

Features of the centrifugal pump

离心泵的特征

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

离心泵是一种动力使旋转叶轮转动，使动的流体流动的机器，这被称为水力泵送原理

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.

依据此原理，流体加速流过叶轮，在出口处增加的速度被称为压力差

Q/H curve

Q / H 曲线

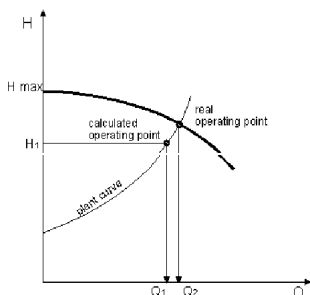
在离心泵中水头H与流量Q相关，这种关系被称为泵的特性，用曲线图表示

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

在基本测试中，泵以恒定转速工作，这样Q和H是一系列变化的工作点

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.

为了便于比较各规格的泵，我们只用水体流体。
Q / H 曲线上的工作点被连接起来



一旦流量Q确定，那么水头H即计算出，设备的工作点即被确定通常工作点不在Q / H 曲线上

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 .

根据必需的水头，当设备曲线与泵曲线相交的工作点即是离心泵的工作点，流量从 Q_1 升到 Q_2

The required operating point is obtained by adapting the pump to the specified operating conditions. 这些必需的工作点是泵在设定工作条件下获得的

This can be done by the following actions: 这些将在下列行为中完成

- throttling the flow 节流
- correcting the diameter of the impeller 选择正确的叶轮尺寸
- Adjusting the speed of the drive 调节进给转速

关小节流阀或在泵的排出管上放一个锐口板，将增大压差，设备曲线也将变化
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.

工作点 B 1 (泵曲线与设备曲线的交叉点) 移到 B 2
The operating point B1 (intersection point between pump curve and plant curve) moves on the pump curve to B2.

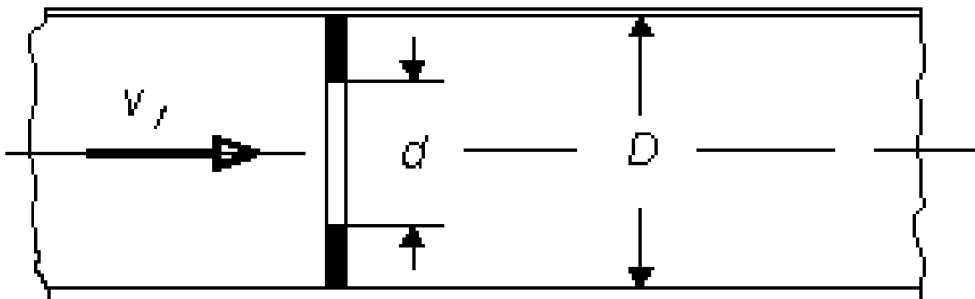
Note: throttling reduces the overall efficiency. 节流将降低全部的效率

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. 节流或装锐口板是很经济的控制方法，是应该被推荐的

锐口板的摩擦损失是很容易计算出的
The friction loss in an orifice plate can be calculated easily:

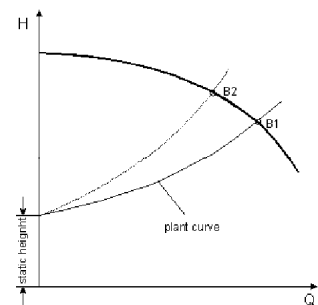
$$\Delta p_v = \zeta \times \frac{\rho}{2} v_1^2 \times 10^{-5}$$

ρ [kg/m³]
 v_1 [m/s]
 Δp_v [bar]



节流

Throttling the flow



Orifice plate calculation

锐口板的计算

Centrifugal pumps

值 在下表定出

See the values ζ stated in the table below.

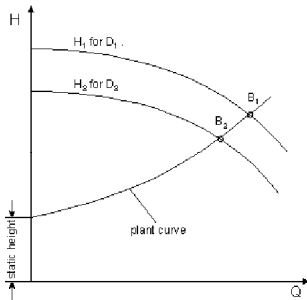
Aperture ratio $m = (d/D)^2$	Resistance value ζ
0.05	800
0.1	250
0.2	50
0.3	20
0.4	4

Calculation:

- 通常定比值找出 m ，计算出 P_v 。
- 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 .
如果 P_v 变化，给出 d 值计算出新的 P_v 值

Correction of the impeller diameter

修区叶轮直径

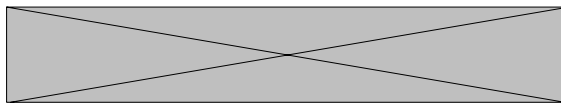


A correction of the impeller diameter is to be favoured when a permanent reduction of flow rate or differential head is required. The performance of the pump is adjusted towards the duty point by reducing the impeller diameter. 当有永久性流量变化和压力变化时，修区叶轮直径是有利的，减小叶轮直径将使泵的性能调整到重要的点

The operating point is shifted from B1 to B2. This is the point where the new pump curve meets the plant curve. 工作点从 B1 转移到 B2，这是新的泵曲线与设备曲线交叉点

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

所需的叶轮直径将被下列公式很容易的定出



N = power consumption N 功耗

D = impeller diameter D 叶轮直径

Q = flow rate Q 流量

H = total head 总压头

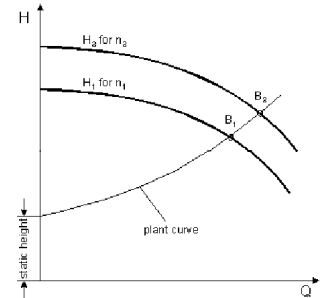
Note: the efficiency of the pump decreases with increasing correction.

泵的效率将随着修正的增加而降低的

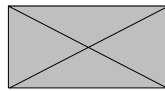
当用变速马达或变频器改变泵转速时，许多变化的工作点将被连续设置
 A great number of various operating points can be set continuously, when modifying the pump speed using a variable speed drive or frequency inverter. The operating point moves on the pump curve from B to B2. 工作点在泵曲线上从 B 1 变为 B 2

考虑到全面的效率，这是流量控制的**最佳方法**。使用变速马达或变频器
 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. 会增加额外的成本，可以从经济学上评估下

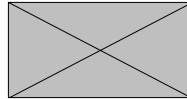
Pump speed control 泵的转速控制



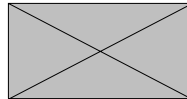
The flow rate changes linearly to the speed.
流量变化与转速成正比



The total head changes with the square of speed.总压头与转速成正比



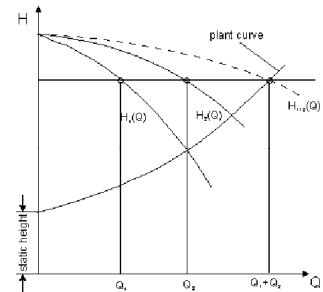
The power consumption changes with the third power of the speed.
功耗与转速成正比



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.

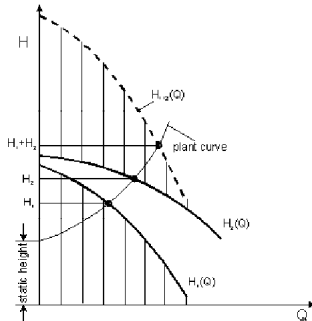
泵的并联将使在相应的压力下流量增加，将导致泵有不同的 Q / H 曲线

Parallely connected pumps 泵的并联



Centrifugal pumps

Pumps connected in series 泵的串联



多级离心泵就相当于几个单独的泵串联在一起
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.
当需要产生很大的压力 F ，把泵串联在一起是可取的

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 .

在相应的流量下把各个泵不同的压头相加，能计算出串联泵总的性能曲线

Cavitation 气蚀

Cavitation can be recognised by a strongly increased noise level of the pump with a simultaneous reduced flow rate. 气蚀发生时通常伴随着渐增的噪声

什么原因导致了离心泵发生气蚀？
What causes cavitation in centrifugal pumps？

当极低的压力发生于泵的进口叶轮处时，由于压力剧减将导致流体产生一些小的蒸气泡
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.

这些随着流体的气泡在压力增加时会剧烈的爆破 这些爆破将产生高达 1 0 0 0 0 0 B A R 的局部压力

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.

如果泵长时间在气蚀下，叶轮，泵壳，泵盖将会磨损

表面将会出现典型的穿孔，凹坑

How to avoid cavitation? 如何避免气蚀？

我们确保泵在各个方面，在相应温度下，流体压力都要大于其蒸气压力
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. 要知道被传送产品的蒸气压力表

Vapour pressure

蒸气压力

The NPSH value of the plant must be at least 0.5 m higher than the NPSH value of the pump. 设备的N P S H值至少要比泵的N P S H值大0 . 5

For a safe and cavitation free operation the following formular is valid:
要不产生气蚀，下面的公式是正确的

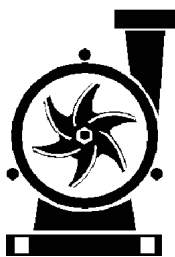
$$\text{NPSH}_{\text{plant}} > \text{NPSH}_{\text{Pump}} + 0.5 \text{ m}$$

The vapour pressure of the product is dependent on the temperature and will rise with increasing temperature. 产品的蒸气压力与温度有关，随着温度的升高而升高

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

如果泵送不同温度的产品，那要根据最大的蒸气压力来确定设备的N P S H值

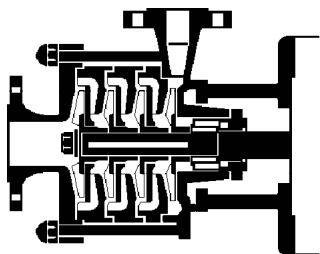
离心泵的类型 Centrifugal pump types



Fristam离心泵系列由下列型号组成：
The **Fristam** centrifugal pump range consists of following pump types:

Fristam的FP离心泵是开式叶轮，有最优化的涡型设计，保证了产品的柔和处理以及减少了物料的升温问题。可传送粘度高达1000 mPa s的物料，流体可以含气体或固体颗粒也可以是均质或异质的，低NPSH值，可保证泵在不利环境下工作，

- **Fristam** centrifugal pump **FP** 适用淹没抽吸以及CIP / SIP
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.



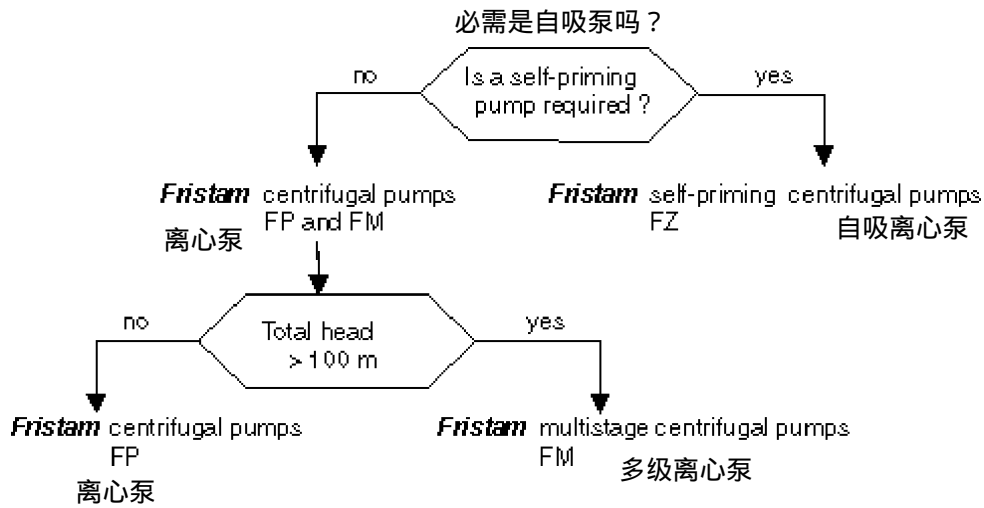
FM系列是为高压系统设计的多级离心泵，适用于特别的压力场合，如过滤系统，热交换系统膜滤，反渗透等系统的增压，填料等

- **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**
自吸式离心泵FZ，采用侧面通道原理，用放射的叶轮来压送流体
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..
密闭的间隙确保卓越的吸入性能，使吸入管既能排气又能吸到带气体的产品
是适宜设备的排水的问题

Selection criteria



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

在 F P 和间 F M 依据必需的流量选择

Centrifugal pumps

Centrifugal pump FP

离心泵 F P



Selecting the correct size

选择正确的规格

Example: 举例

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

Total head 总压头 $H_A = 75 \text{ m}$

Step 1:

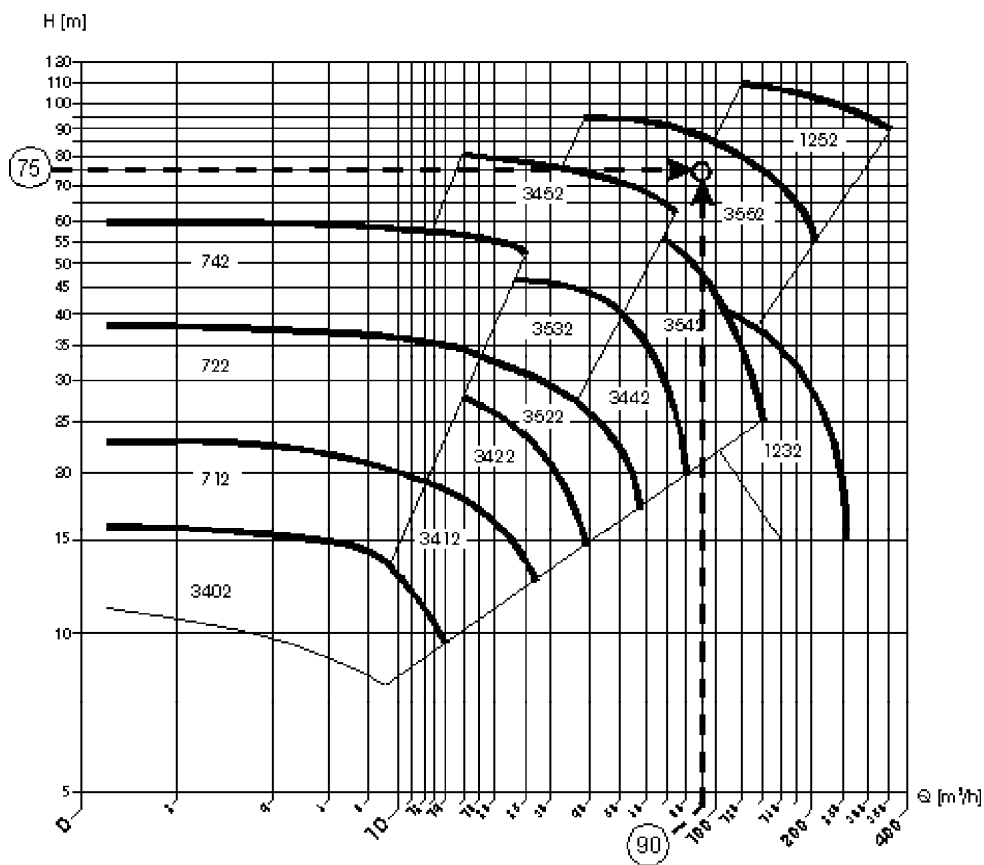
步骤 1: 选择泵的规格
Select the pump size.

FP sizes

F P 的规格

Size selection

规格选择



Selected pump size: **FP 3552**

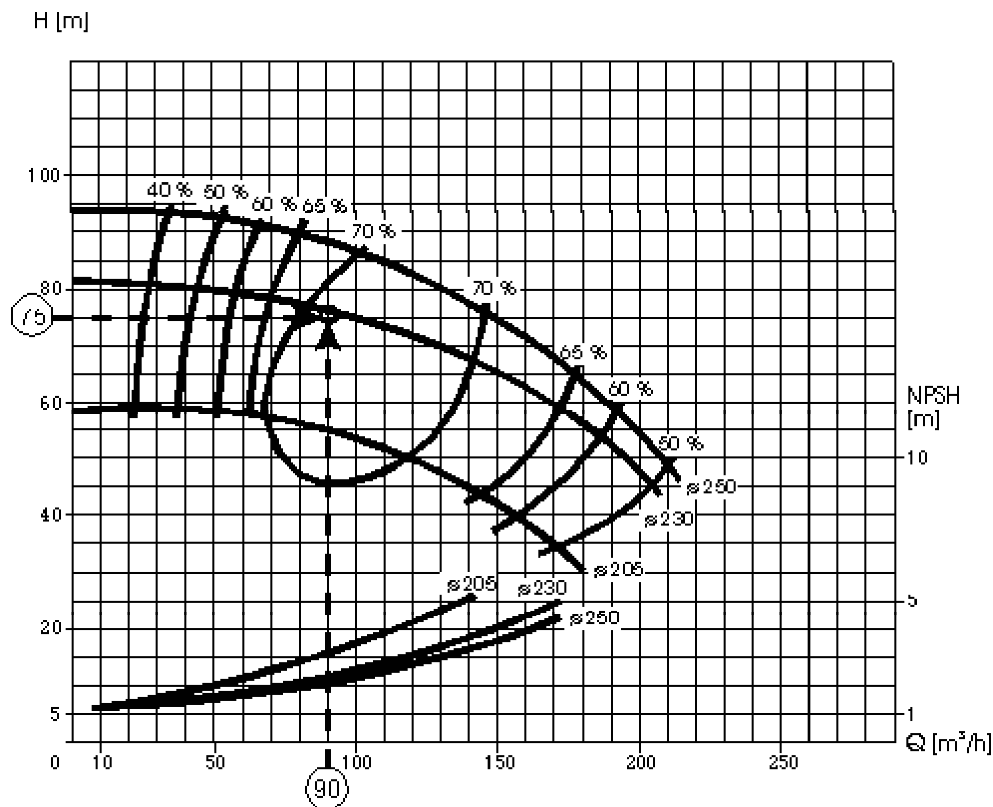
选择泵的规格为 F P 3 5 5 2

Step 2: 步骤 2 : 在泵的图表中输入设备的工作点
Enter the operating point of your plant into the pump diagram.

如果点不在泵曲线上, 那么可通过节流, 减小叶轮直径, 调整马达转速
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) 来调整泵的性能

Centrifugal pump FP performance diagram
F P 离心泵性能图

FP 3552



Impeller diameter resulting from the diagram = 230 mm

从图表中选择叶轮直径 = 230

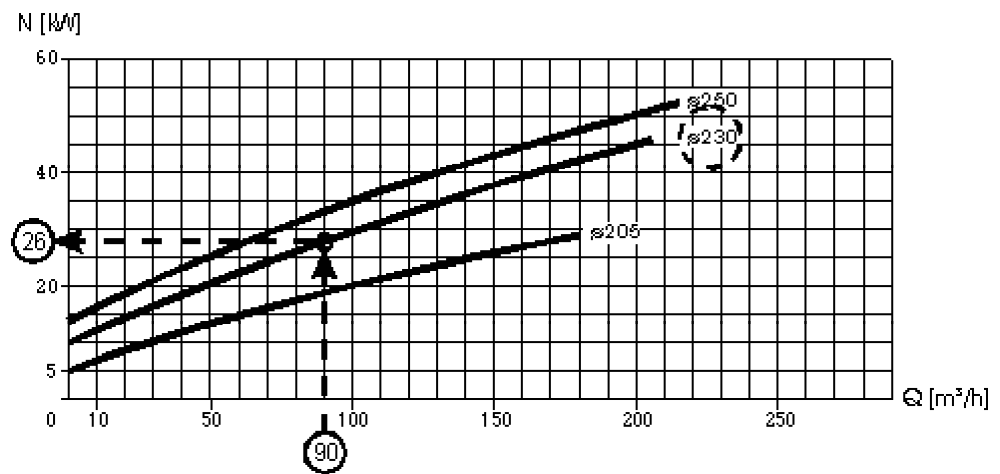
Centrifugal pumps

Power consumption of the pump 泵的功耗

Step 3: 步骤 3 : 在功率曲线中, 用流量与叶轮线相交找到功率

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.

选择更高功率的马达
Select the motor with the next higher power rating.



依照表功耗 : N = 26 kW

Power consumption according to the diagram: N = 26 kW

selected motor: 30.0 kW 选择马达 30 kW

pump efficiency 泵的效率

Step 4: 步骤 4 :

Check the efficiency 检查效率

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

Q [m³/h]
 H [m]
 N [kW]
 ρ [kg/dm³]

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

ρ_{water} = 1 kg/dm³

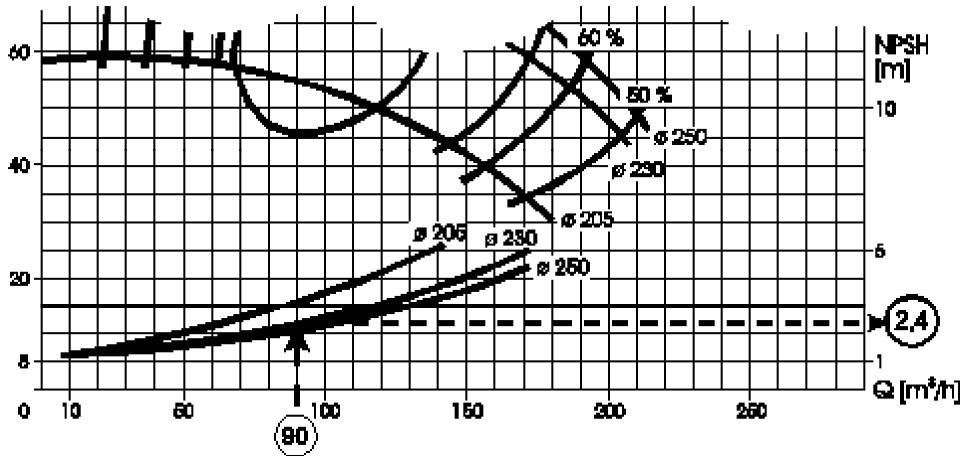
$$\eta = 0.7 \Rightarrow 70\%$$

Step 5: 步骤 5 : 检查是否 $NPSH_{plant} > NPSH_{pump}$

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

Check NPSH value

检查 NPSH 值



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

泵的 NPSH 值从表中查得 = 2.4 m

Centrifugal pumps

自吸离心泵 F.Z
Self-priming
centrifugal pump FZ



Selecting the correct size 选择正确的规格

Example: 举例

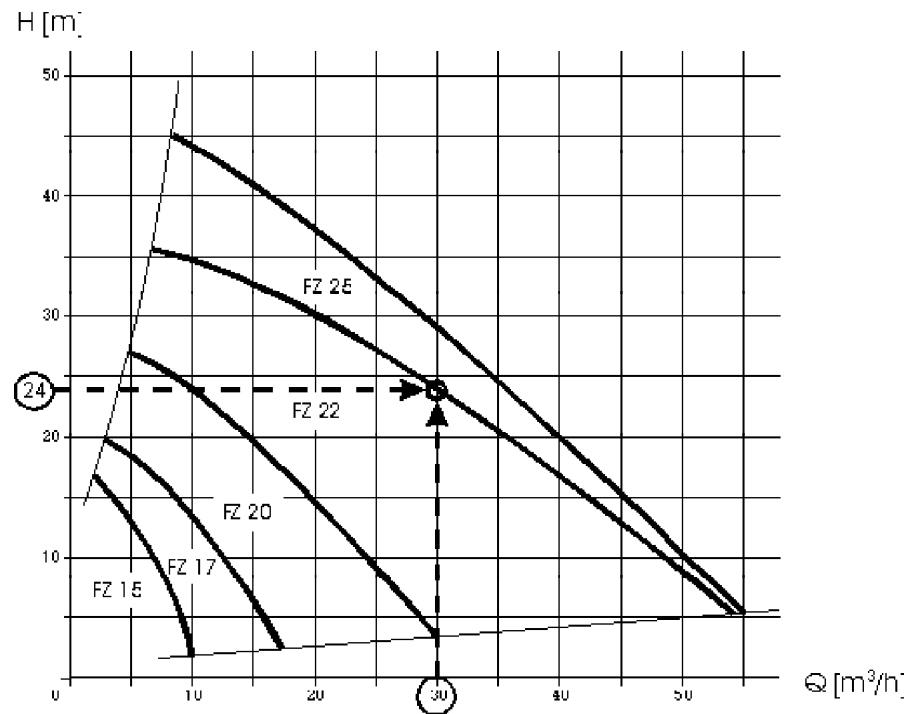
Flow rate 流量 $Q_A = 30 \text{ m}^3/\text{h}$

Total head 总压头 $H_A = 24 \text{ m}$

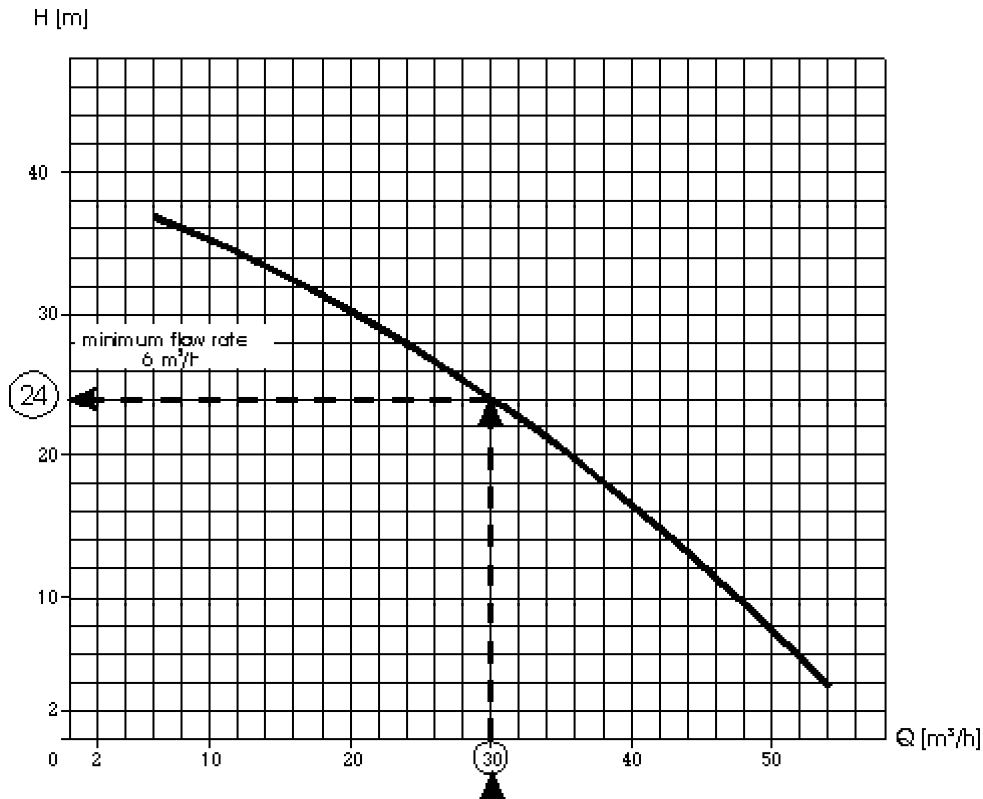
Size selection
规格选择

Step 1: 步骤 1 : 在设备的工作点之上曲线选择泵的型号
select the pump size whose curve is above to the operating point of the plant.

FZ sizes



Selected pump size: **FZ 22**



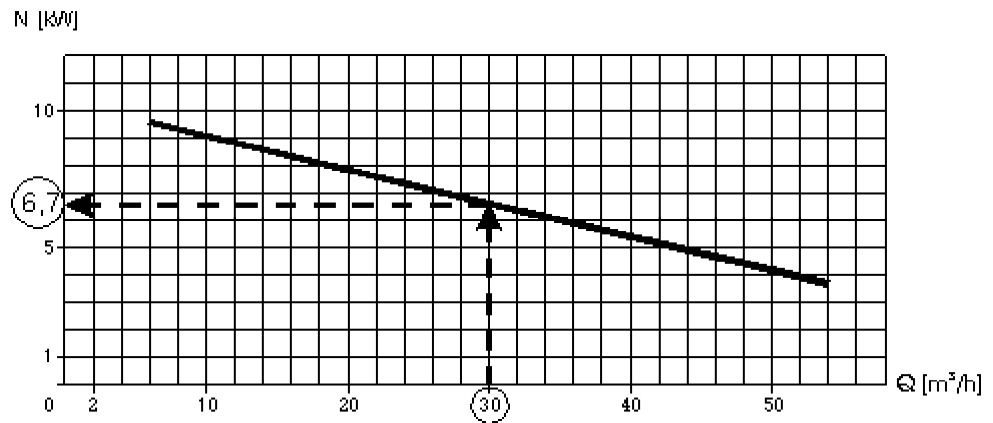
Power consumption
of the pump

泵的功耗

Note: F Z 性能的调整仅能通过节流或变化转速来获得，不可能通过修整叶轮直径来获得
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: 步骤 2 : 当设计流量向上功耗曲线的线的值为功耗值 , 选高的马达功率
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.



从表中 : $N = 6.7$ kW , 选择马达 : 7.5 kW

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

Multistage centrifugal pump FM 多级离心泵

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

同选择单级离心泵 F P 一样来选择

