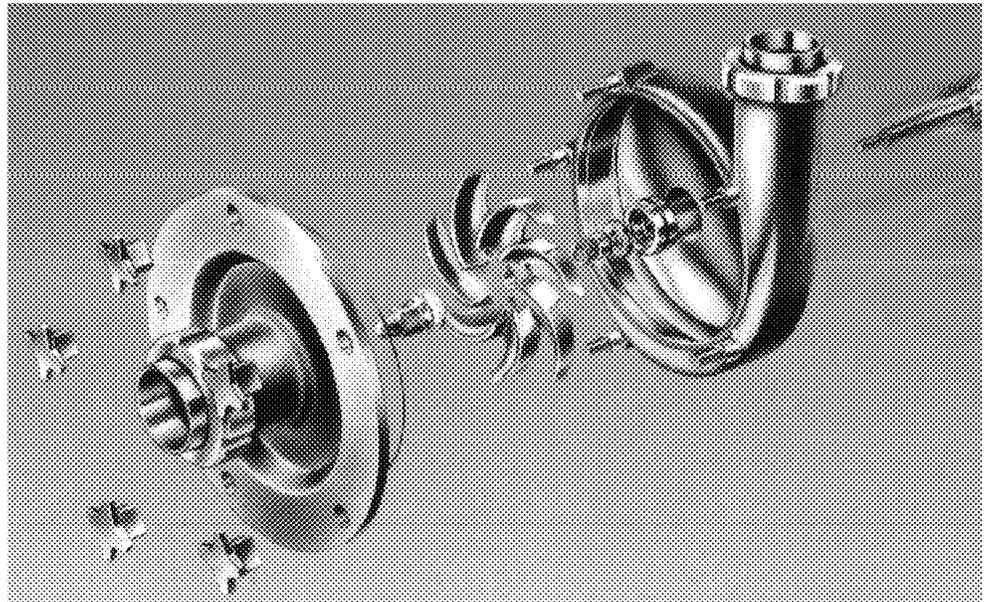


Centrifugal pumps

Features of the centrifugal pump

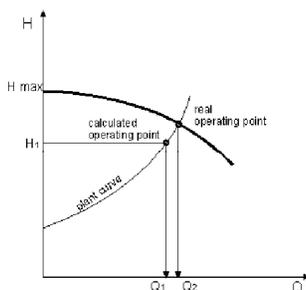
Centrifugal pumps are fluid-kinetic machines designed for power increase within a rotating impeller. Therefore it is also called the hydrodynamic pumping principle.

According to this principle, the fluid is accelerated through the impeller. In the outlet connection of the centrifugal pump, the resulting increase in speed is converted into delivery head.



Q/H curve

In centrifugal pumps the delivery head H depends on the flow rate Q . This relationship, also called pump performance, is illustrated by curves.



During a bench test, the pump is operated at constant speed and the values Q and H are determined for the various operating points. In order to allow a comparison between the various pump types these measurements are carried out using only water as liquid. With these operating points a Q/H curve can be drawn connecting the points on the graph.

Once the flow rate Q is defined and the delivery head H is calculated, the operating point of the plant can be determined. Usually the operating point is not on the Q/H curve of the pump. Depending on the required delivery head, the centrifugal pump will find its operating point when the plant curve and pump curve meet. The flow rate rises from Q_1 to Q_2 .

The required operating point is obtained by adapting the pump to the specified operating conditions.

This can be done by the following actions:

- throttling the flow
- correcting the diameter of the impeller
- Adjusting the speed of the drive

Partially closing a throttle valve or mounting an orifice plate into the discharge pipe of the pump will increase the pressure drop. The plant curve is shifted.

The operating point B1 (intersection point between pump curve and plant curve) moves on the pump curve to B2.

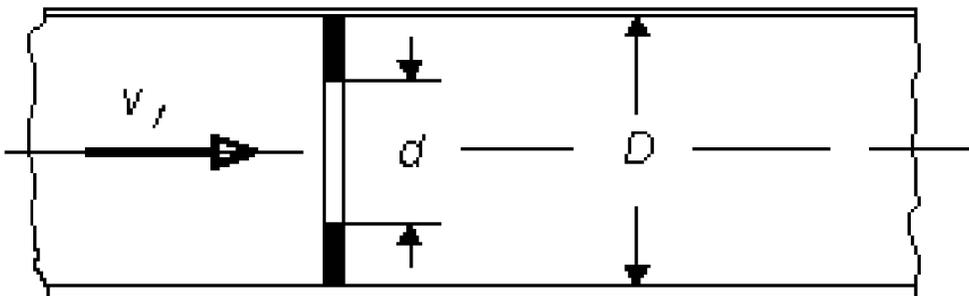
Note: throttling reduces the overall efficiency.

A throttle control or a mounted orifice plate is the less expensive control regarding the investment expenses. In case of significant power requirement, an economic appraisal is highly recommended.

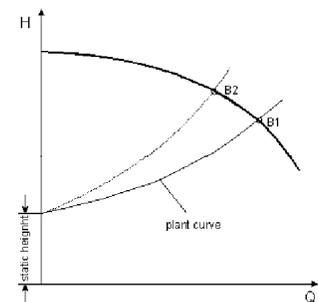
The friction loss in an orifice plate can be calculated easily:

$$\Delta p_v = \zeta \times \frac{\rho}{2} v_1^2 \times 10^{-5}$$

ρ [kg/m³]
 v_1 [m/s]
 Δp_v [bar]



Throttling the flow



Orifice plate calculation

Centrifugal pumps

See the values ζ stated in the table below.

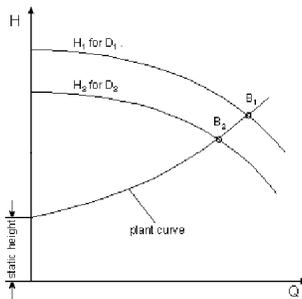
Aperture ratio $m = (d/D)^2$	Resistance value ζ
0.05	600
0.1	250
0.2	50
0.3	20
0.4	4

Calculation:

- take the figure stated in the table for d , see table ζ , calculate Δp_v .
- if Δp_v varies from the required value, take new value for d and calculate once more Δp_v .

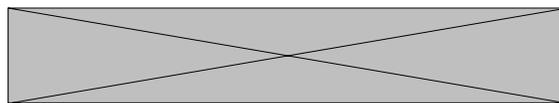
Correction of the impeller diameter

A correction of the impeller diameter is to be favoured when a permanent reduction of flow rate or differential head is required. The performance of the pump is adjusted towards the duty point by reducing the impeller diameter.



The operating point is shifted from B1 to B2. This is the point where the new pump curve meets the plant curve.

The required impeller diameter can be determined easily using following formulae:



N = power consumption
 D = impeller diameter
 Q = flow rate
 H = total head

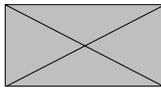
Note: the efficiency of the pump decreases with increasing correction.

Centrifugal pumps

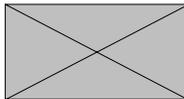
A great number of various operating points can be set continuously, when modifying the pump speed using a variable speed drive or frequency inverter. The operating point moves on the pump curve from B to B2.

Considering the overall efficiency, this is the best way of flow control. Using a variable-speed drive or a frequency inverter additional costs can arise and should be evaluated in an economic appraisal.

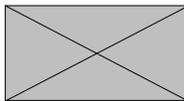
The flow rate changes linearly to the speed.



The total head changes with the square of speed.

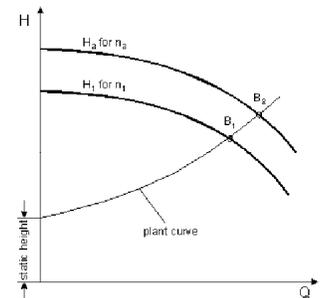


The power consumption changes with the third power of the speed.

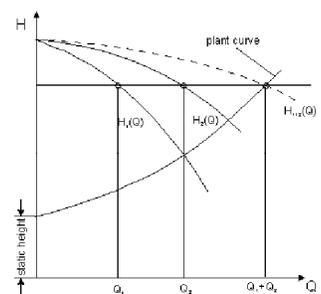


In the case of pumps connected in parallel the fluid flows are added with corresponding delivery head. This applies to pumps even with different Q/H curve.

Pump speed control

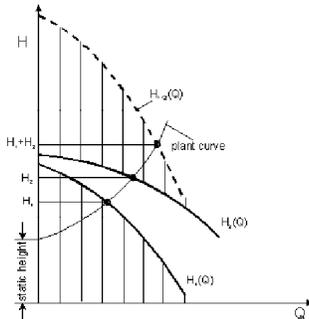


Parallely connected pumps



Centrifugal pumps

Pumps connected in series



A multistage centrifugal pump performs as single stage pumps connected in series.

Note:

A stationary pump in a system creates a considerable pressure drop. Therefore it is recommendable to install a by pass around pumps which are connected in series.

The overall performance curve of centrifugal pumps connected in series can be calculated by adding the differential head of each pump at the relevant flow rate .

Cavitation

Cavitation can be recognised by a strongly increased noise level of the pump with a simultaneous reduced flow rate.

What causes cavitation in centrifugal pumps ?

The lowest pressure point in a pump occurs at the inlet of the pump impeller. Due to local pressure reduction part of the fluid may evaporate generating small vapour bubbles. These bubbles are carried along by the fluid and implode instantly when they get into areas of higher pressure. These implosions can create local pressure peaks up to 100.000 bar.

If a pump is cavitating over longer periods, the impeller, the pump housing and cover will wear out. The surface is typically perforated and pitted.

How to avoid cavitation?

We should ensure that at all points of the pump, the fluid pressure is higher than the vapour pressure at the corresponding temperature. Take the pressure stated in the vapour-pressure-table of the product to be transferred.

The NPSH value of the plant must be at least 0.5 m higher than the NPSH value of the pump.

For a safe and cavitation free operation the following formula is valid:

$$\text{NPSH}_{\text{plant}} > \text{NPSH}_{\text{Pump}} + 0.5 \text{ m}$$

The vapour pressure of the product is dependent on the temperature and will rise with increasing temperature.

If the product is pumped at different temperatures the maximum vapour pressure should be used to determine the NPSH value of the plant.

Vapour pressure

Centrifugal pumps

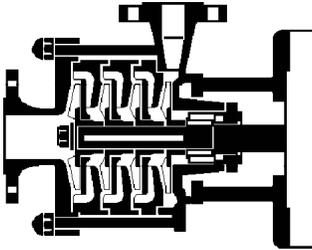
Centrifugal pump types

The **Fristam** centrifugal pump range consists of following pump types:



- **Fristam** centrifugal pump **FP**

The design principle of the **Fristam** centrifugal pump FP with open impeller and optimised volute guarantees shear sensitive handling of and minimum heat transfer to the product. Viscosities up to 1000 mPa are no problem. The fluid may contain air or gas, may be homogeneous or contain additives. Low NPSH values make it possible to use the pump also under unfavourable conditions. The **Fristam** centrifugal pump FP is designed as a pump for flooded suction and fully suitable for CIP and SIP application.



- **Fristam** multistage centrifugal pump **FM**

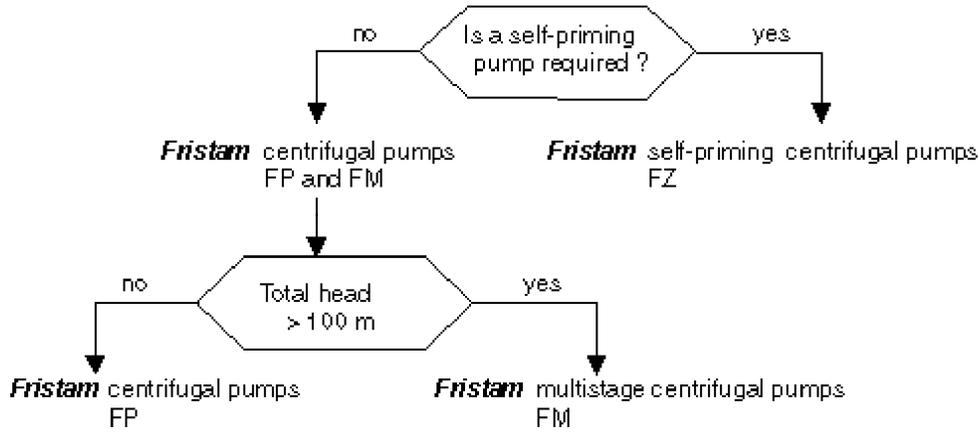
The centrifugal pump FM is designed as a multistage pump especially developed for high delivery heads. The centrifugal pump FM can be used for difficult pressure conditions such as feed pump for filters, heat exchangers and fillers, as well as for recirculation and as booster pump in membrane filtration and reverse osmosis plants.



- **Fristam** self-priming centrifugal pump **FZ**

The centrifugal pump FZ works on the water ring-side channel principle. Impellers with radial blades transfer the pressure energy to the liquid. Close clearances make it possible to obtain an excellent suction performance. Thus it is possible to pump gaseous products and to deaerate the suction line. This ensures also an optimum drain of the plant..

Selection criteria



The selection between the pump types FP and FM also depends on the required flow rate.

Centrifugal pumps

Centrifugal pump FP



Selecting the correct size

Example:

Flow rate $Q_A = 90 \text{ m}^3/\text{h}$

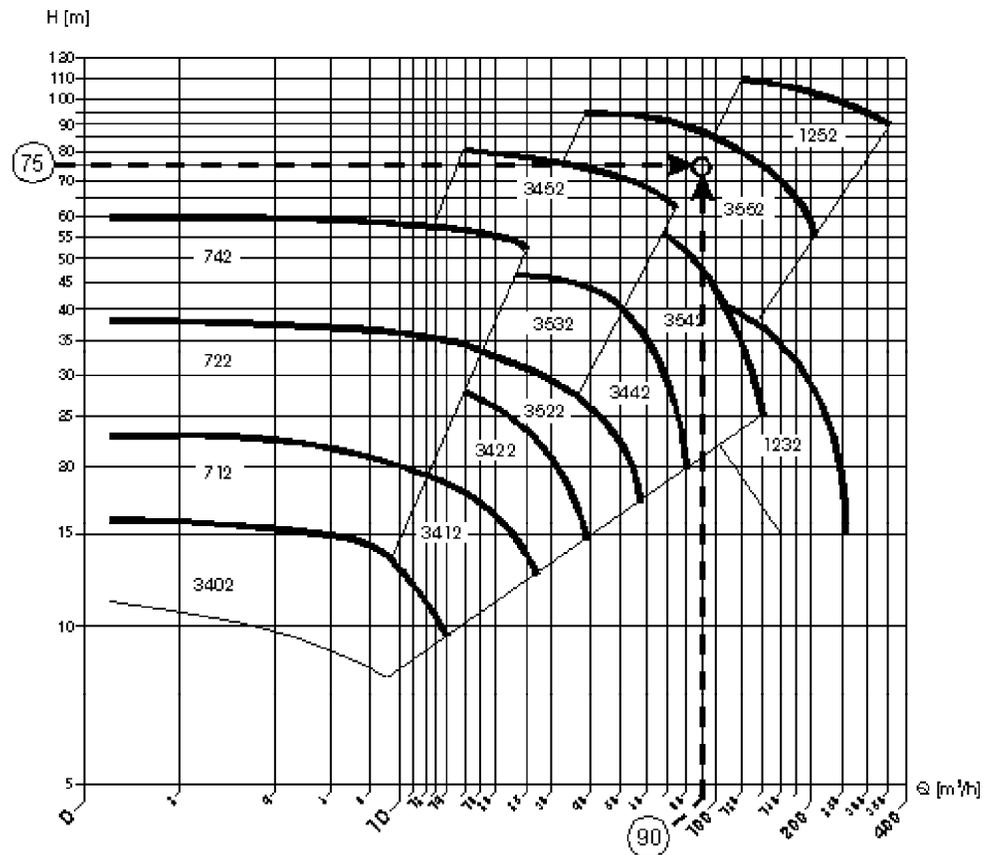
Total head $H_A = 75 \text{ m}$

Step 1:

Select the pump size.

FP sizes

Size selection



Selected pump size: **FP 3552**

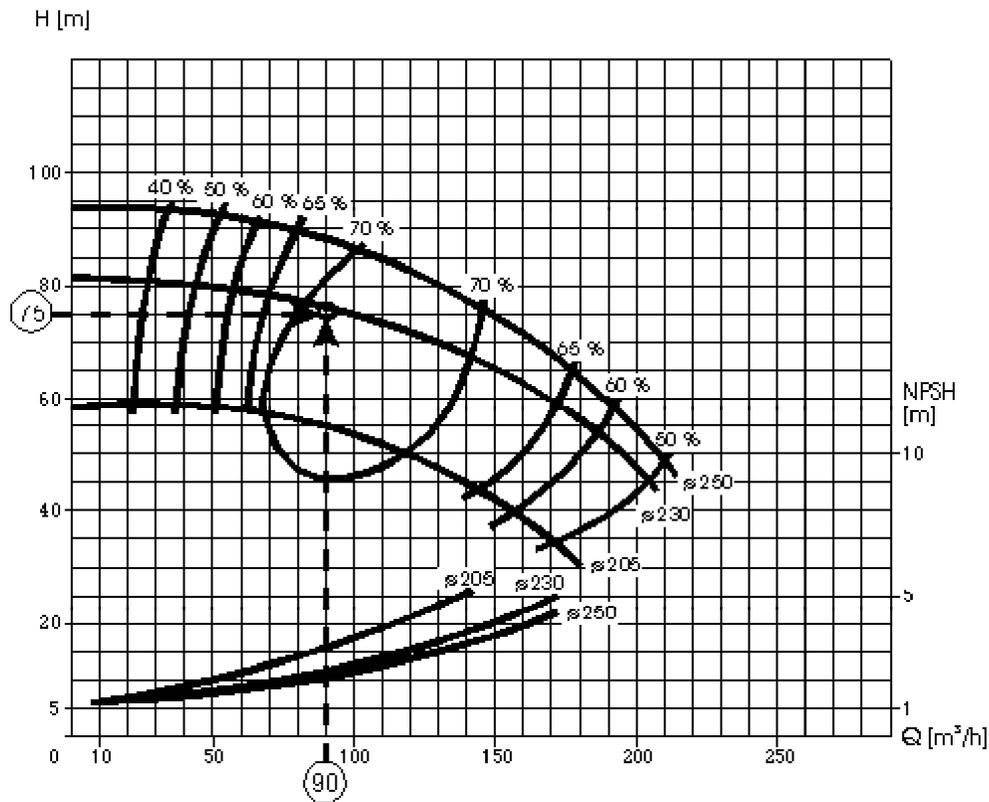
Step 2:

Enter the operating point of your plant into the pump diagram.

Centrifugal pump FP performance diagram

If the duty point is not exactly on the pump curve, the performance of the pump can be adjusted by throttling the flow, reducing the impeller diameter or adjusting the output speed of the drive. (see page 21–23)

FP 3552



Impeller diameter resulting from the diagram = 230 mm

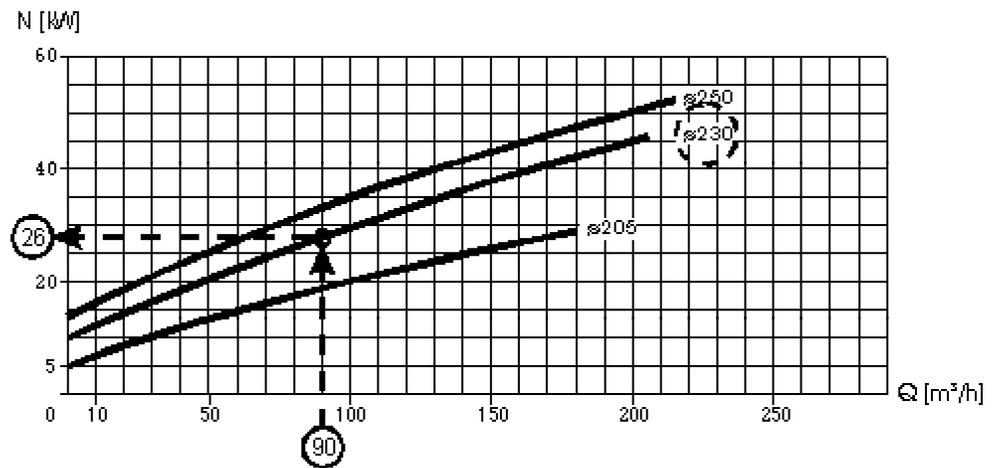
Centrifugal pumps

Power consumption of the pump

Step 3:

Find the power consumption of the pump at the point in the diagram where the power curve of the impeller used meets the design flow rate.

Select the motor with the next higher power rating.



Power consumption according to the diagram: $N = 26 \text{ kW}$

selected motor: 30.0 kW

pump efficiency

Step 4:

Check the efficiency

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

Q [m³/h]
 H [m]
 N [kW]
 ρ [kg/dm³]

$$\eta = \frac{90 \times 75 \times 1}{367 \times 26}$$

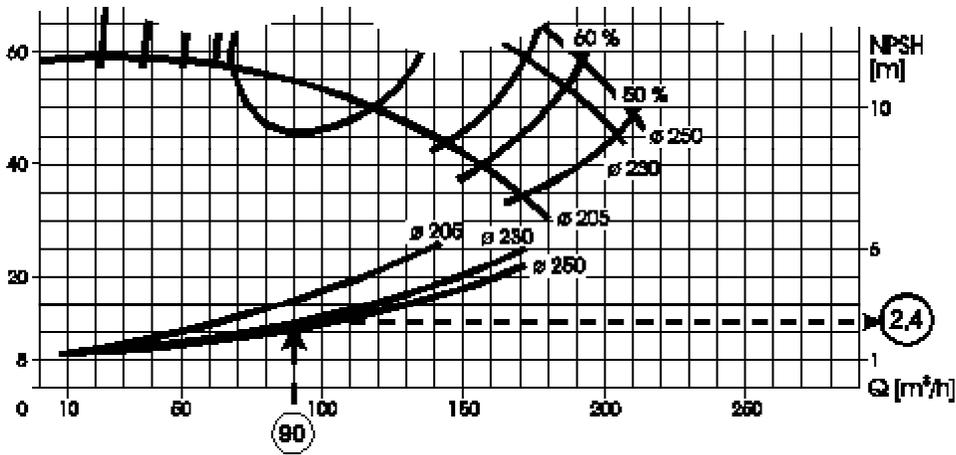
$\rho_{\text{water}} = 1 \text{ kg/dm}^3$

$$\eta = 0.7 \Rightarrow 70\%$$

Step 5:

Check if $NPSH_{plant} > NPSH_{Pump}$

Check NPSH value



Resulting NPSH value of the pump from the diagram = 2.4 m

Centrifugal pumps

Self-priming centrifugal pump FZ



Selecting the correct size

Example:

Flow rate $Q_A = 30 \text{ m}^3/\text{h}$

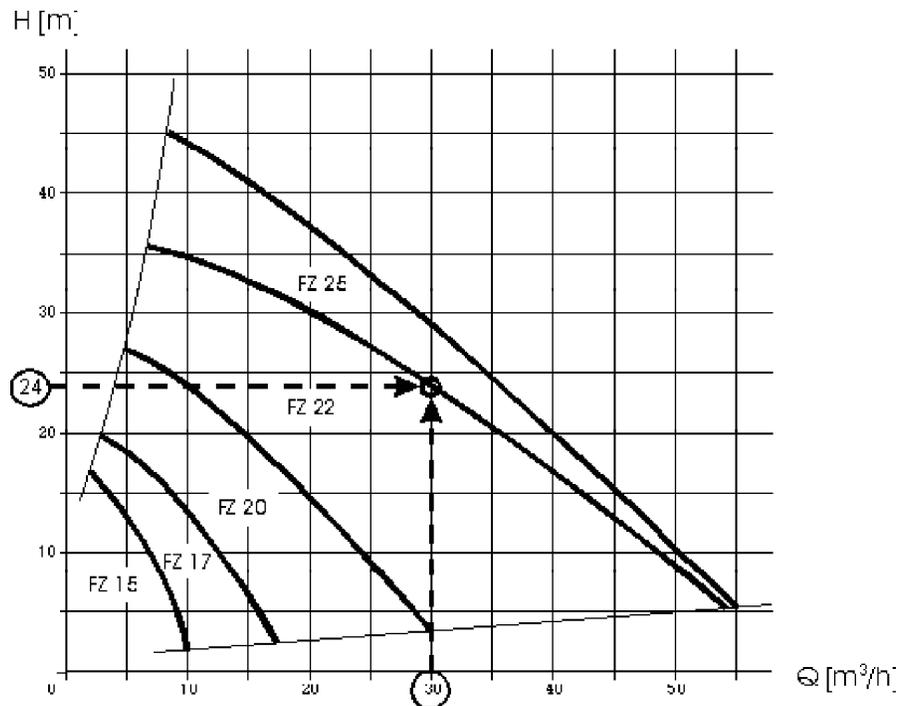
Total head $H_A = 24 \text{ m}$

Size selection

Step 1:

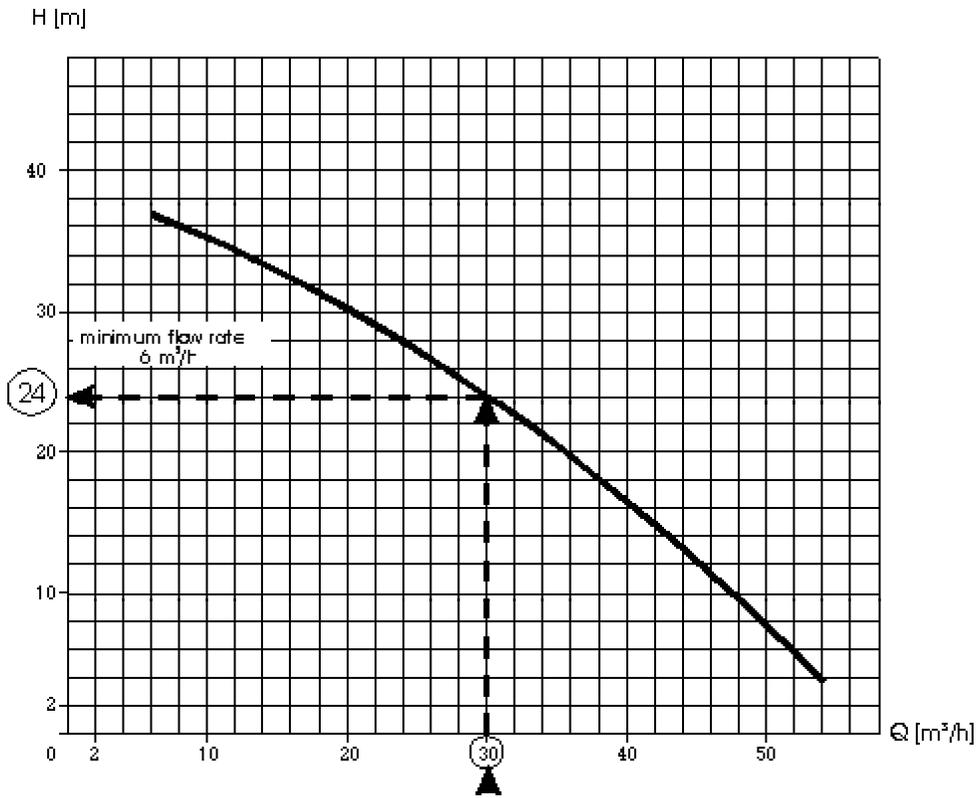
select the pump size whose curve is above to the operating point of the plant.

FZ sizes



Selected pump size: **FZ 22**

Power consumption of the pump



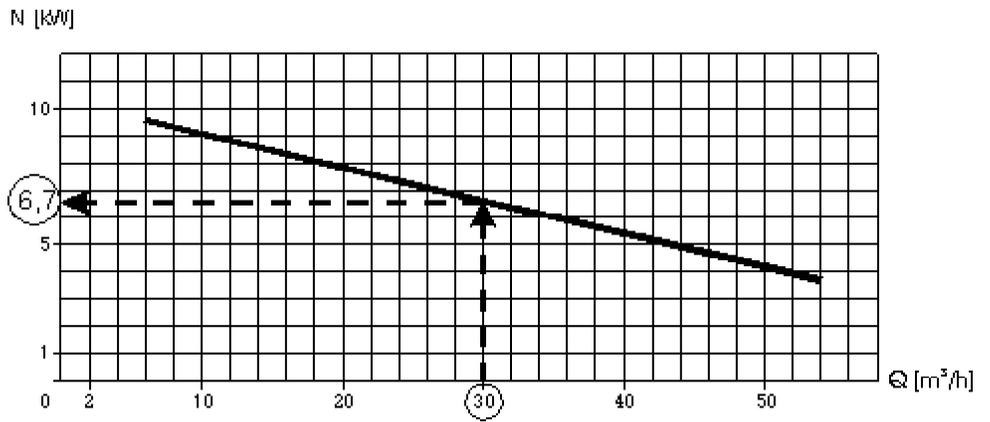
Note:

The performance of FZ pumps can be adjusted to the required operating point only by throttling the flow (see page 21/22) or variation of the speed (see page 23). It is **not possible** to modify the impeller diameter.

Centrifugal pumps

Step 2:

Find the power consumption of the pump at the point in the diagram where the power curve meets the design flow rate. Select the motor with the next higher power rating.



From the diagram: $N = 6.7$ kW, selected motor: 7.5 kW

Multistage centrifugal pump FM

The selection is carried out the same way as single-stage centrifugal pumps FP are selected (See page 28).

