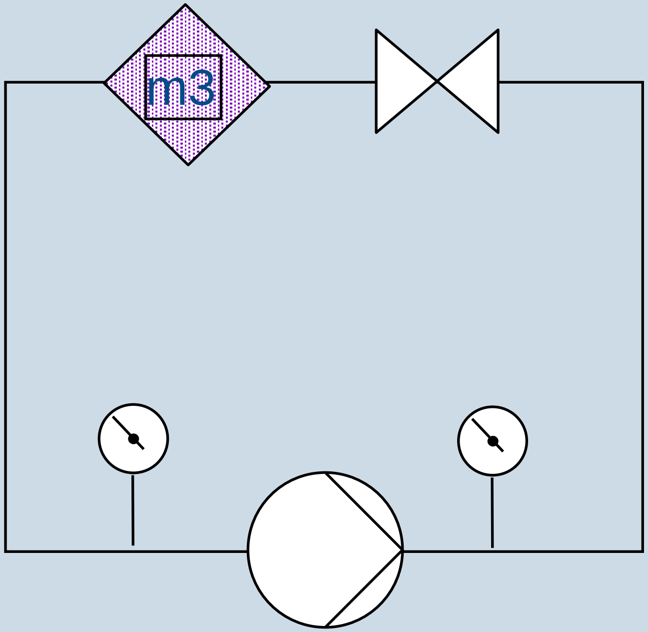
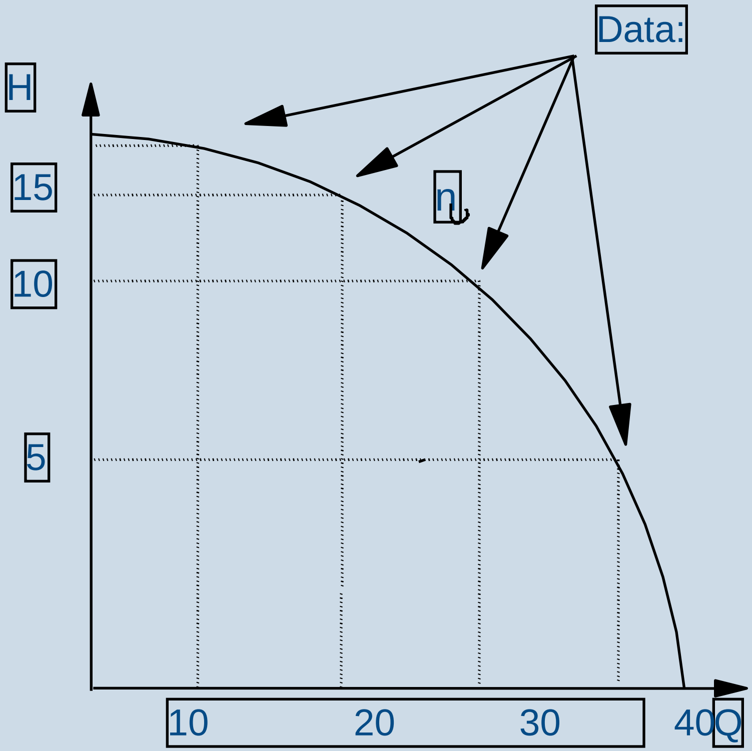
Grundfos
Pump Theory

Pump theory

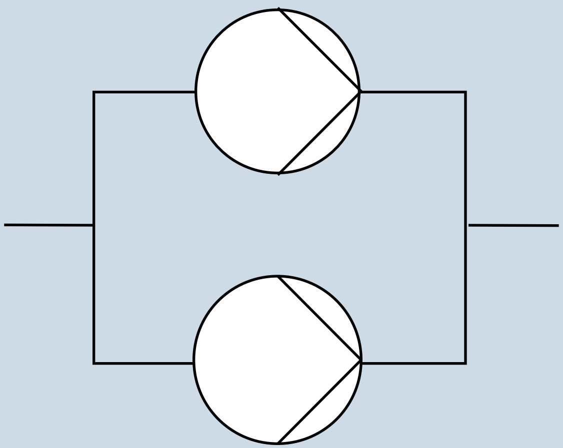
Construction of curves

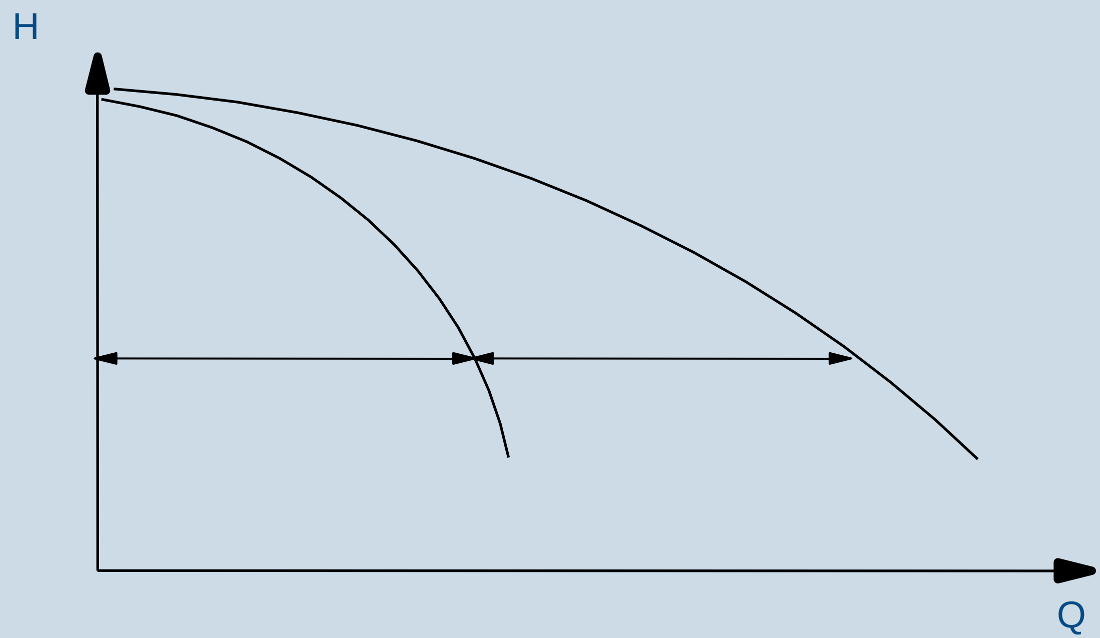




Pump theory

Parallel operation of similar pumps

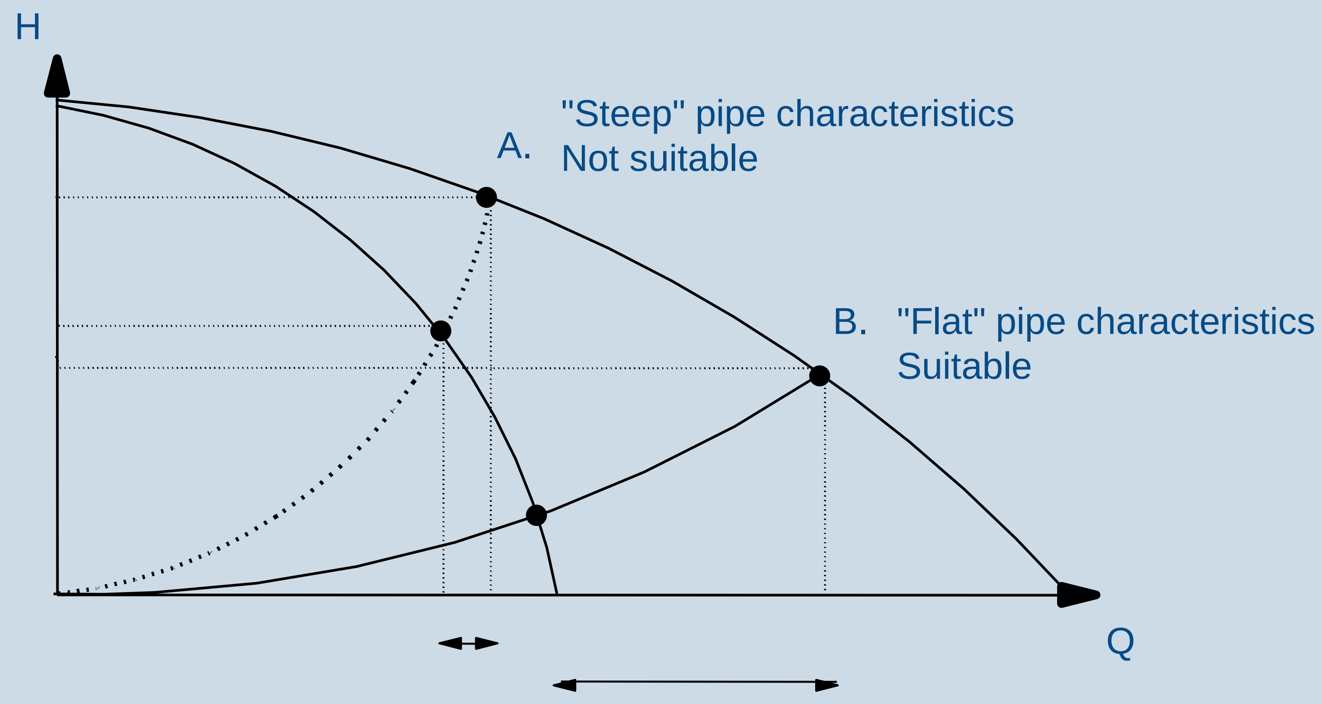




Theoretic:
Double flow: [2 x Q]
Same head:
[1 x H]

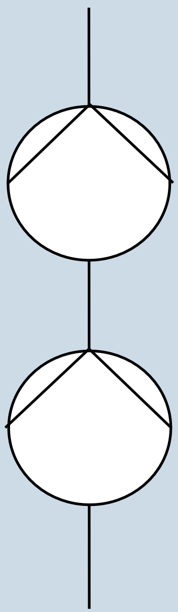
Pump theory

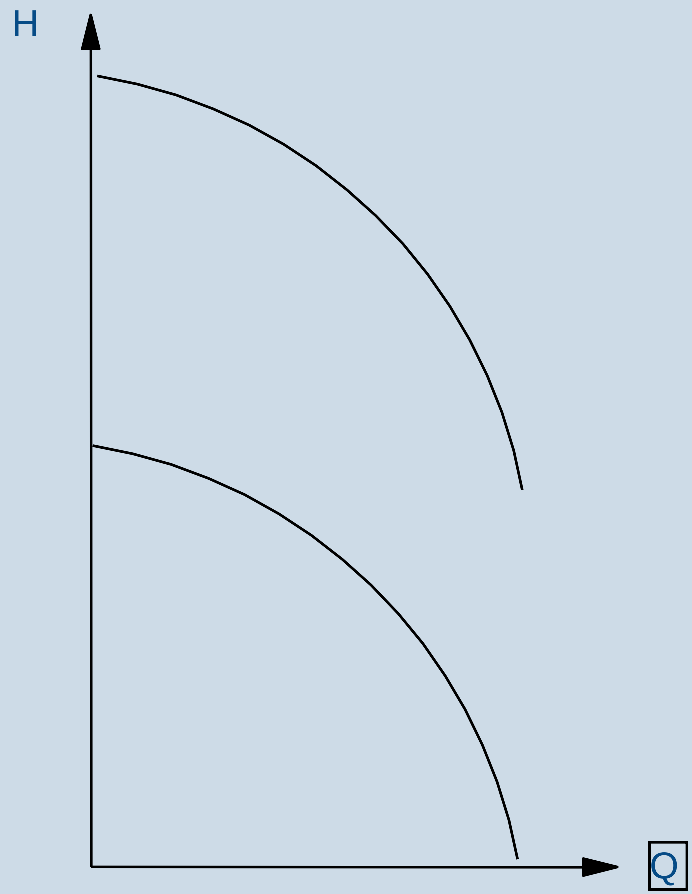
Parallel operation of similar pumps



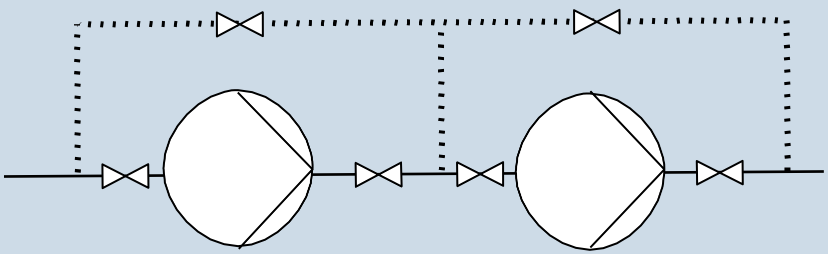
Pump theory

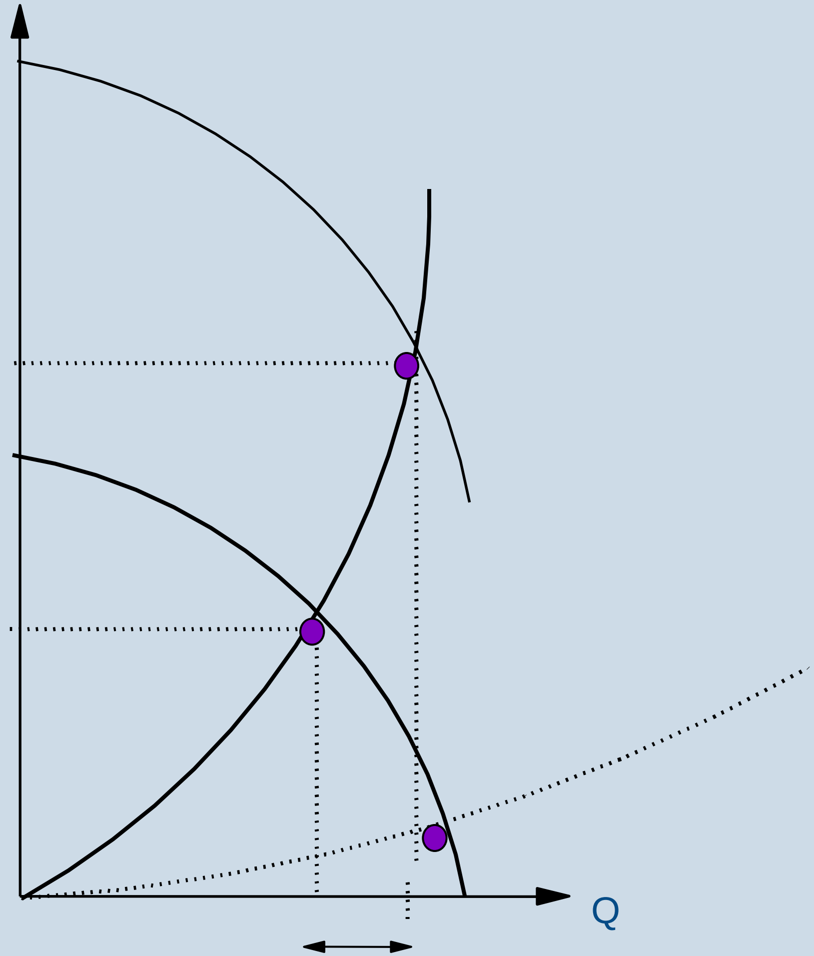
Series operation of pumps





Series operation of pumps

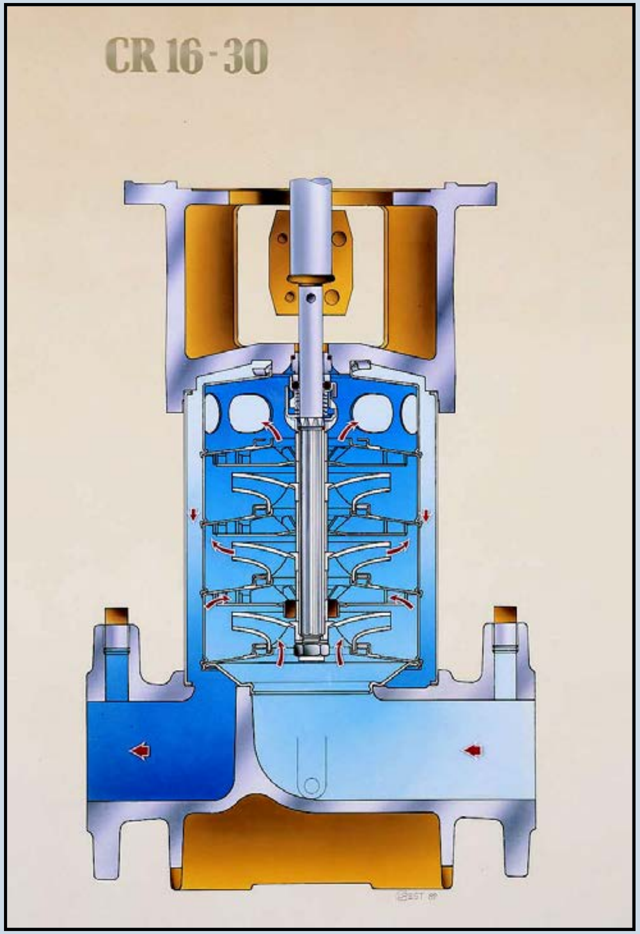




Theoretic:

Double head [2 x H]

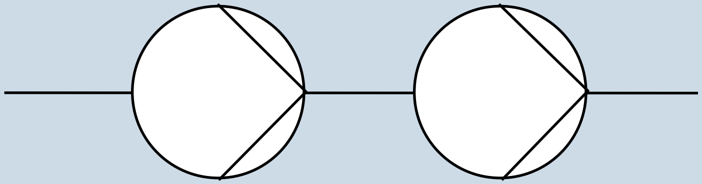
Same flow [1 x Q]



Series operation of pumps

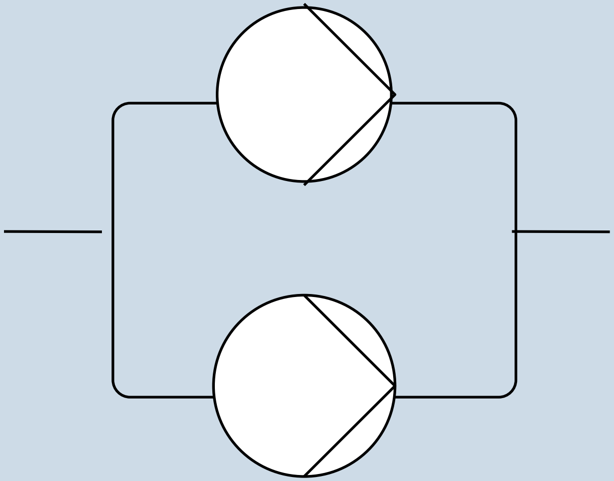
Often used in:

> Water supply systems
> Wash-down systems
> Industrial applications



Parallel Operation of Pumps

Parallel operation of pumps



Often used in:

> District heating systems
> Central heating systems
> Water supply systems
> Air conditioning/cooling systems

Primarily as:

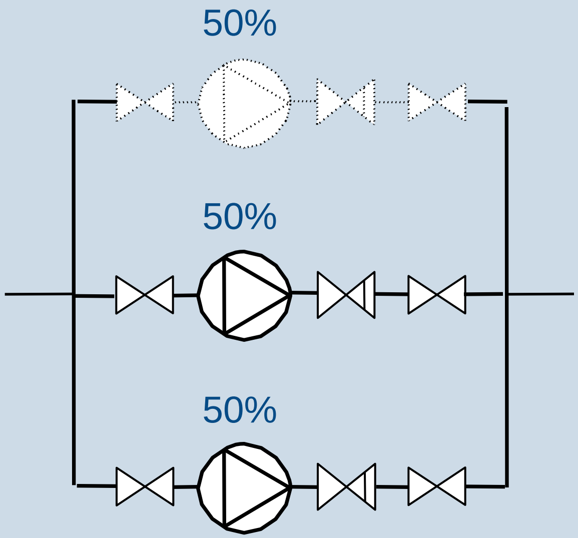
> Main pumps
> Zone pumps

Basis:

> Highly varied consumption
> Desire for emergency operation
> Energy savings, etc.

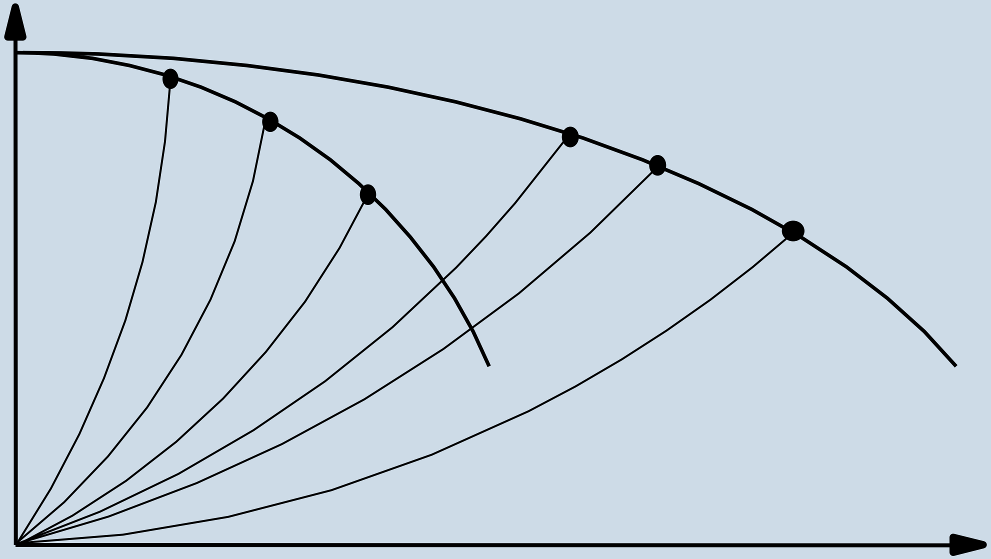
Pump theory

Parallel operation of similar pumps

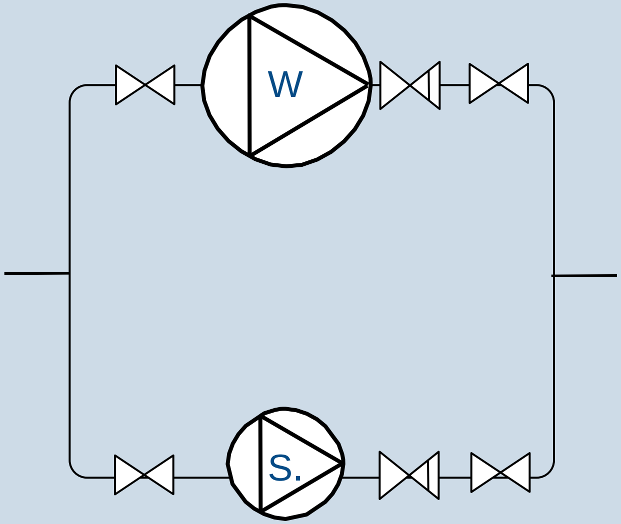


Example of construction:

> 2 x 50 % pumps
+ 1 back-up



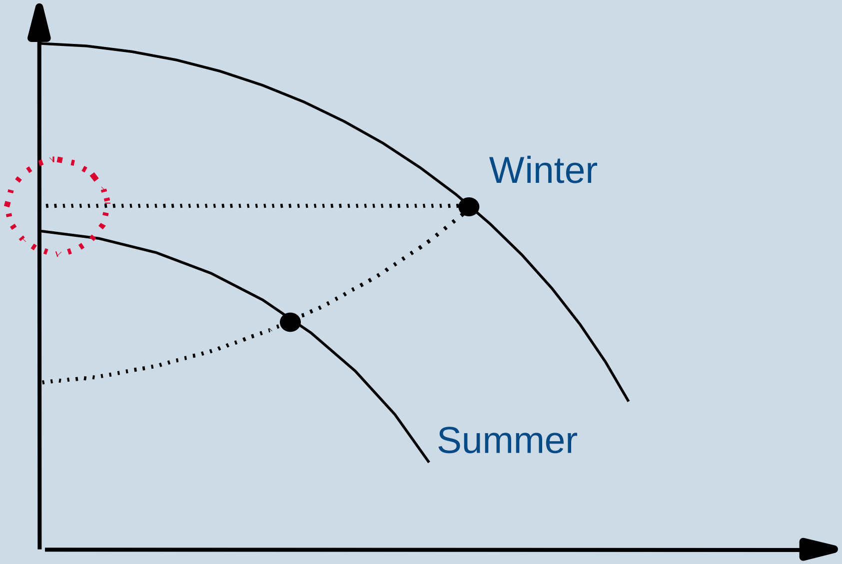
Parallel operation of pumps



Example of construction:

> 1 large winter pump

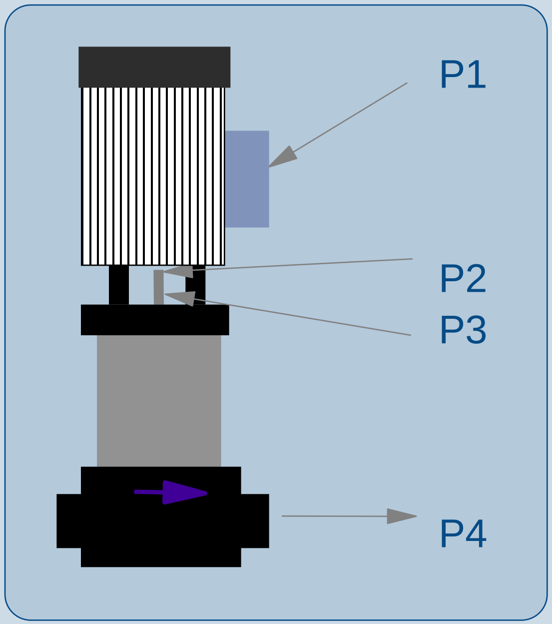
> 1 small summer pump

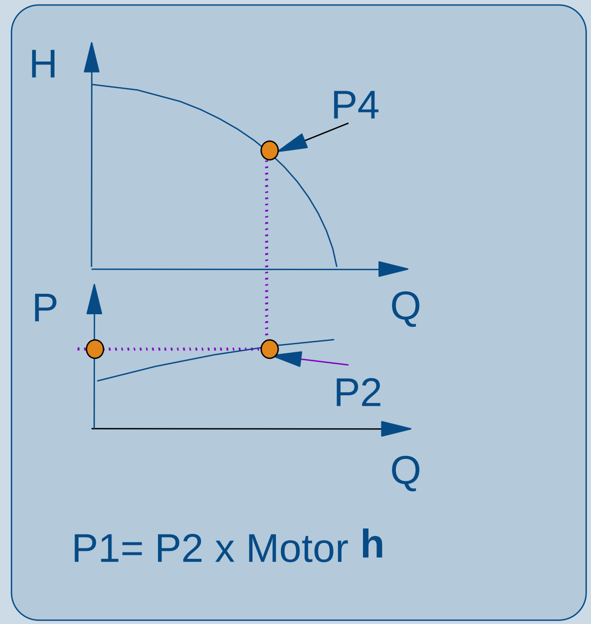


Power Consumption

Pump theory

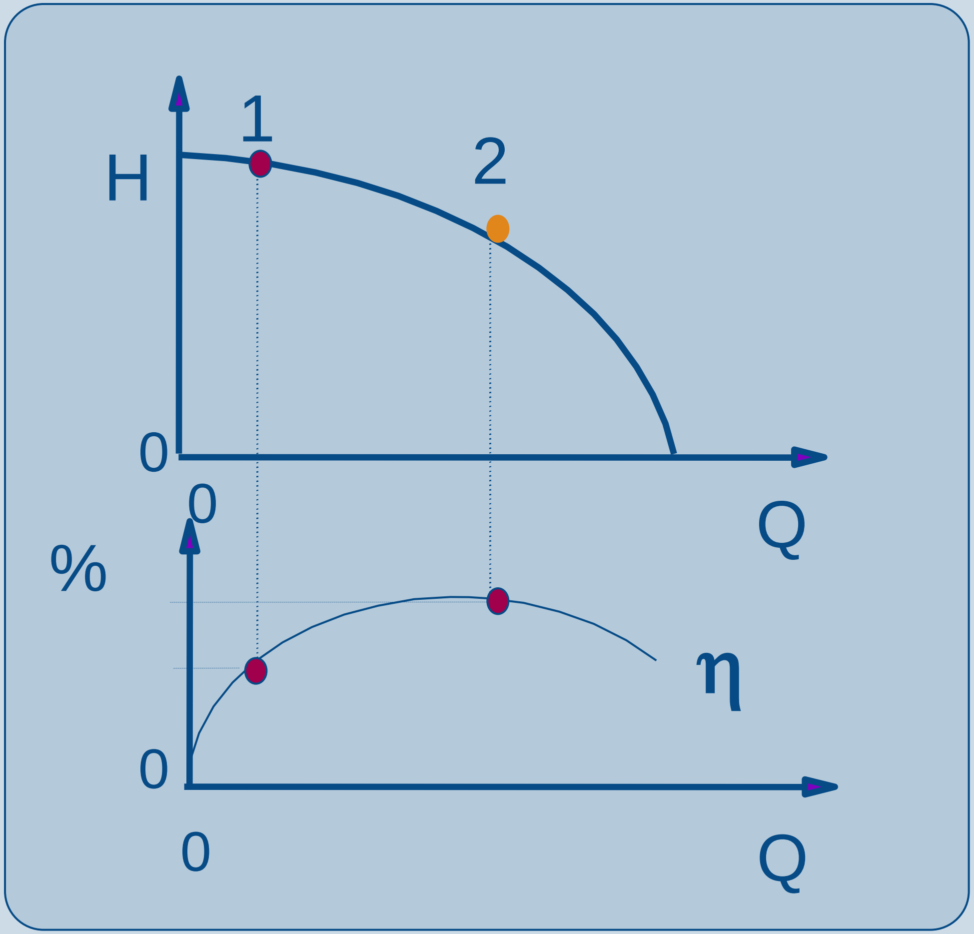
Power curve





1 : Duty point with poor η

2 : Duty point with good η



Pump theory

Efficiency - Formula

$$P = \frac{Q \times H \times g \times D}{\eta}$$

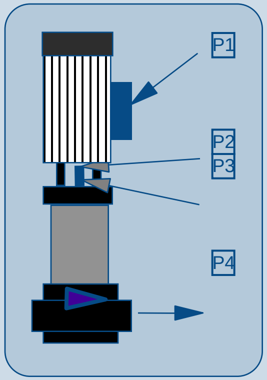
$$P = \frac{\frac{1}{3600} \times 1 \times 9.81 \times 1000}{1} = \underline{2.72}$$

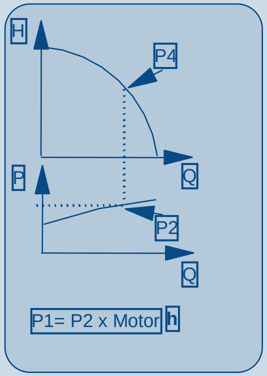
$Q = m^3/s$
$m = H\ [m]$
$g = 9.81\ m/s$
D (density) $= kg/m^3$

$$P = \frac{m^3/h \times H[m] \times 2.72}{\eta \times 1000} = kW$$

Pump theory

Example: LP 100-125/137





Capacity: 130 m³/h
Head: 16 m

P4: $$\frac{130m^3/h \times 16m(H) \times 2.72}{1000} = 5.65kW$$

P2: $$\frac{130m^3/h \times 16m(H) \times 2.72}{0.75 \times 1000} = 7.53kW$$

P1: $$\frac{130m^3/h \times 16m(H) \times 2.72}{0.83 \times 0.75 \times 1000} = 9.07kW$$

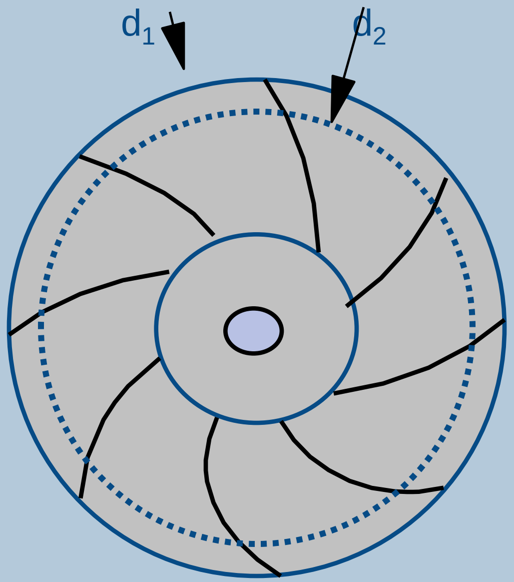
Adaptation of Pump Performance to Actual Duty Point

Changing impeller diameter

Theoretical formula

$$d_2 = \sqrt{\frac{Q_2}{Q_1}} \times d_1$$

Warning
Changing the diameter also changes the efficiency



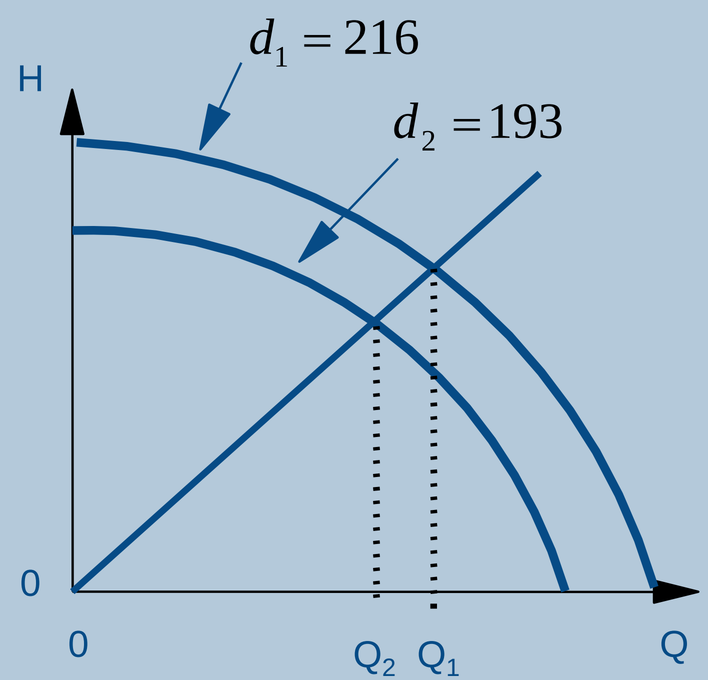
Impeller

Changing impeller diameter

$$d_2 = d_1 \times \sqrt{\frac{Q_2}{Q_1}}$$

$$d_2 = 216 \times \sqrt{\frac{40}{50}}$$

$$d_2 = 193$$



Warning
Consult manufacturer (Grundfos) for accurate data

Speed Control

Affinity Law

$$\frac{n_x}{n} = \left(\frac{Q_x}{Q}\right)$$

Speed **n** is proportional to flow **Q**

$$\frac{H_x}{H} = \left(\frac{Q_x}{Q}\right)^2$$

Head **H** is proportional to flow **Q** in second power.

$$\frac{P_x}{P} = \left(\frac{Q_x}{Q}\right)^3$$

Input power **P** is proportional to flow **Q** in third power

Effects of variable speed

$n1 \times (Q2/Q1) = n2$

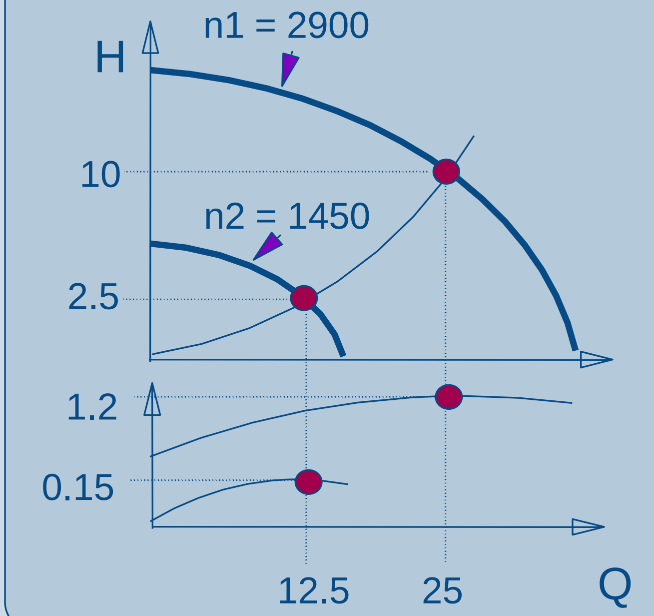
$2900 \times (12.5/25)$ **= 1450**

$H1 \times (Q2/Q1)^2 = H2$

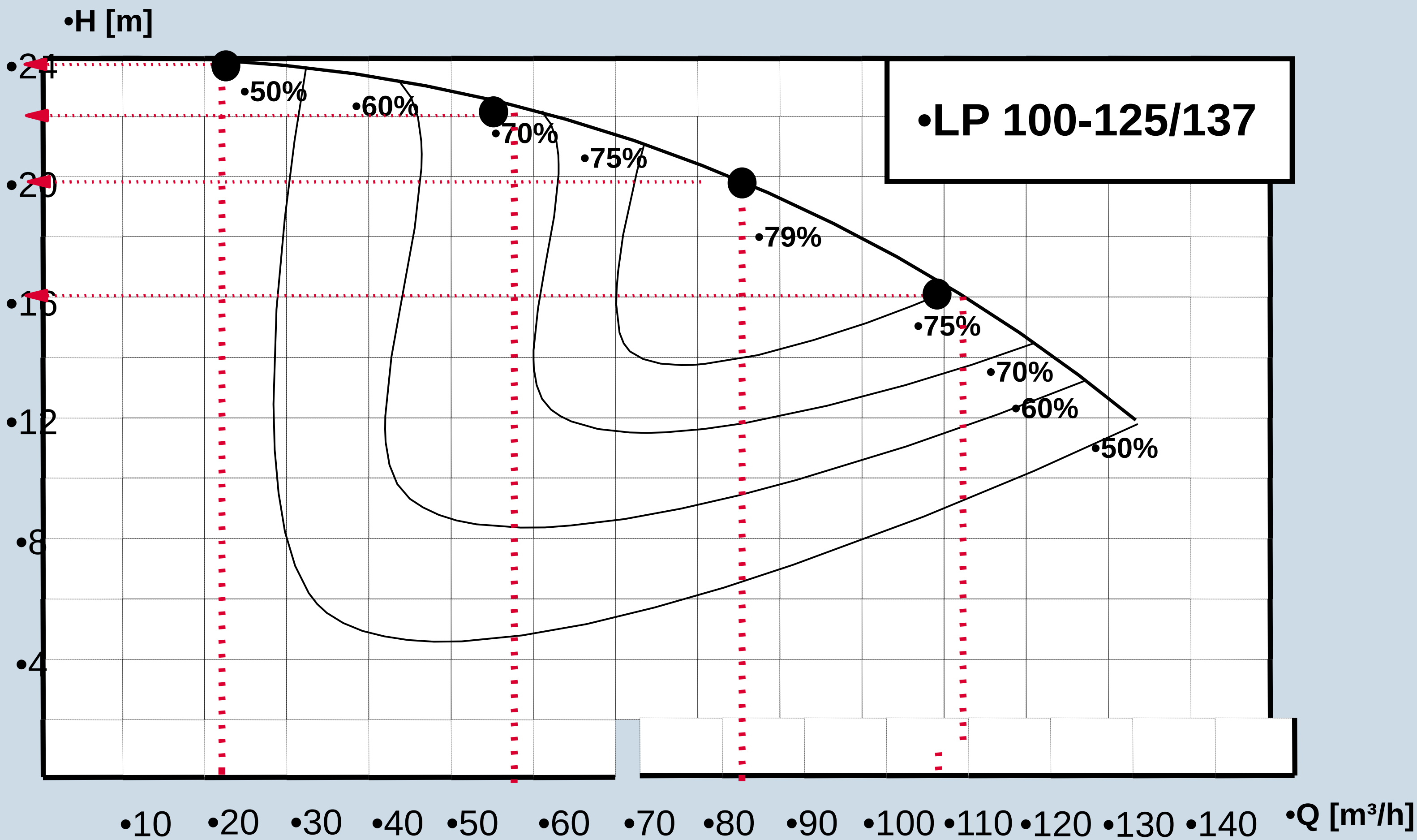
10 $\times (12.5/25)^2 =$ **2.5**

$P1 \times (Q2/Q1)^3 = P2$

1.2 $\times (12.5/25)^3 =$ **0.15**



Standard pump



Standard pump calculations

$$P = \frac{m^3/h \times head[m] \times 2.72}{\eta \times 1000} = kW$$

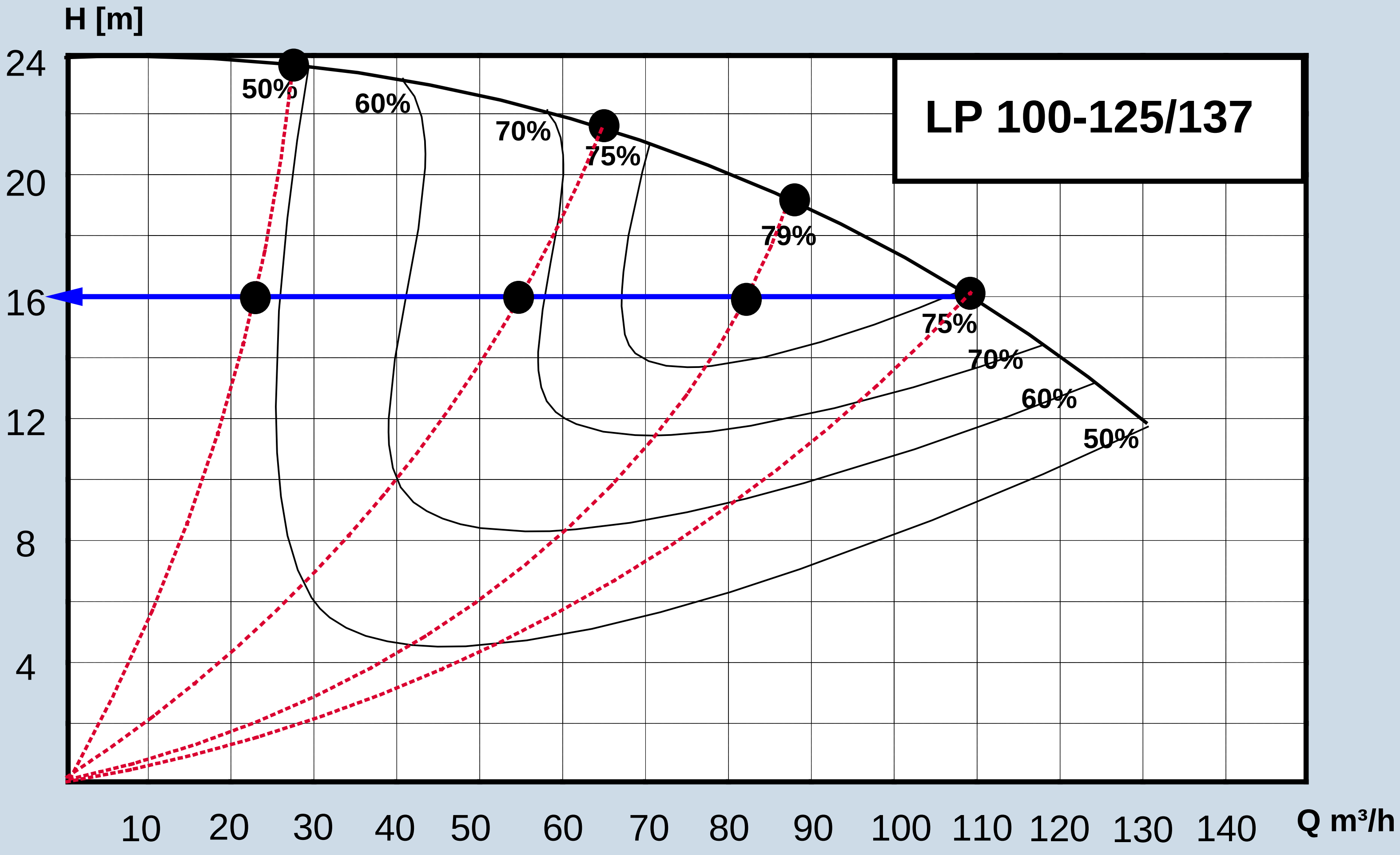
1. $$\frac{110 \times 16 \times 2.72}{0.76 \times 1000} = 6.20kW$$

2. $$\frac{82 \times 20 \times 2.72}{0.78 \times 1000} = 5.71kW$$

3. $$\frac{55 \times 22 \times 2.72}{0.67 \times 1000} = 4.91kW$$

4. $$\frac{22 \times 24 \times 2.72}{0.47 \times 1000} = 3.05kW$$

VFD pumps / constant pressure



Calculation VFD pump
Constant pressure

$$P = \frac{m^3/h \times head[m] \times 2.72}{\eta \times 1000} = kW$$

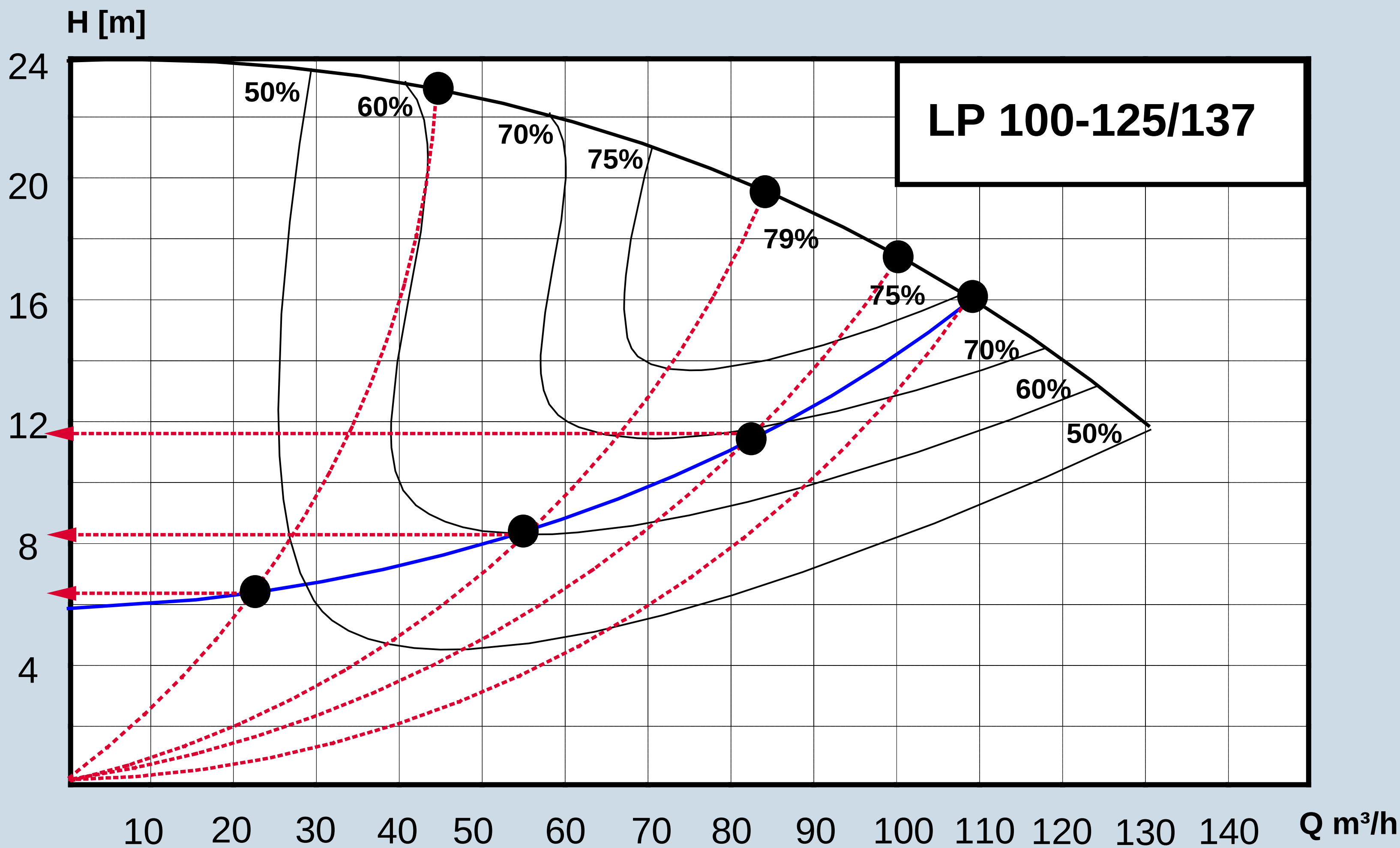
1 $$\frac{110 \times 16 \times 2.72}{0.76 \times 1000} = 6.20kW$$

2 $$\frac{82 \times 16 \times 2.72}{0.79 \times 1000} = 4.51kW$$

3 $$\frac{55 \times 16 \times 2.72}{0.73 \times 1000} = 3.28kW$$

4 $$\frac{22 \times 16 \times 2.72}{0.48 \times 1000} = 1.99kW$$

VFD pump / Proportional pressure



Calculation of VFD pump
Proportional pressure

$$P = \frac{m^3/h \times head[m] \times 2.72}{\eta \times 1000} = kW$$

1. $$\frac{110 \times 16 \times 2.72}{0.76 \times 1000} = 6.20kW$$

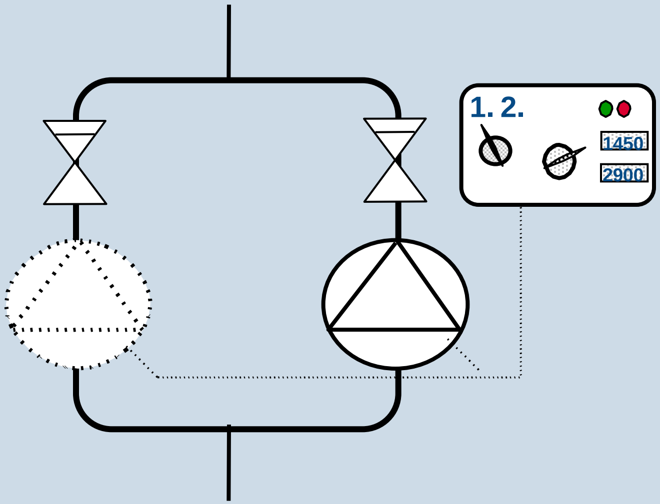
2. $$\frac{82 \times 11 \times 2.72}{0.78 \times 1000} = 3.75kW$$

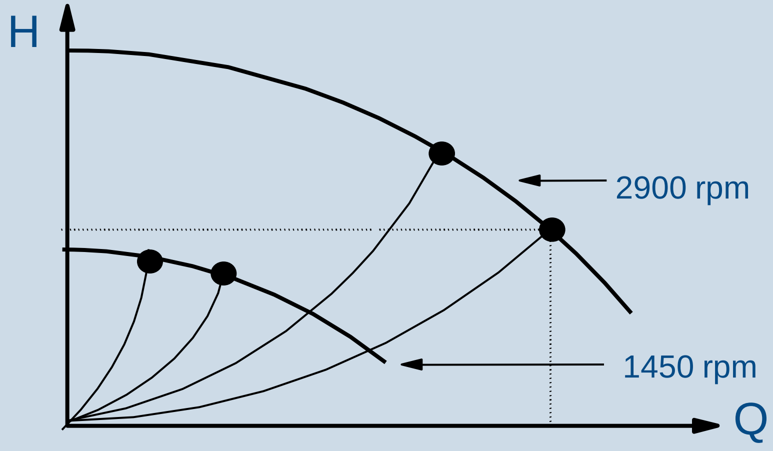
3. $$\frac{55 \times 9 \times 2.72}{0.785 \times 1000} = 1.72kW$$

4. $$\frac{22 \times 7 \times 2.72}{0.64 \times 1000} = 0.65kW$$

Pump with change-pole motor

Example of construction:
> 1 pump with 2 and 4 poles

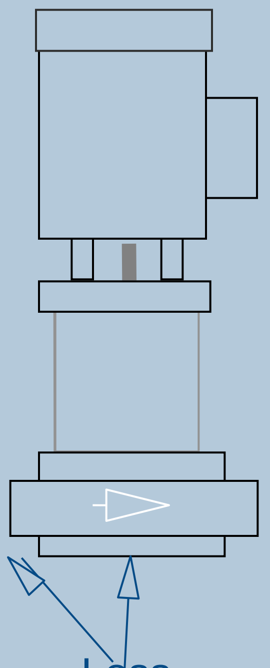


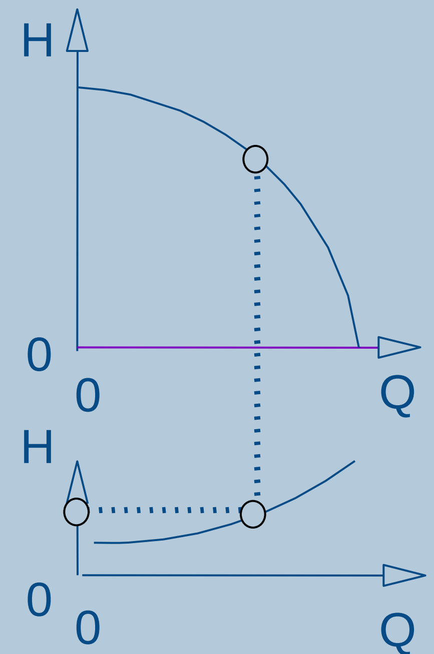


Suction Conditions

What is NPSH ?

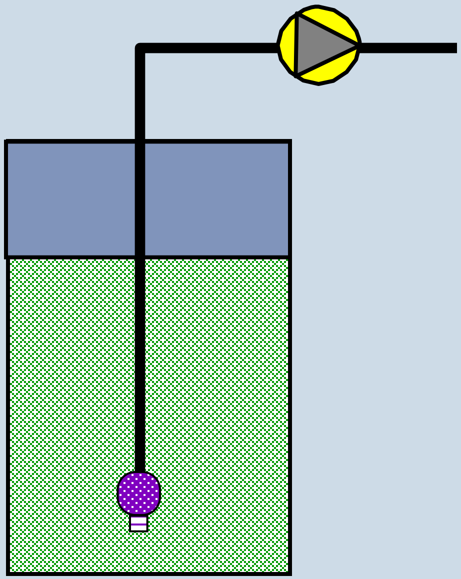
Net **P**ositive **S**uction **H**ead





NPSH is usually stated in metres

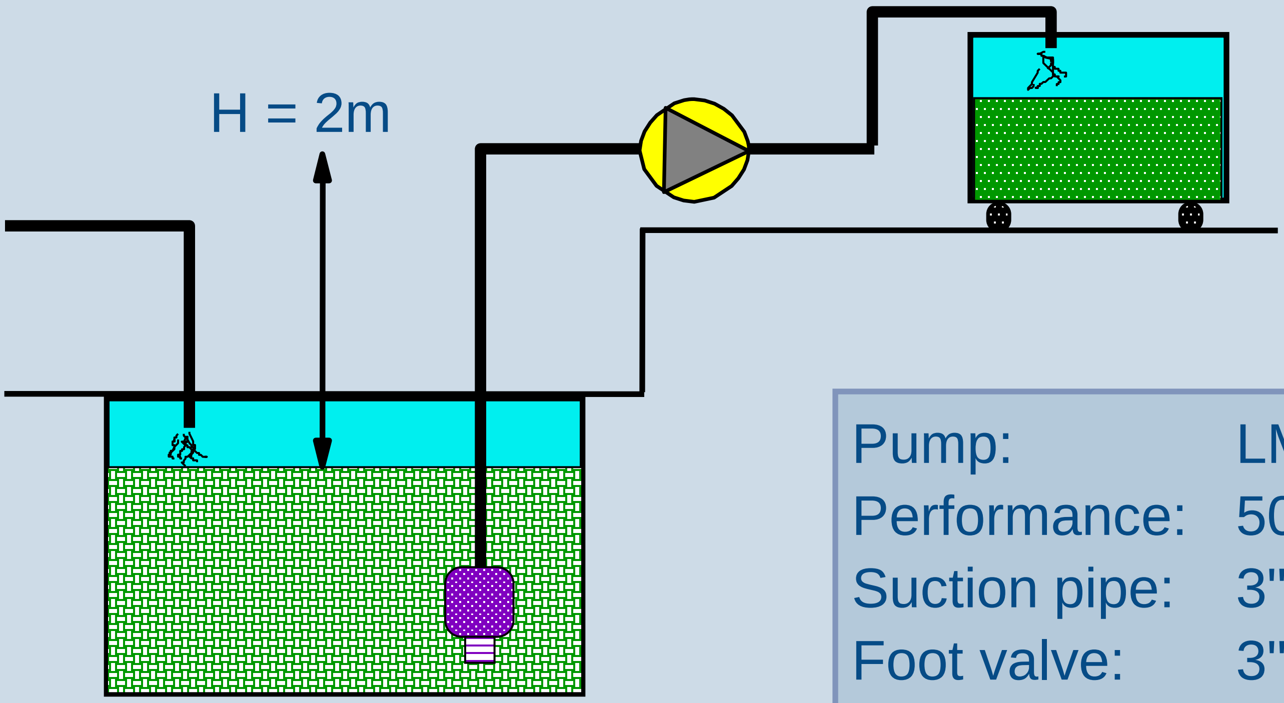
Suction Conditions



What is the maximum depth from which a pump can draw water?

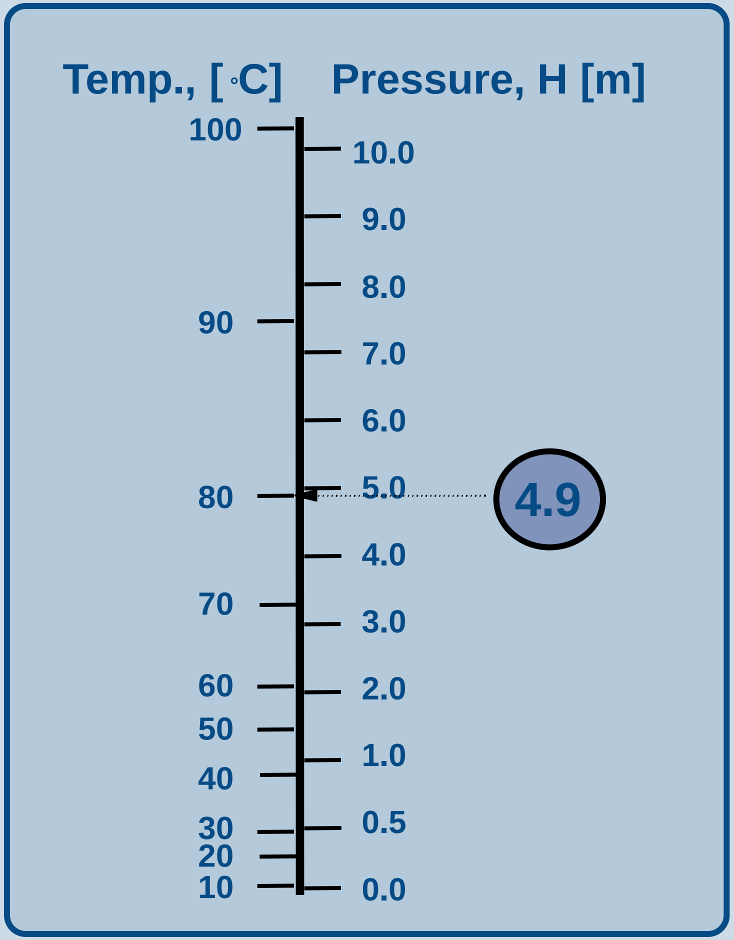
> 10.13m [barometric pressure]
> Friction loss in pipes and foot valve
> Vapour pressure
> NPSH
> Safety??

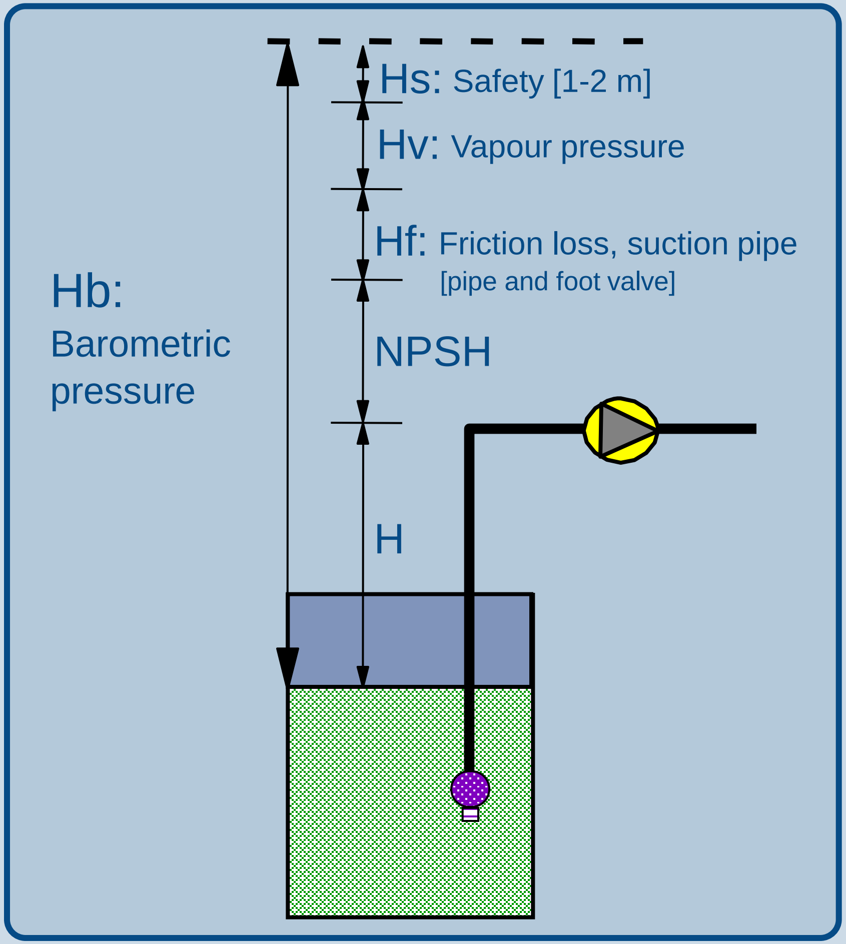
Calculation of Suction Lift



Pump:	LM 80-200/187
Performance:	50 m³/h
Suction pipe:	3"
Foot valve:	3" with spring
Water temp.:	+80°C

Vapour pressure and calculation of suction lift



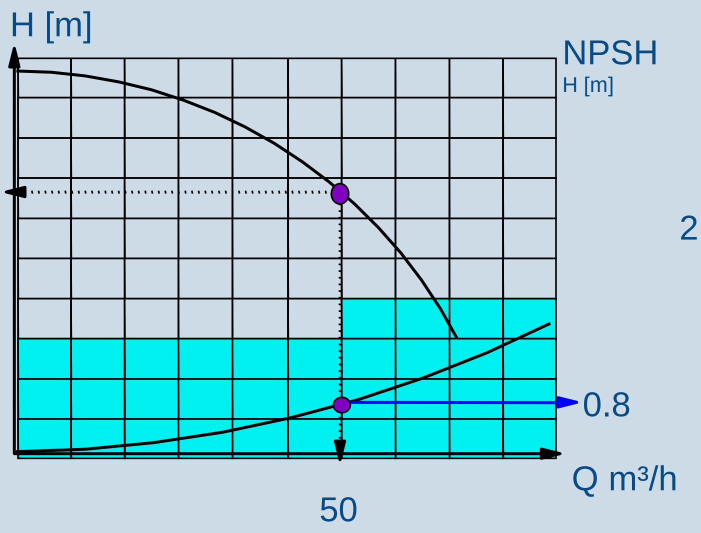


Barometric Pressure

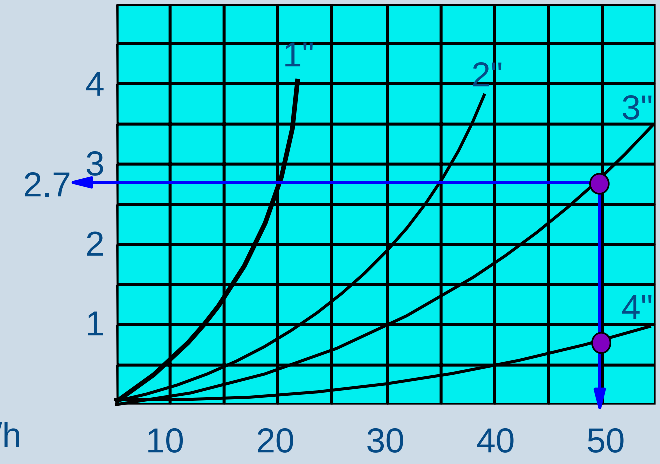
Denmark:	10.13 m
China**:**	9.11 m
Tibet:	6.62 m
Beijing:	10.30 m
Shanghai:	10.35 m

Calculation of Suction Lift

LM 80-200/187



Foot valves



Calculation of Suction Lift

Barometric pressure	10.13 m
NPSH	0.80 m
Vapour pressure	4.90 m
Pressure loss	0.30 m
Pressure loss, foot valve	2.70 m
Safety	1.00 m
Suction lift, actual	**0.43 m**