.92	1.30	1.36	1.88	3.58	2.35	3.88	4.36	0.77	0.82	1.16	1.99	2.23	2.46	

Fehlende Daten auf Anfrage.

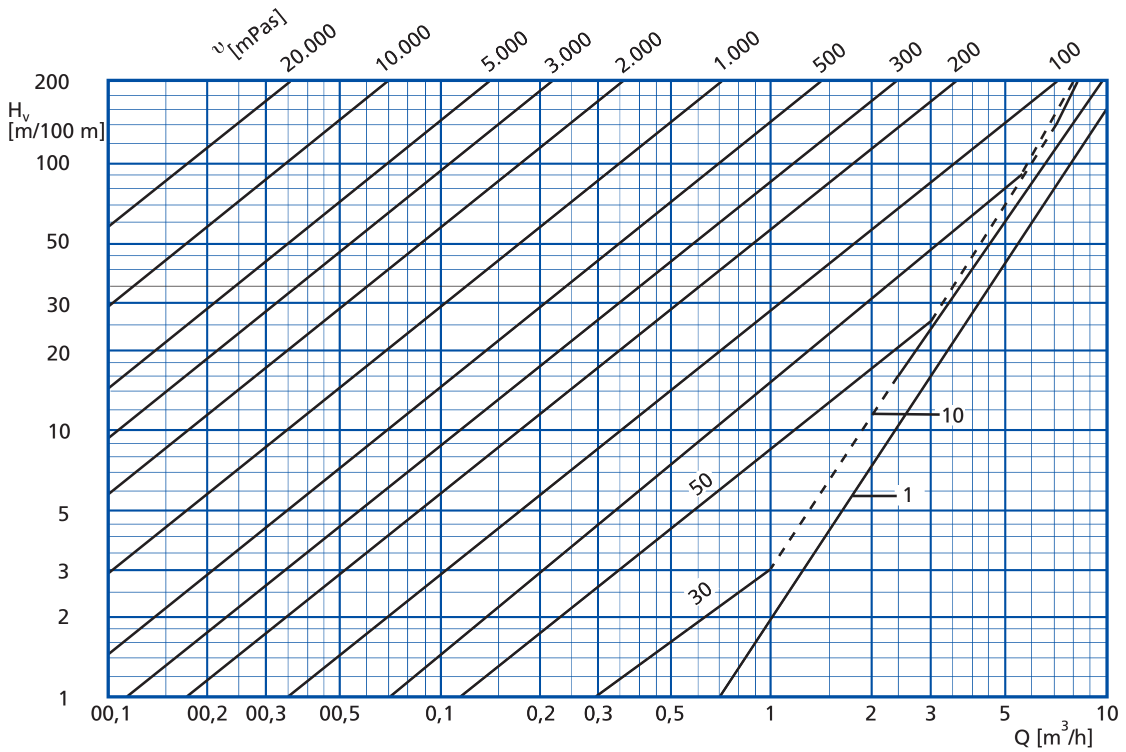
8.4 Vapour pressure table for water

t °C	T K	p_D bar	ρ kg/dm³		t °C	T K	p_D bar	ρ kg/dm³
0	273,15	0,00611	0,9998		61	334,15	0,2086	0,9826
1	274,15	0,00657	0,9999		62	335,15	0,2184	0,9821
2	275,15	0,00706	0,9999		63	336,15	0,2286	0,9816
3	276,15	0,00758	0,9999		64	337,15	0,2391	0,9811
4	277,15	0,00813	1,0000		65	338,15	0,2501	0,9805
5	278,15	0,00872	1,0000		66	339,15	0,2615	0,9799
6	279,15	0,00935	1,0000		67	340,15	0,2733	0,9793
7	280,15	0,01001	0,9999		68	341,15	0,2856	0,9788
8	281,15	0,01072	0,9999		69	342,15	0,2984	0,9782
9	282,15	0,01147	0,9998		70	343,15	0,3116	0,9777
10	283,15	0,01227	0,9997		71	344,15	0,3253	0,9770
11	284,15	0,01312	0,9997		72	345,15	0,3396	0,9765
12	285,15	0,01401	0,9996		73	346,15	0,3543	0,9760
13	286,15	0,01497	0,9994		74	347,15	0,3696	0,9753
14	287,15	0,01597	0,9993		75	348,15	0,3855	0,9748
15	288,15	0,01704	0,9992		76	349,15	0,4019	0,9741
16	289,15	0,01817	0,9990		77	350,15	0,4189	0,9735
17	290,15	0,01936	0,9988		78	351,15	0,4365	0,9729
18	291,15	0,02062	0,9987		79	352,15	0,4547	0,9723
19	292,15	0,02196	0,9985		80	353,15	0,4736	0,9716
20	293,15	0,02337	0,9983		81	354,15	0,4931	0,9710
21	294,15	0,02485	0,9981		82	355,15	0,5133	0,9704
22	295,15	0,02642	0,9978		83	356,15	0,5342	0,9697
23	296,15	0,02808	0,9976		84	357,15	0,5557	0,9691
24	297,15	0,02982	0,9974		85	358,15	0,5780	0,9684
25	298,15	0,03166	0,9971		86	359,15	0,6011	0,9678
26	299,15	0,03360	0,9968		87	360,15	0,6249	0,9671
27	300,15	0,03564	0,9966		88	361,15	0,6495	0,9665
28	301,15	0,03778	0,9963		89	362,15	0,6749	0,9658
29	302,15	0,04004	0,9960		90	363,15	0,7011	0,9652
30	303,15	0,04241	0,9957		91	364,15	0,7281	0,9644
31	304,15	0,04491	0,9954		92	365,15	0,7561	0,9638
32	305,15	0,04753	0,9951		93	366,15	0,7849	0,9630
33	306,15	0,05029	0,9947		94	367,15	0,8146	0,9624
34	307,15	0,05318	0,9944		95	368,15	0,8453	0,9616
35	308,15	0,05622	0,9940		96	369,15	0,8769	0,9610
36	309,15	0,05940	0,9937		97	370,15	0,9094	0,9602
37	310,15	0,06274	0,9933		98	371,15	0,9430	0,9596
38	311,15	0,06624	0,9930		99	372,15	0,9776	0,9586
39	312,15	0,06991	0,9927		100	373,15	1,0133	0,9581
40	313,15	0,07375	0,9923		102	375,15	1,0878	0,9567
41	314,15	0,07777	0,9919		104	377,15	1,1668	0,9552
42	315,15	0,08198	0,9915		106	379,15	1,2504	0,9537
43	316,15	0,08639	0,9911		108	381,15	1,3390	0,9522
44	317,15	0,09100	0,9907		110	383,15	1,4327	0,9507

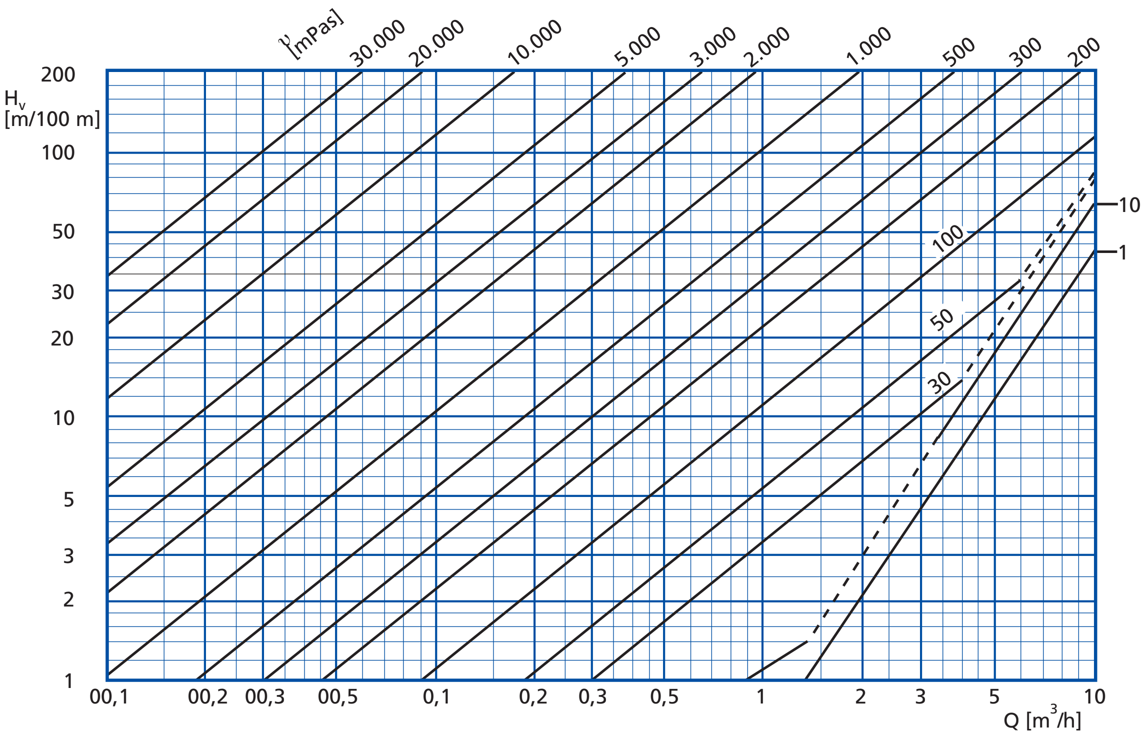
t °C	T K	p_D bar	ρ kg/dm³		t °C	T K	p_D bar	ρ kg/dm³
45	318,15	0,09582	0,9902		112	385,15	1,5316	0,9491
46	319,15	0,10086	0,9898		114	387,15	1,6362	0,9476
47	320,15	0,10612	0,9894		116	389,15	1,7465	0,9460
48	321,15	0,11162	0,9889		118	391,15	1,8628	0,9445
49	322,15	0,11736	0,9884		120	393,15	1,9854	0,9429
50	323,15	0,12335	0,9880		124	397,15	2,2504	0,9396
51	324,15	0,12961	0,9876		130	403,15	2,7013	0,9346
52	325,15	0,13613	0,9871		140	413,15	3,6850	0,9260
53	326,15	0,14293	0,9866		150	423,15	4,7600	0,9168
54	327,15	0,15002	0,9862		160	433,15	6,3020	0,9073
55	328,15	0,15741	0,9857		170	443,15	8,0760	0,8973
56	329,15	0,16511	0,9852		180	453,15	10,2250	0,8869
57	330,15	0,17313	0,9846		190	463,15	12,8000	0,8760
58	331,15	0,18147	0,9842		200	473,15	15,8570	0,8646
59	332,15	0,19016	0,9837		250	523,15	40,5600	0,7992
60	333,15	0,19920	0,9832		300	573,15	87,6100	0,7124

8.5 Pressure drops depending on viscosity

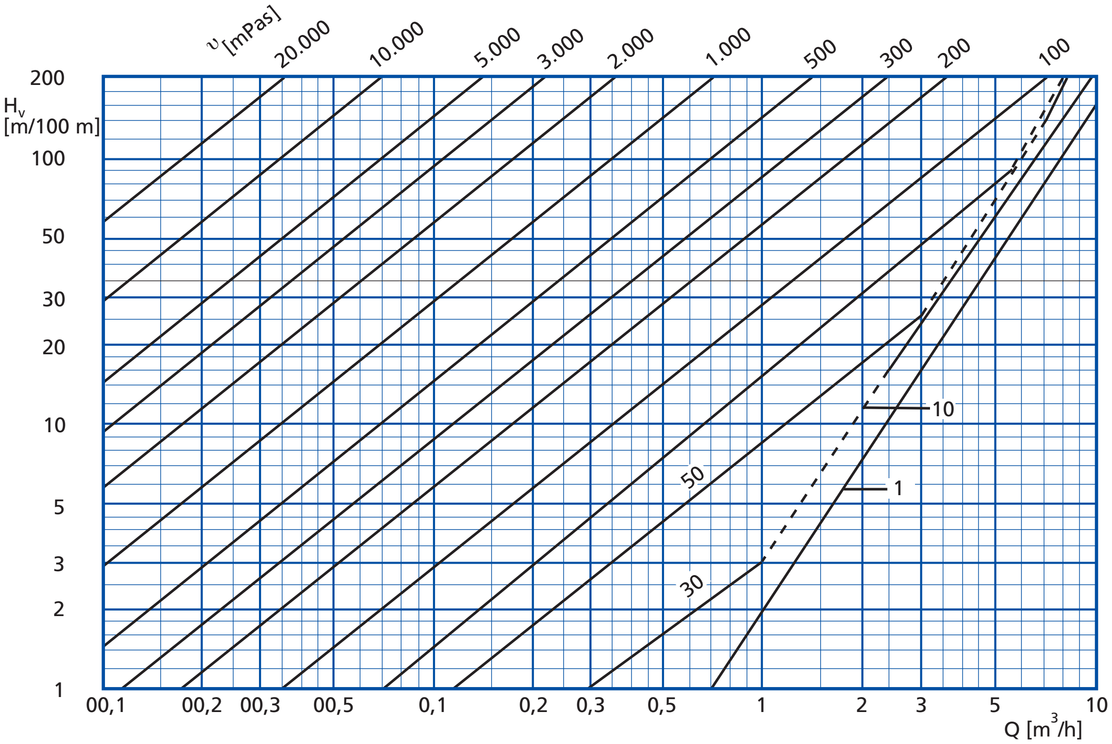
DN 25



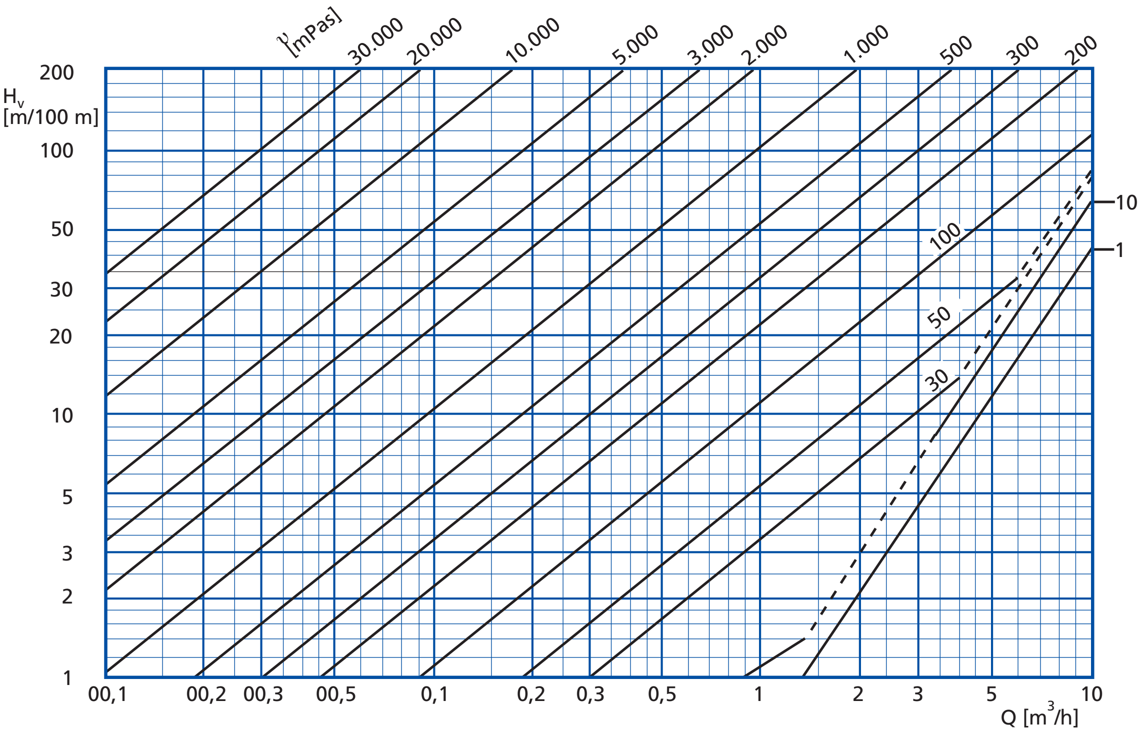
DN 32



DN 40



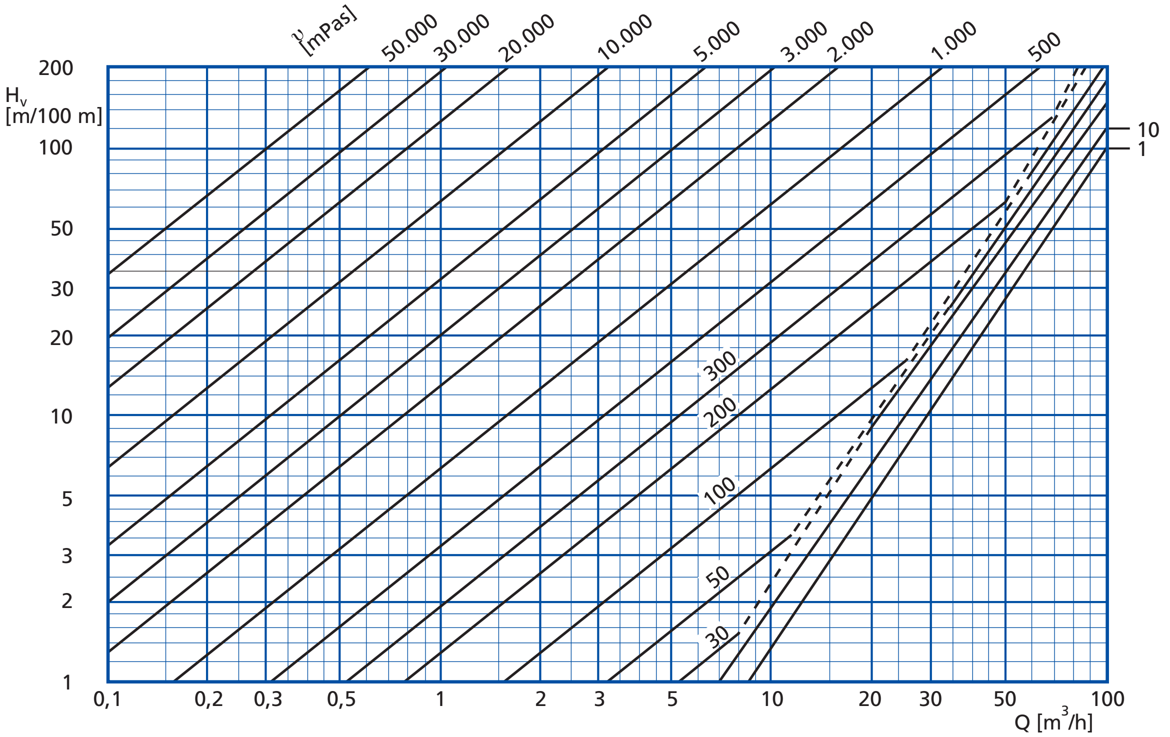
DN 50



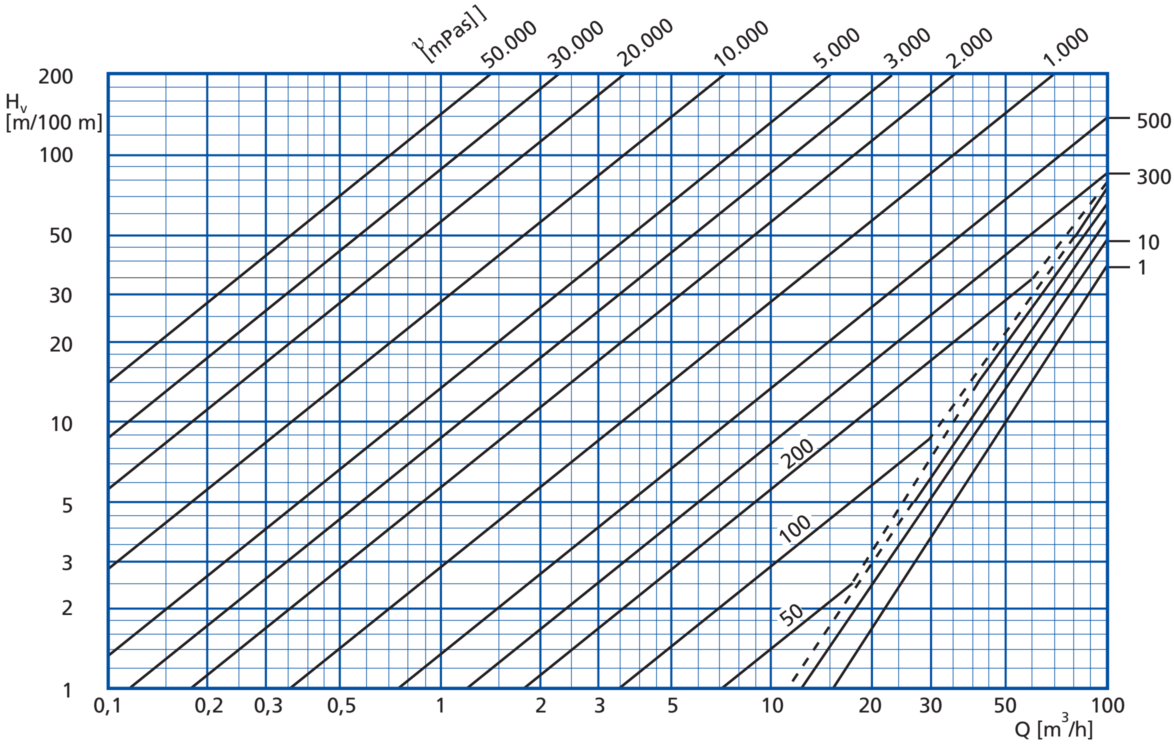
- - - - Transition range from laminar to turbulent flow (Re: ≈ 1.400 – ≈ 3.500 / Accuracy ± 5 %), Pressure drop H_v per 100 m pipe length (k = 0.05)

8.5 Pressure drops depending on viscosity (continued)

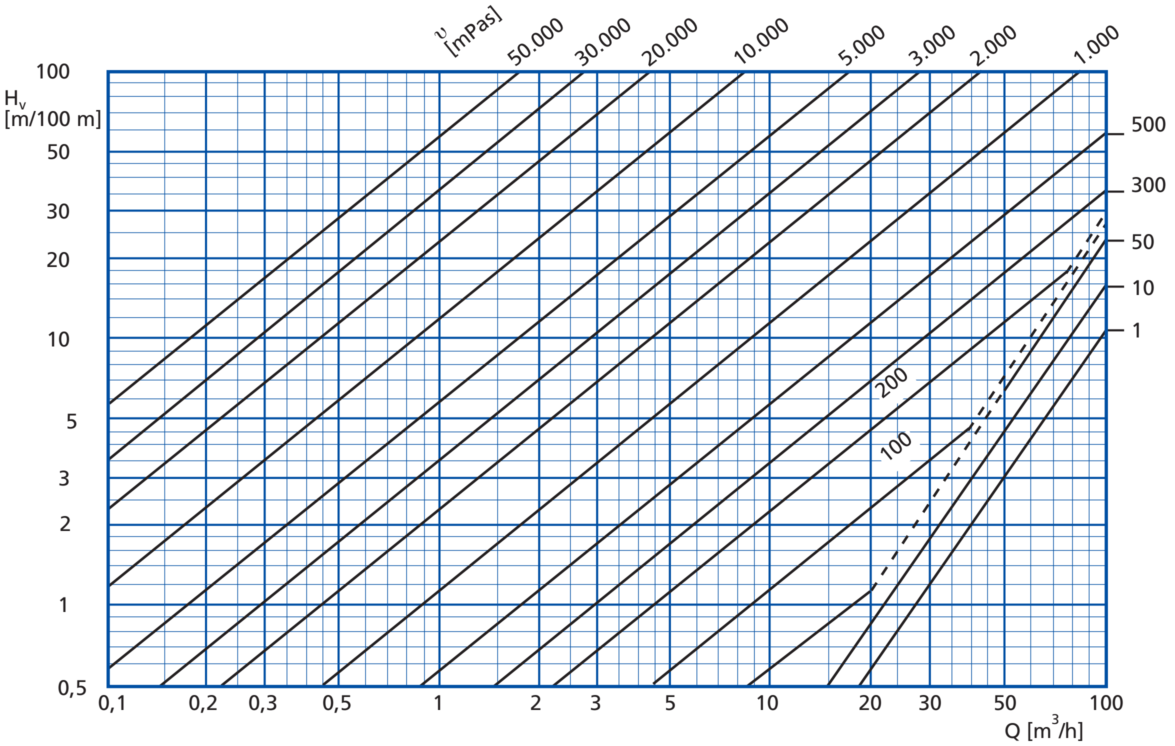
DN 65



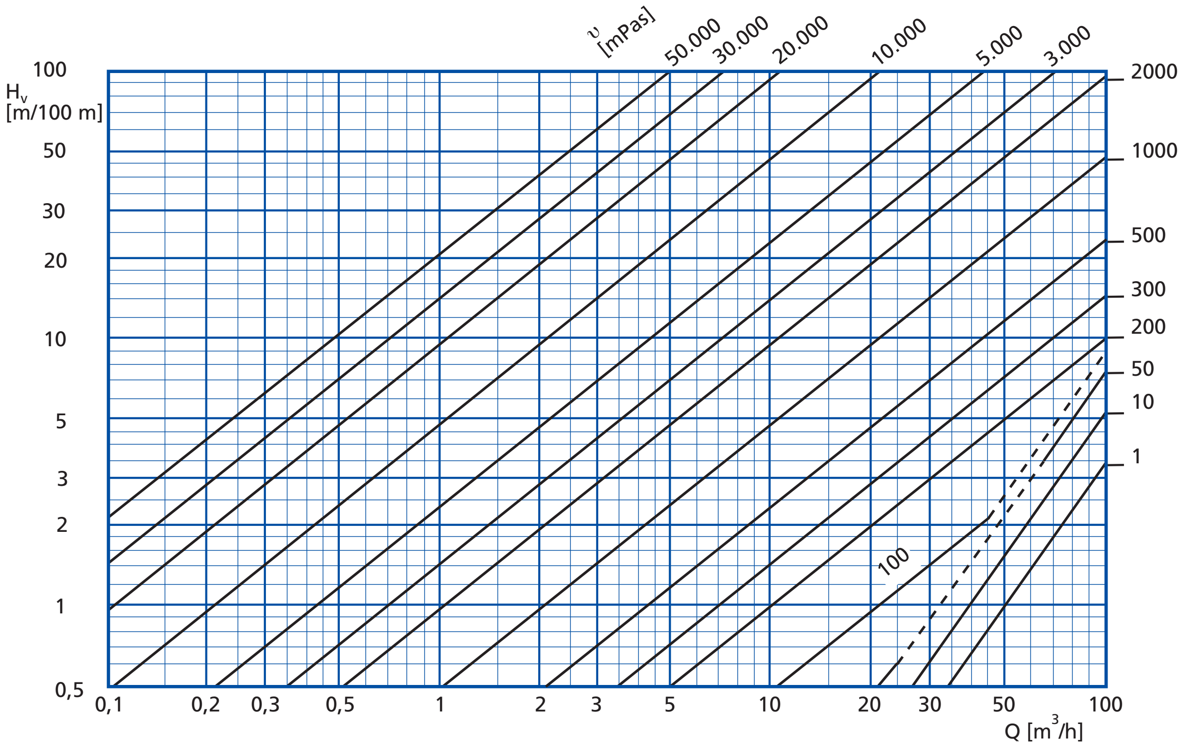
DN 80



DN 100



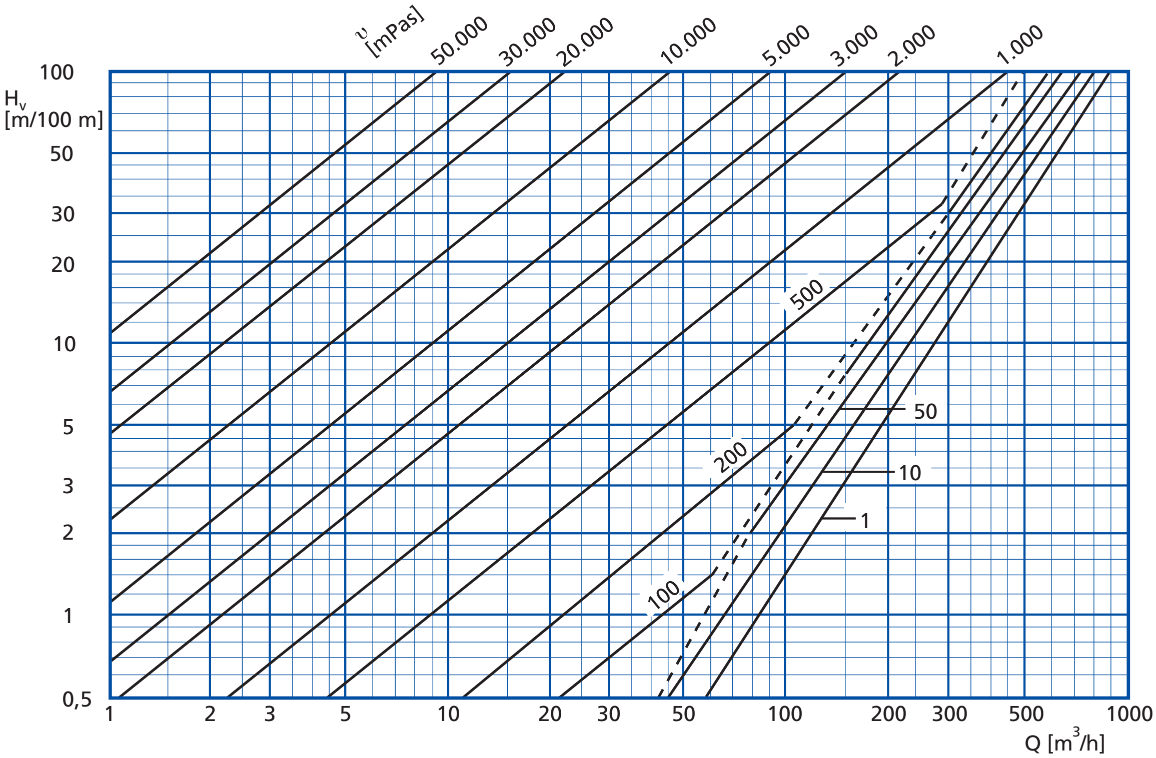
DN 125



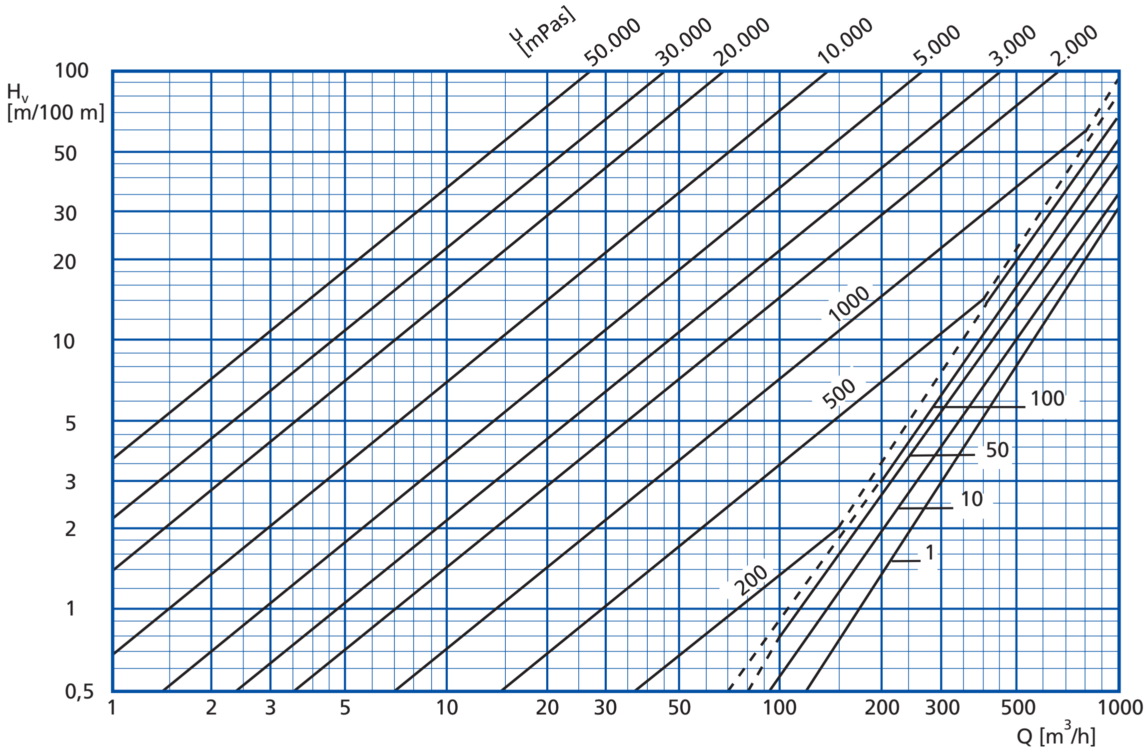
- - - - - Transition range from laminar to turbulent flow (Re: ≈ 1.400–≈ 3.500 / Accuracy ± 5 %), Pressure drop H_v per 100 m pipe length (k = 0.05)

8.5 Pressure drops depending on viscosity (continued)

DN 150



DN 200



- - - - - Transition range from laminar to turbulent flow (Re: ≈ 1.400–≈ 3.500 / Accuracy ± 5 %), Pressure drop H_v per 100 m pipe length (k = 0.05)

8.6 SI-Units

Legal units (Abstract for centrifugal pumps)

Designation	Formula symbols	Legal units (the unit listed first should be used)	not admitted units	Conversion
Length	l	m km, cm, mm		base unit
Volume	V	m^3 cm^3, mm^3, (Liter)	cbm, cdm	
Flow rate	Q	m^3/h		
Volumetric flow	V	m^3/s, l/s		
Time	t	s (second) ms, min, h, d		base unit
Speed	n	1/min 1/s		
Mass	m	kg (Kilogram) g, mg, (Tonne)	pound, centner	base unit
Density	ρ	kg/m^3 kg/dm^3, kg/cm^3		
Force	F	N (Newton = kg m/s^2) kN, mN	kp, Mp	1 kp = 9.81 N
Pressure	p	bar (bar = N/m^2) Pa	kp/cm^2, at, m WS, Torr,	1 bar = 10^5 Pa = 0.1 MPa 1 at = 0.981 bar = 9.81 x 10^4Pa 1 m WS = 0,98 bar
Energy, Wort, Heat amount	W, Q	J (Joule = N m = W s) kJ, Ws, kWh,	kp m kcal, cal	1 kp m = 9.81 J 1 kcal = 4.1868 kJ 1 kWh = 3600 kJ
Flow head	H	m (Meter)	m Fl.S.	
Power	P	W (Watt = J/s = N m/s) MW, kW	kp m/s, PS	1 kp m/s = 9.81 W; 1 PS = 736 W
Temperature, t-difference	T	K (Kelvin) °C	°K, grd	base unit
Kinematic viscosity	ν	m^2/s mPas	St (Stokes), °E,…	1St = 10^{-4} m^2/s 1 cSt = 1 mPas Approximation: mPas = (7.32 x °E - 6.31/°E) $\nu = \frac{\eta}{\rho}$
Dynamic viscosity	η	Pa s (Pascal seconds = N s/m^2)	P (Poise), …	1P = 0.1 Pa s

8.7 Conversion table of foreign units

Designation	Unit	Unit code	British		USA	
Length	1 inch	in	25.4	mm	25.4	mm
	1 foot	ft = 12 in	0.3048	m	0.3048	m
	1 yard	yd = 3 ft	0.9144	m	0.9144	m
	1 mile	mi = 1.760 yd	1.6093	km	1.6093	km
	1 nautical mile	mi	1.8532	km	1.8532	km
Surface	1 square inch	sq in	6.4516	cm^2	6.4516	cm^2
	1 square foot	sq ft	929.03	cm^2	929.03	cm^2
	1 square yard	sq yd	0.8361	m^2	0.8361	m^2
	1 acre		4,046.86	m^2	4.046,86	m^2
	1 square mile	sq mi	2.59	km^2	2.59	km^2
Volume	1 cubic inch	cu in	16.387	cm^3	16.387	cm^3
	1 cubic foot	cu ft	28.3268	dm^3	28.3268	dm^3
	1 register ton	RT =100 cu ft	2.8327	m^3	2.8327	m^3
	1 British shipping ton	= 42 cu ft	1.1897	m^3	-	
	1 US shipping ton	= 40 cu ft	-		1.1331	m^3
	1 gallon	gal	4.5460	dm^3	3.7854	dm^3
	1 US oil-barrel (crude oil)	-			0.159	m^3
Mass & weight	1 ounce	oz (avdp)	28.3495	g	28.3495	g
	1 pound	lb	0.4536	kg	0.4536	kg
	1 stone		6.3503	kg	6.3503	kg
	1 ton		1,016.047	kg	-	
Density	1 pound per cubic foot	lb/cu ft	0.0160	kg/dm^3	0.0160	kg/dm^3
	1 pound per gallon	lb/gal	0.09978	kg/dm^3	0.1198	kg/dm^3
Flow rate	1 gallon per minute	gpm	0.07577	l/s	0.06309	l/s
	1 cubic foot per second	cusec	28.3268	l/s	28.3268	l/s
Force	1 ounce (force)	oz	0.2780	N	0.2780	N
	1 pound (force)	lb	4.4438	N	4.4438	N
	1 short ton	shtn	8.8964	kN	8.8964	kN
Pressure	$1\ \frac{\text{pound (force)}}{\text{square foot}}$	$\frac{\text{lb (force)}}{\text{sq ft}}$	47.88025	Pa	47.88025	Pa
	$1\ \frac{\text{pound (force)}}{\text{square inch}}$	$\frac{\text{lb (force)}}{\text{sq in}}$, psi	68.9476	m bar	68.9476	m bar
Work, Energy, Heat amount	1 foot-pound	ft lb	1.3558	J	1.3558	J
	1 Horse power Hour	Hp h	2.6841	MJ	2.6841	MJ
Power	$1\ \frac{\text{foot-pound (av)}}{\text{per second}}$	$\frac{\text{ft lb}}{\text{s}}$	1.3558	W	1.3558	W
	1 Horse power (Hp)		0.7457	kW	0.7457	kW
Dynamic viscosity	$1\ \frac{\text{pound (mass)}}{\text{foot x second}}$	$\frac{\text{lb (mass)}}{\text{ft s}}$	1.4882	Pa s	1.4882	Pa s

8.8 Viscosity table (guideline values)

	Product	Density ρ	Viscosity η in CPs	Temp °C t	Viscous behaviour type*
Reference	Water	1	1		N
Bakery products	Egg	0.5	60	10	N
	Emulsifier		20		T
	Melted butter	0.98	18	60	N
	Yeast slurry (15%)	1	180		T
	Lecithine		3,250	50	T
	Batter	1	2,200		T
	Frosting	1	10,000		T
Chemicals	Glycerin 100%	1.26	624	30	
	Glycerin 100%	1.26	945	20	
	Glycerin 45%	1.11	5	20	
	Glycerin 80%	1.21	62	20	
	Glycerin 90%	1.23	163	25	
	Glycerin 95%	1.25	366	25	
	Caustic soda 20%	1.22	7	20	
	Caustic soda 40%	1.52	39	20	
	Caustic soda 50%	1.51	20	40	
	Caustic soda 50%	1.52	38	30	
	Nictric acid 10%	1.05	1	20	
Food	Apple pulp		10,020	20	
	Pear pulp		4,000	70	T
	Honey	1.5	2,020	45	
	Mashed potatoes	1	20,000		T
	Ketschup	1.11	560	60	T
	Magarine emulsion		26	50	
	Mayonnaise	1	5,000	25	T
	Nut core		9,500	20	
	Prune juice	1	60	50	T
	Mustard		11,200	20	
Fats & oils	Peanut oil	0.92	42	40	N
	Linseed oil	0.93	30	40	N
	Corn oil	0.92	30		N
	Olive oil	0.91	84	20	
	Vegetable oil	0.92	5	150	N
	Lettuce oil		85	20	
	Lard	0.96	60	40	N
	Soybean oil	0.95	36	40	N
Meat products	Meat emulsion	1	22,000	5	T
	Ground beef fat	0.9	11,000	15	T
	Pork fat (slurry)	1	650	5	T
	Animal fats	0.9	43	40	N
	Pet food	1	11,000	5	T

***Viscous behaviour type**
N = Newtonian
T = Thixotropic

8.8 Viscosity table (continued)

	Product	Density ρ	Viscosity η in CPs	Temp °C t	Viscous behaviour type
Reference	Water	1	1		N
Beverages and concentrates	Apple juice concentrate		7	20	
	Apple wine concentrate	1.3	300	20	
	Beer	1	1	5	N
	Coca Cola	1	1	40	
	Cola-Konzentrat		25	20	
	Egg liqueur		620	20	
	Strawberry syrup		2,250	40	
	Fruit liqueur		12	20	
	Coffee extract 30% i.Tr.		18	20	
	Yeast concentrate (80%)		16,000	4	T
	Herb liqueur		3	20	
	Orange concentrate		1,930	20	
	Orange juice concentrate	1.1	5,000	5	T
	Currant juicesaft		2	20	
Cosmetics, soaps	Face cream		10,000		T
	Hair gel	1.4	5,000		T
	Hand soap		2,000		T
	Shampoo		5,000		T
	Toothpaste		20,000		T
Dairy products	Buttermilk		8	20	
	Cream for churning, acid		550	20	
	Skimmilk, acid		140	20	
	Cottage cheese	1.08	225		T
	Yogurt		1,100		T
	Cacao milkdrink		7	20	
	Cheese		30	70	T
	Evaporated milk 77%	1.3	10,000	25	N
	Evaporated milk 10%		45	20	
	Evaporated milk 7,5%		12	20	
	Evaporated milk, sweetened		6,100	20	
	Concentrated skimmilk		100	20	
	Milk	1.03	1	15	N
	Cream	1.02	20	4	N
	Acid cream		32	20	
	Whole milk	1.03	2	20	
	Yoghurt		900	20	
Confectionary	Hot fudge	1.1	36,000		T
	Cacao butter		42	40	
	Cacao mass		4,000	20	
	Caramel	1.2	400	60	
	Chocolate	1.1	17,000	50	T
	Chocolate coating		2,600	40	
	Toffee	1.2	87,000		T
	Sugar syrup 50%		15	20	
	Sugar syrup 56%	1.27	32	20	
	Sugar syrup 64%	1.31	120	20	

8.9 Mechanical seals (recommendation)

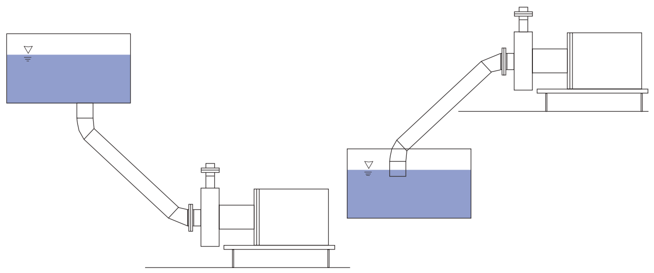
Medium	Concentration %	Temp. C°	Material Carbon/Sic	Sic/Sic	EPDM	FKM	Standard seal	Rinsed seal (Quenched)	Note
Alcohol: ethanol			X		X		X		
Alcohol: butanol			X		X		X		
Alcohol: methanol			X		X		X		
Pineapple juice			X			X	X		
Apple juice, pulp, wine				X	X			X	
Apple juice, acidic				X	X			X	
Apricot juice			X		X		X		
Beer				X	X	X		X	
Beer yeast, wort				X		X		X	
Blood			X			X	X		
Butter			X		X	X	X		
Buttermilk			X		X	X	X		
Egg liqueur			X			X		X	
Egg yolk			X			X		X	
Ice cream			X			X	X		
Peanut oil			X			X	X		
Fat, fatty alcohol			X			X	X	X	
Fatty acids		150		X		X	X		
Fish glue / oil / meal				X		X		X	
Fruit pulp			X		X		X		
Gelatine			X		X	X		X	heated
Glucose			X		X	X	X		
Hair shampoo			X			X		X	
Body lotion			X			X	X		
Honey			X			X		X	
Hop mash				X		X	X		
Coffee extract				X	X	X		X	
Cacao butter - oil				X	X	X			
Mashed potatoes				X	X		X	X	
Potato starch			X			X		X	
Cheese, cheese cream				X	X	X		X	
Ketchup (tomatoe extract)			X		X		X		
Adhesives: vegetable			X		X	X			
Adhesives: synthetic			X	X		X		X	
Adhesives: animal glue			X	X		X		X	
Adhesives: cellulose			X	X	X			X	
Carbon dioxide			X			X		X	
Coco oil			X			X	X	X	
Lactose (milk/sugar solution)			X	X		X	X		
Limonades, alcoholfree beverages			X	X	X		X		
Limonades, syrup			X	X		X	X	X	

8.9 Mechanical seals (recommendation)

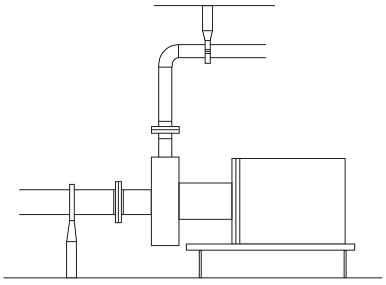
			Material						
Medium	Concentration %	Temp. °C	Carbon/Sic	Sic/Sic	EPDM	FKM	Standard seal	Rinsed seal (Quenched)	Note
Corn oil			X			X	X		
Mayonnaise			X				X	X	
Marmelade			X	X		X	X		
Melasse				X	X	X	X		
Milk		<80	X		X		X		
Milk		<140	X		X	X		X	
Whey			X		X			X	
Caustic soda	<2		X		X		X		
Caustic soda	<20			X	X			X	
Caustic soda	<10	80°	X	X	X		X	X	
Olive oil			X			X	X	e	
Orange juice			X			X	X		
Vegetable oil			X			X	X		
Rape oil			X		X	X	X		
Cane sugar solution				X		X		X	
Beet mash			X			X	X		
Juice (solution)				X		X	X	X	
Cream			X			X	X		
Lettuce oil			X			X	X		
Nitric acid	<2		X			X	X		
Nictric acid	<60	<65		X		(X)	X	X	PTFE
Brine	<5			X		X	X		
Black liquor				X		X			
Lard			X			X	X		
Soap solution			X			X	X		
Mustard				X		X		X	
Soybean oil			X			X	X		
Tomato juice			X			X	X		
Walöl			X			X	X		
Water		<140	X		X		X		
Wine				X			X	X	
Wine brandy			X		X		X		
Citrus fruit juice			X			X		X	
Sugar solution	>10			X		X		X	
Sugar solution	<10		X			X	X		
Sugar cane			X	X		X		X	
Sugar beet juice			X			X		X	

8.10 Assembly instructions

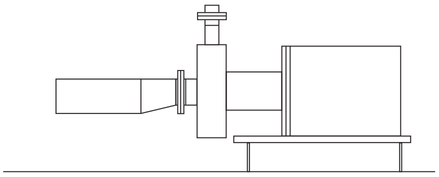
The suction pipe should be placed steadily ascending to the pump, the supply pipe steadily descending to the pump.



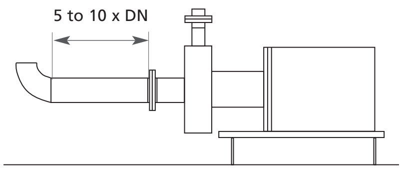
The pump should be adequately relieved from pipe forces acting on the pump.



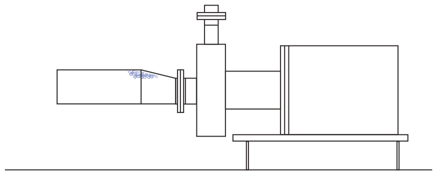
The cone of a conical suction pipe upstream the pump should be acutely conical in order to avoid deposits.



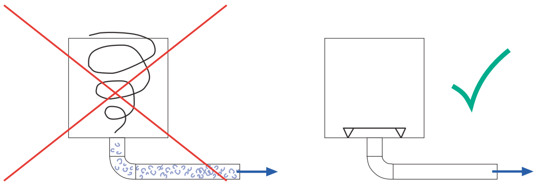
Never install a pipe bend directly upstream the pump. The distance should be the five to tenfold in diameter of the inlet socket.



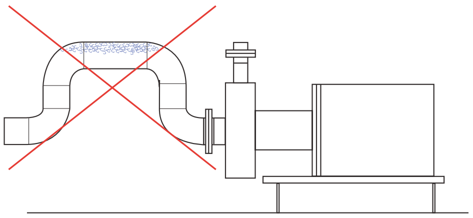
A conical suction pipe upstream the pump with top cone prevents soiling on one hand, on the other hand it leads to the formation of air cushions.



Connecting the pump to a tank, air drawing-off vortex should be avoided.



Avoid air cushions.



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