Positive displacement pumps

正位移泵的工作原理与特征
Features and operating principle of a positive displacement pump

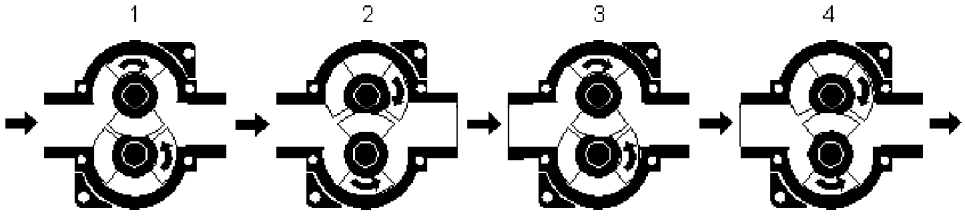
正位移泵是静流体学的机器，它是只能正向传送，不能反向工作的一个封闭系统。
Positive displacement pumps are hydrostatic machines. They operate with a positive transfer and should not work against a closed system.

所有的转子泵都用同样的原理设计，两个转子在两个平行轴上，用同步的齿轮来驱动
All rotary pumps are designed after the same principle. Two rotors are arranged on parallel shafts and driven by an external synchronous gear box.

两转子对应旋转极小的轴向与径向间隙保证转子间或与泵身间互不接触
在任何位置转子都是吸入面与压出端间的屏障，通过极小的间隙来维持密封，
不需要另外的密封阀
The rotors rotate in opposite directions to each other. Small radial and axial clearances assure that they have no contact with each other, or the pump body. The rotors are designed to form a barrier between the suction and pressure side of the pump in any position. The sealing is only maintained by narrow gaps. There are no additional seals or valves.

在吸入端转子渐大的孔吸入产品，做圆周运动到压出端时，
两转子之间孔被压扁以压出产品，每次从吸入端到压出端的流量是恒定的
The increasing cavity between the rotors on the suction side is filled with the product. The product is displaced in a circumferential direction and discharged on the pressure side as the cavity between the rotors is collapsing. This generates a constant flow from the suction to the discharge side of the pump.

Operating scheme
原理图样



1. Suction and filling of the upper chamber and simultaneous displacement of the product present in the lower chamber
上腔充进产品同时
下腔产品下移

2. Displacement of the product present in the upper chamber and simultaneous suction and filling of the lower chamber
上腔产品位移同时
下腔充满产品

3. Discharge of the product present in the upper chamber and simultaneous displacement of the product present in the lower chamber
上腔产品放出
下腔产品位移

4. Displacement of the product present in the upper chamber and simultaneous discharge of the product present in the lower chamber
上腔产品位移
下腔产品放出

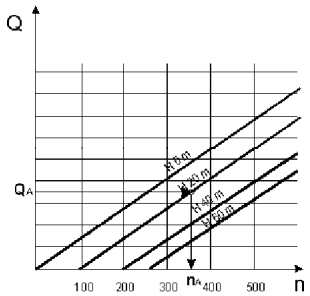
Rotary pumps ensure a gentle fluid transfer with minimum stress or damage to the product.
转子泵确保轻柔的流体传动，确保最小的压力不损坏产品

Positive displacement pumps

性能曲线（仅是水）
Performance curve
(only for water)

正位移泵的流量Q与转速成正比
With positive displacement pumps the flow rate Q is linear dependent on the pump speed n.

测试中流量被变化的转速与总压头决定，为了方便比较各种泵的性能，测试的流体总是水
On a test stand the flow rate is determined for various speeds and total head. In order to allow a comparison between the various pump designs and types, these tests are always carried out with water.



一旦流量Q与总压头H被确定，从图表中即能算出相应的转速
Once the flow rate Q and the total head H have been determined, a pump speed n that corresponds to this operating point will result from the diagram.

正位移泵通常是固定转速的，其流量也是恒定的
The positive displacement pump is usually operated with a fixed speed drive. The flow rate is constant.

泵转速
Pump speed

能通过调整泵的转速来调整流量以适应不同的工作环境
The flow rate can be adjusted to the various operating conditions by changing the pump speed.

粘度
Viscosity

当设计或选择泵的型号时，产品粘度必须被考虑到。
The viscosity of the product must be always taken into consideration for the design and selection of the pump type.

高粘的度产品需要更多的时间进入位移腔，因此为避免气蚀而导致的容积效率降低
Fluids with higher viscosities require more time to enter the displacement chamber. In those cases the pump speed must be adjusted accordingly to avoid cavitation which reduces the volumetric efficiency and increases the wear. A pump operating with cavitation creates a considerable noise level.
和转子叶轮的磨损，必须调整泵的转速。发生气蚀的泵会产生相当大的噪声水平

Clearance losses
间隙损失

Regardless of the low clearance between the rotor and the pump body, a slip from the pressure side back to the suction side will be generated when waterlike products are transfered.
在像水样的产品传送中，不管转子与泵身间的 间隙如何小，总会有一部分从压出端流向吸入端。

In case of circumferential piston pumps the slip stops at a product viscosity of about 200 mPa s and at about 500 mPa s in the case of rotary lobe pumps.
使扇型转子泵停止间隙倒流的产品粘度大约是２００－５００ｍＰａｓ

Positive displacement pumps

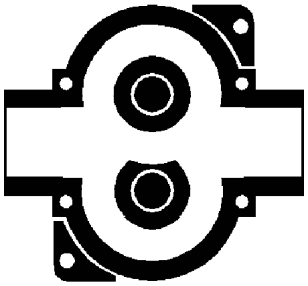
Ｆｒｉｓｔａｍ提供两种不同的正位移泵来满足需求

Fristam supplies two different positive diplacement pump designs depending on the application.

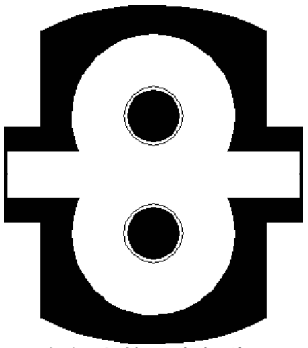
Designs

Ｆｒｉｓｔａｍ圆周转子泵ＦＫ　ＦＫＬ，它在泵腔，转子间只有极小的间隙

因此这些设计保证了卓越的自吸性能，适合不同的高压力



- ***Fristam*** circumferential piston pumps **FK** and **FKL**
  The circumferential piston pumps type FK and FKL have a very narrow clearance in the pump chamber and a gland sealing allover. Due to these design features circumferential piston pumps have an outstanding suction performance and are suitable for high differential heads.



- ***Fristam*** rotary lobe pumps **FL**
  Due to the gland/line sealing, rotary lobe pumps type FL are mainly used for flooded suction conditions. They reach slightly lower differential heads than the circumferential piston pumps especially at low viscous products, but can run at higher speeds.

Ｆｒｉｓｔａｍ凸轮转子泵ＦＬ

由于盖线密封，ＦＬ主要用于淹没式的吸入条件，相对ＦＫ尤其是对低粘度产品，ＦＬ只有很小的压力损失，

而且能在更高的转速下运转

ＦＫ　ＦＬ可用在温度很高的产品中

设计版本

Design versions

Circumferential piston pumps and rotary lobe pumps can be used for hot products

- up to approx. 90 °C using **rotors with standard dimensions** 高于９０度转子使用标准尺寸
- up to approx. 150 °C using **rotors with high temperature dimensions.** 高于１５０度转子使用高温尺寸

They are suitable for automatic cleaning (CIP process) and sterilisation (SIP process).

他们适用自动清洗（ＣＩＰ处理）和（ＳＩＰ处理）

The pumps can be supplied with horizontal or vertical ports. Various types of connections such as flanges, clamps or different threads are available.

产品输入输出口可设计为水平或垂直。端口连接可为法兰，夹头或螺纹连接

Positive displacement pumps

选型
Selection of design

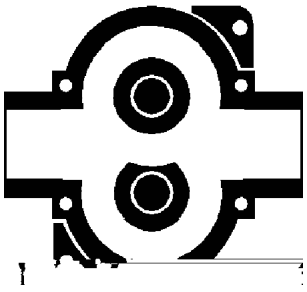
他们之间的选择主要是
The design selection depends amongst other:

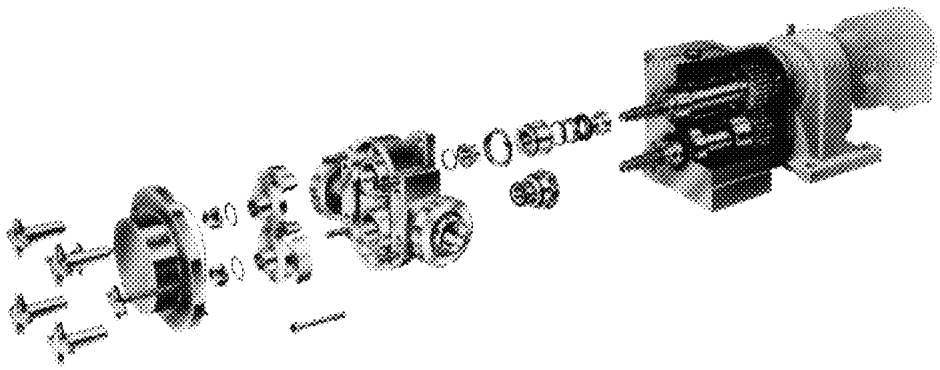
还可以根据不同的压力来选择
An additional selection criteria is the difference in pressure performance of the various types.

ＦＬ最大压头１２０m• ***Fristam*** rotary lobe pumps **FL**, maximum total head 120 m (12 bar)
ＦＫ最大压头２００m• ***Fristam*** circumferential piston pump **FK**, maximum total head 200 m (20 bar)
ＦＫＬ最大压头２５０m ***Fristam*** circumferential piston pump **FKL**, maximum total head 250 m (25 bar)

Circumferential piston pumps FK, FKL
圆周转子泵ＦＫ　ＦＫＬ

Ｆｒｉｓｔａｍ圆周转子泵有非常精细的间隙。这样他们在吸入管中产生一个小真空
The Fristam circumferential piston pumps are manufactured with very close clearances. Thus they can generate a small vacuum in the suction pipeline. Due to the atmospheric pressure or system pressure the product is forced into the pump chambers.
由于大气压力或系统压力，产品就被推入泵腔内



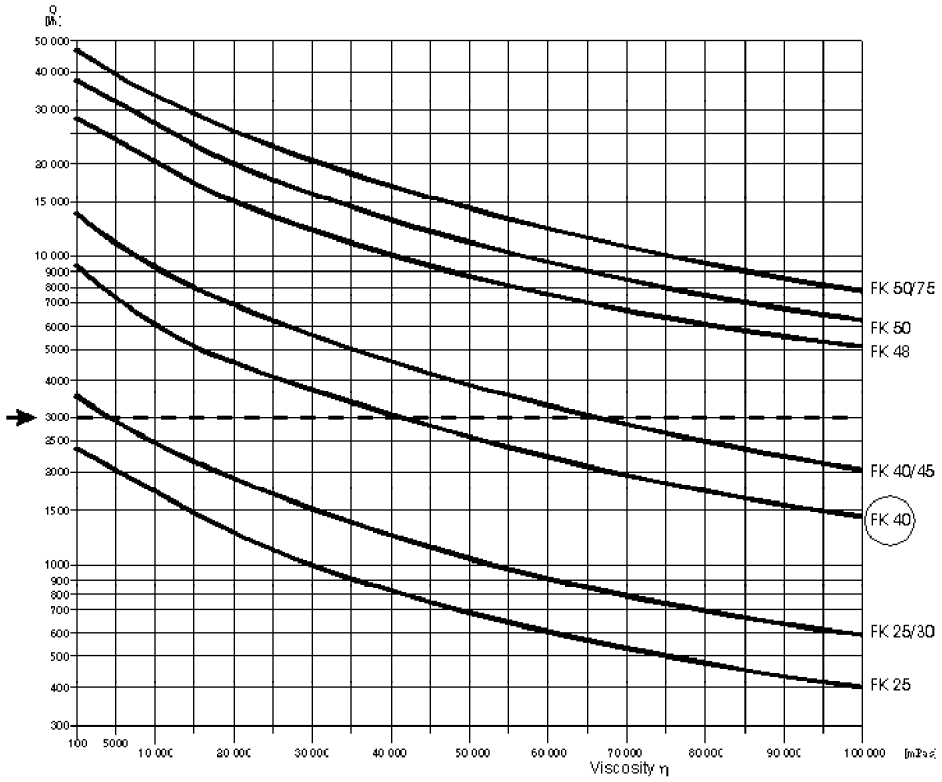


Example: 举例

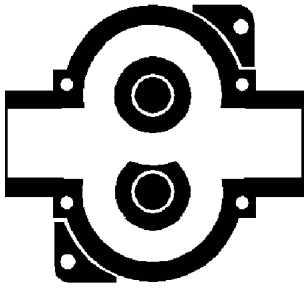
Flow rate 流量 Q = 3000 l/h
Total head 总压头 H = 120 m

Pump to be used for products with different viscosities.
泵用来泵送不同粘度的产品

FK pump basic selection diagram
F K泵基本选型表

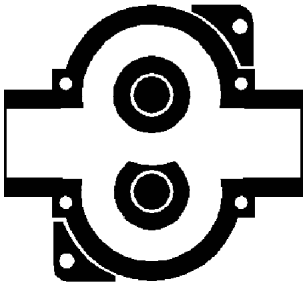


Type selection
选型



for case 1: water
case 2: 10 mPa s | selected: **FK 40**
case 3: 10,000 mPa s ≠

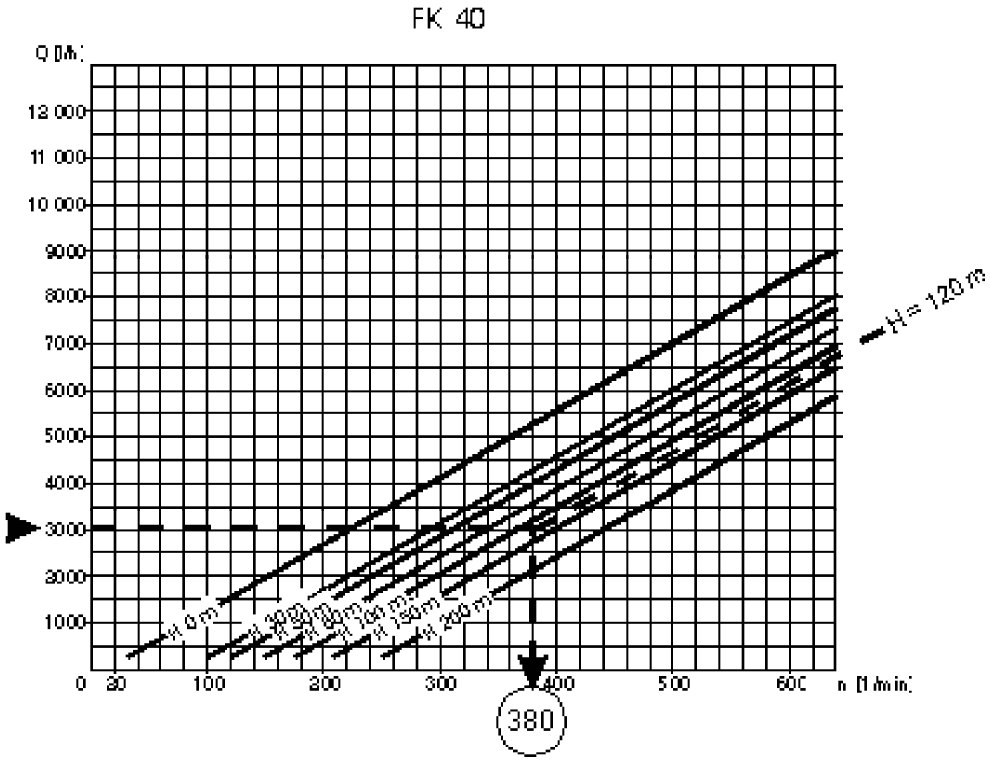
Case 1: viscosity
η ∪ 1 mPa s
粘度 η = 1 m P a s



Example: 举例

Q = 3000 l/h
H = 120 m ∪ p = 12 bar
η = 1 mPa s

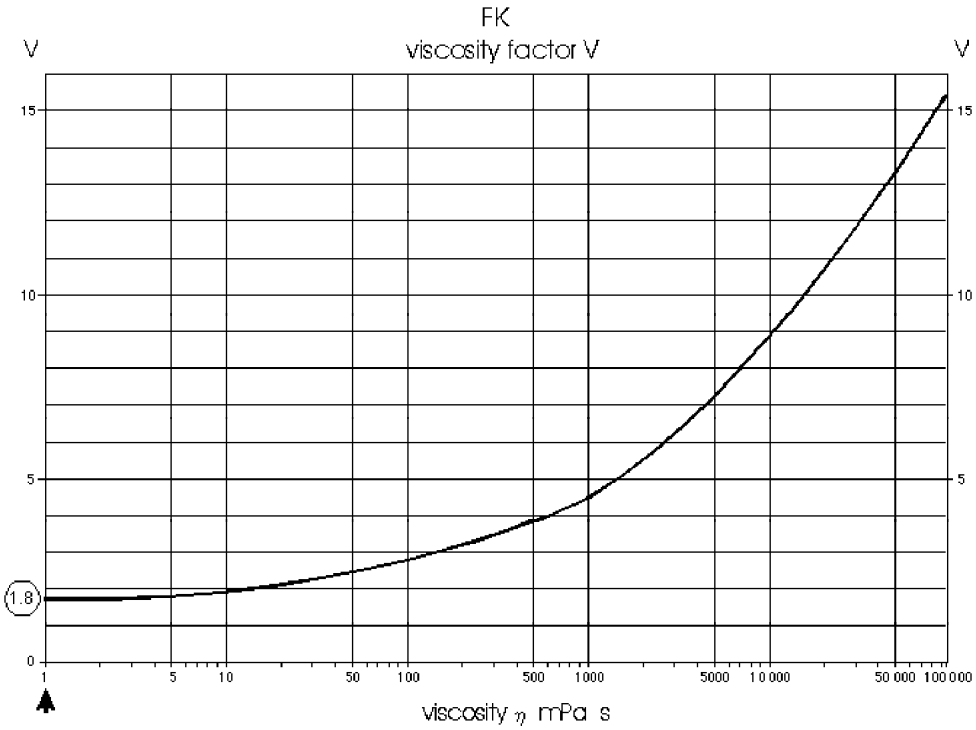
Step 1: 步骤 1 ：读出转速 N
read speed n [1/min]



resulting from the diagram: speed n = 380 1/min
从表中得出转速 N

Step 2: 步骤 2 ；定出粘度系数
define viscosity factor

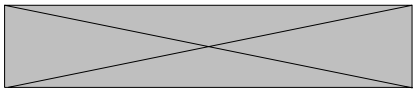
Case 1: viscosity
η ∪ 1 mPa s



Viscosity factor V = 1.8
粘度系数 V = 1 . 8

Case 1: viscosity
η ∪ 1 mPa s

Step 3: 步骤 3 ：计算泵所需的功率
Calculate the power N [kW] required for the pump drive.



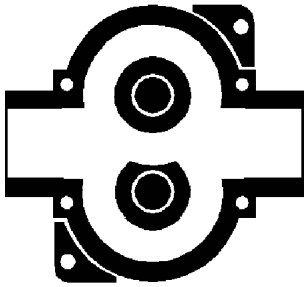
压力 p = pressure [bar]
粘度系数 V = viscosity factor
转速 由图表所定 n = speed [1/min], stated in the diagram
流量 / 每转 C = flow rate/revolution [l/rev.]

PK	25	25/30	40	40/45	48	50	50/75
C	0,07	0,11	0,26	0,36	0,77	1,1	1,37

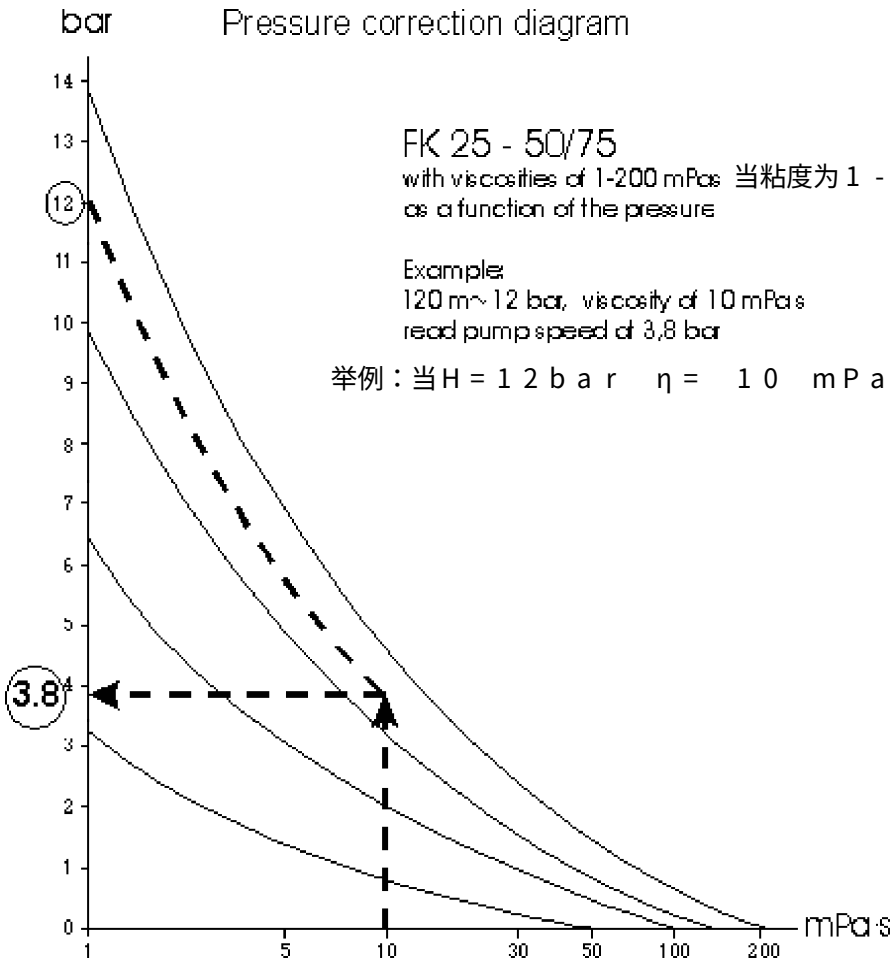
Example: $$N = \frac{(2 \times 12 + 1.8) \times 380 \times 0.26}{1000} = 2.5\ kW$$

Example:
Q = 3000 l/h
H = 120 m ∪ p = 12 bar
η = 10 mPa s

Case 2:
viscous product
η up to 200 mPa s



Step 1:
speed correction 修正转速

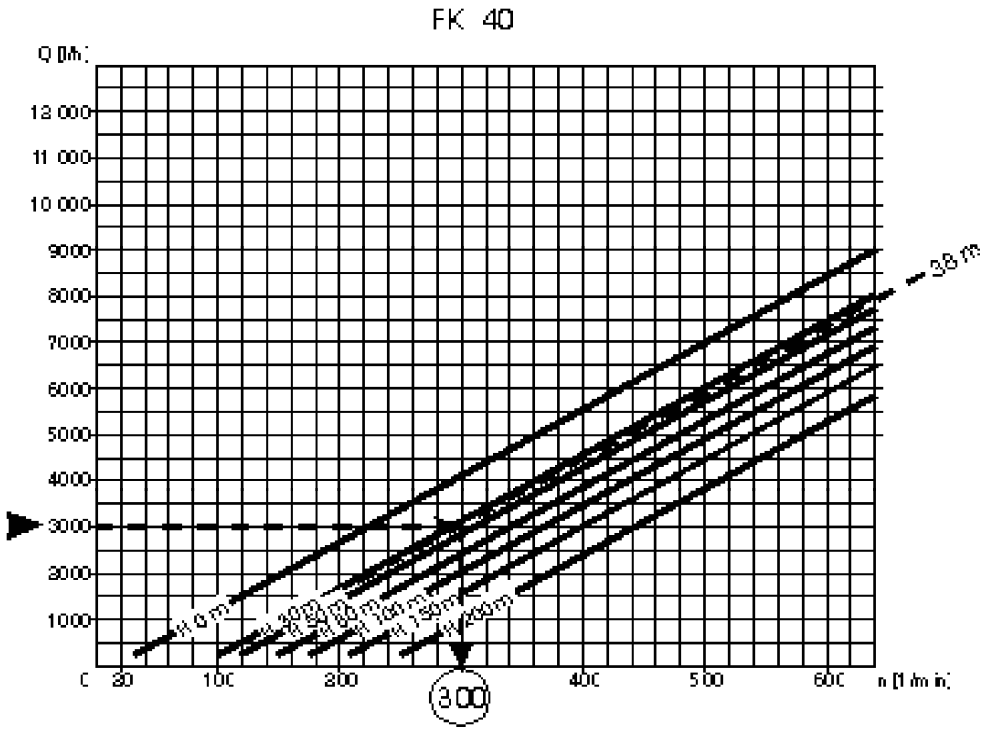


依据表格：P = 3．8 BAR
stated in the diagram: p = 3.8 bar.

Define now the speed required for the corrected pressure.
从修正的压力中读出转速

Case 2: viscous product
η up to 200 mPa s

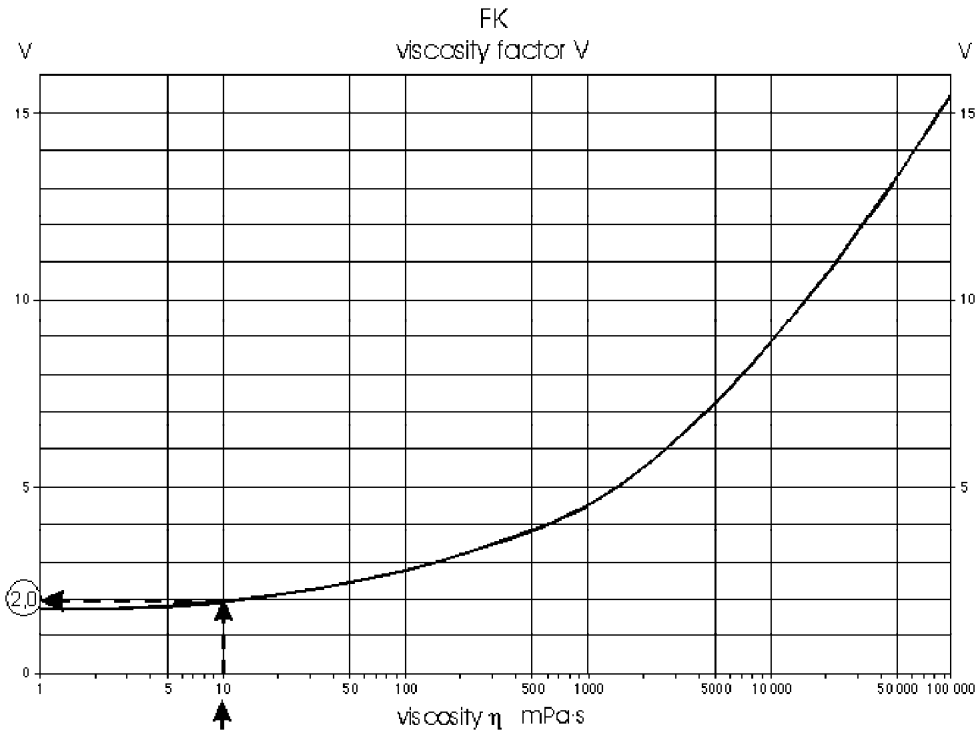
Step 2:
read speed n [1/min] 读出转速



stated in the diagram: speed n = 300 1/min
从图表中得出转速

Step 3:
define viscosity factor　定义粘度系数

Case 2:
viscous product
η up to 200 mPa s



stated in the diagram: viscosity factor V = 2.0
从表中得出粘度系数

Case 2: viscous product η up to 200 mPa s

Step 3: 计算电机功率选出马达
Calculate power consumption N [kW] to select the pump drive.

$$N = \frac{(2 \times p + V) \times n \times C}{1000}$$

压力 p = pressure in bar ∪ H/10
粘度系数 V = viscosity factor
当H = 3 8 M的转速 n = speed with H = 38 m
流量 / 每转 C = flow rate/revolution [l/rev.]

PK	25	25/30	40	40/45	48	50	50/75
C	0.07	0.11	0.26	0.36	0.77	1.1	1.37

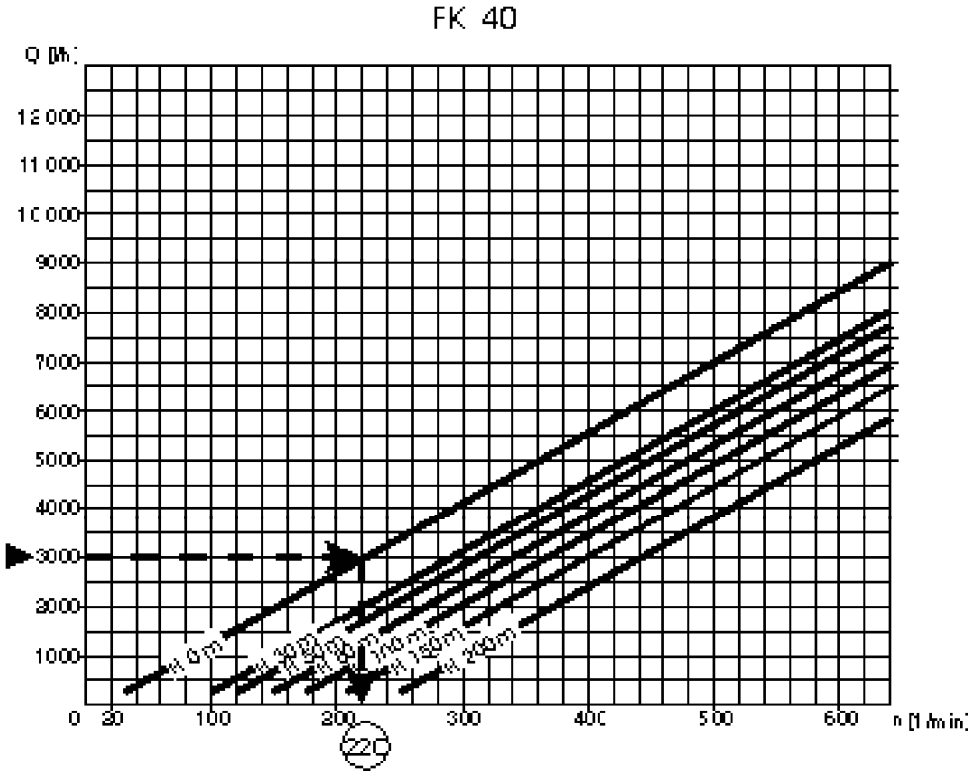
Example :

$$N = \frac{(2 \times 12 + 2) \times 300 \times 0.26}{1000} = 2.03 \text{ kW}$$

Example: 举例

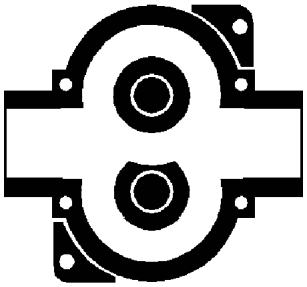
Q = 3000 l/h
H = 120 m ∪ p = 12 bar
η = 10,000 mPa s

Step 1: 步骤 1 ：读出在 H = 0， η > 200 mPa s 转速
read speed with H = 0, η > 200 mPa s



Stated in the diagram: n = 220 1/min
从表中得出转速

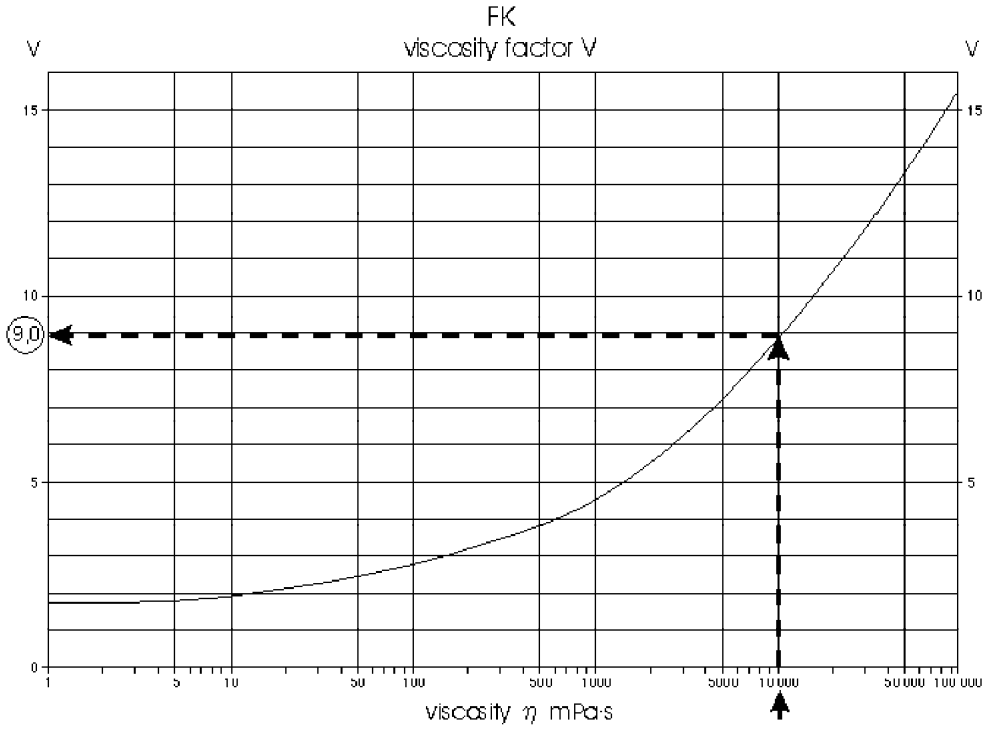
Case 3:
viscous product
η = 200–100,000 mPa s



Case 3:
viscous product
η = 200–100,000 mPa s

Step 2:
read viscosity factor V.

步骤 2 ：读出粘度系数 V



stated in the diagram: V = 9.0
从表中得出 V = 9 . 0

Step 3: 步骤 3 ：计算电机功率选择马达
Calculate the absorbed power N [kW] to select the pump drive.

$$N = \frac{(2 \times p + V) \times n \times C}{1000}$$

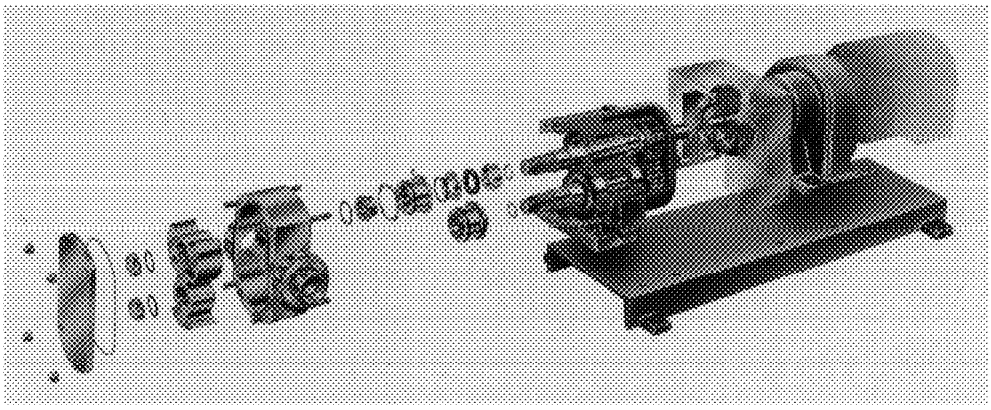
p = pressure [bar] ∪ H/10 压力（ＢＡＲ） = Ｈ / １０
V = viscosity factor 粘度系数
n = speed [1/min], stated in the diagram 转速 从表中得出
C = flow rate/revolution [l/rev.] 流量 / 每转

Example:

$$N = \frac{(2 \times 12 + 9.0) \times 220 \times 0.26}{1000} = 1.9\ kW$$

Case 3:
viscous product
η = 200–100,000 mPa s

Rotary lobe pump FL
凸轮转子泵 F L



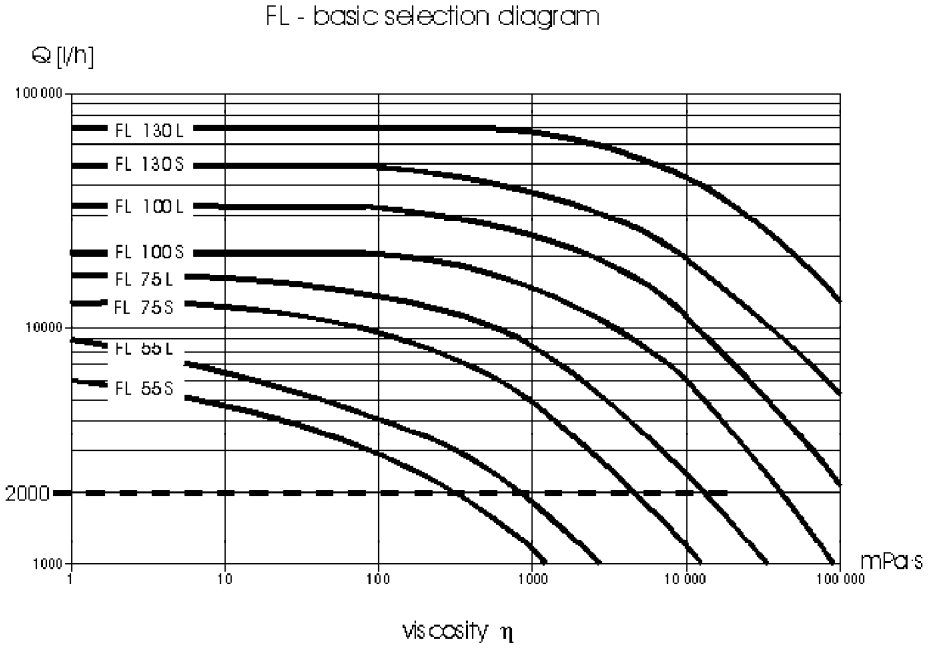
Example: 举例

Flow rate Q = 2000 l/h 流量 Q = 2 0 0 0 L / H

Total head H = 60 m 总压头 H = 6 0 M

Selection
选型

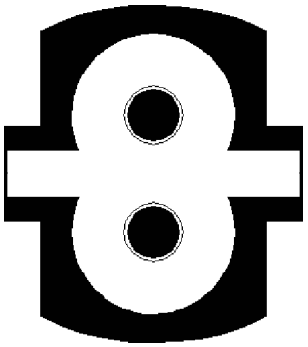
Pump to be used for products with different viscosities.
泵应用于不同粘度的产品



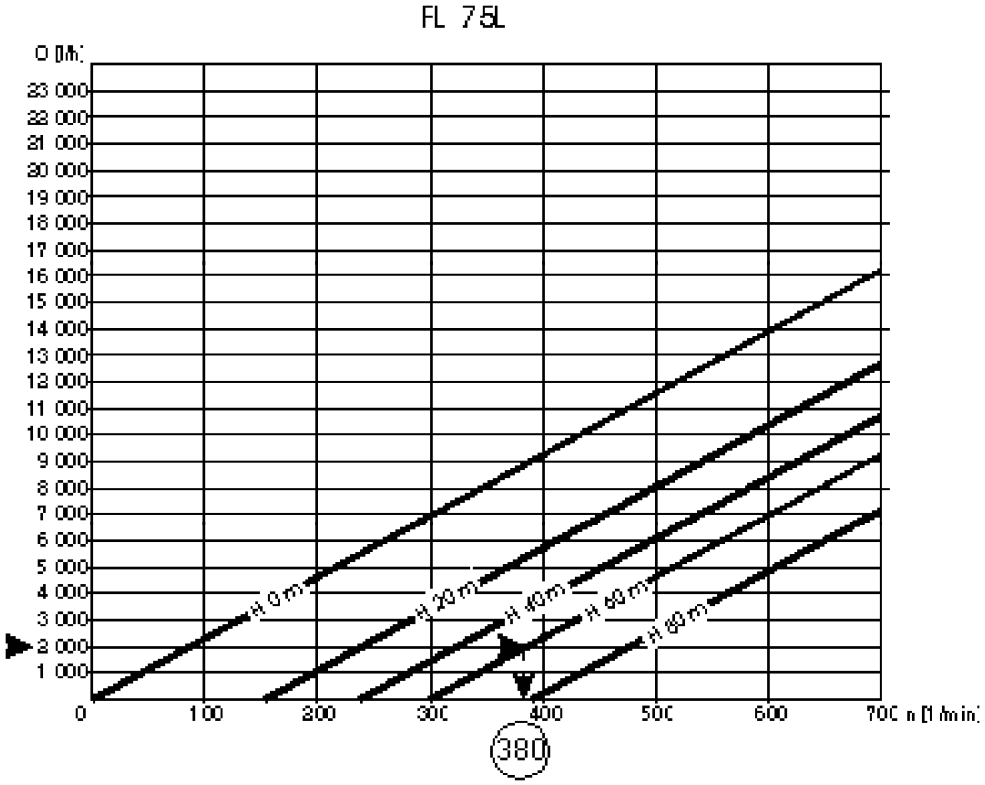
for case number 1: water
case number 2: 10 mPa s | selected: **FL 75 L**
case number 3: 10,000 mPa s ≠

Flow rate 流量` Q = 2000 l/h
Total head总压头 H = 60 m
η = 1 mPa s (water).

Case 1: viscosity
η ∪ 1 mPa s



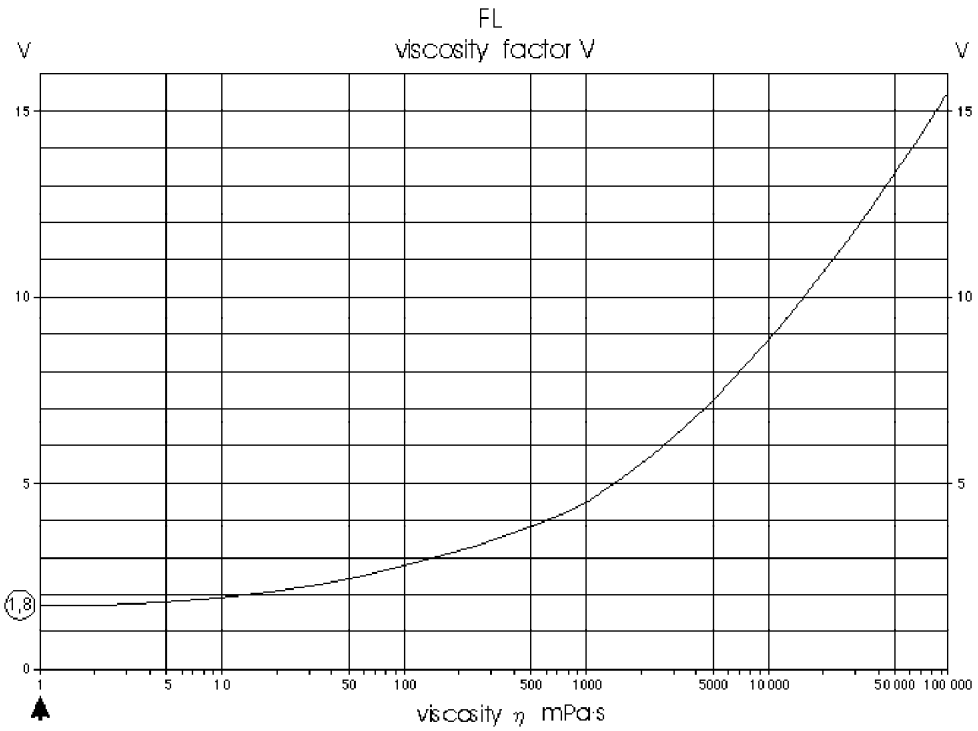
Step 1:
read speed n [1/min] . 读取转速



read: speed n = 380 1/min
读出转速 N = 3 8 0

Case 1: viscosity
$\eta \cup$ 1 mPa s

Step 2: 定义粘度系数
define viscosity factor



stated in the diagram: viscosity factor V = 1.8

根据表定义粘度系数 V = 1 . 8

Step 3:
计算出功率N选择马达
Calculate the absorbed power N [kW] to select the pump drive.

Case 1: viscosity
η ∪ 1 mPa s

$$N = \frac{(2 \times p + V) \times n \times C}{1000}$$

p = pressure in bar ∪ H/10 压力（BAR）= H / 10
V = viscosity factor 粘度系数
n = speed with H = 0 当H = 60时的转速
C = flow rate/revolution [l/rev.] 流量 / 每转

FLF	55S	55L	75S	75L	100S	100L	120S	120L
C	0.106	0.152	0.283	0.389	0.69	1.07	1.80	2.54

Example:

$$N = \frac{(2 \times 6 + 1.8) \times 380 \times 0.389}{1000} = 2.04 \text{ kW}$$

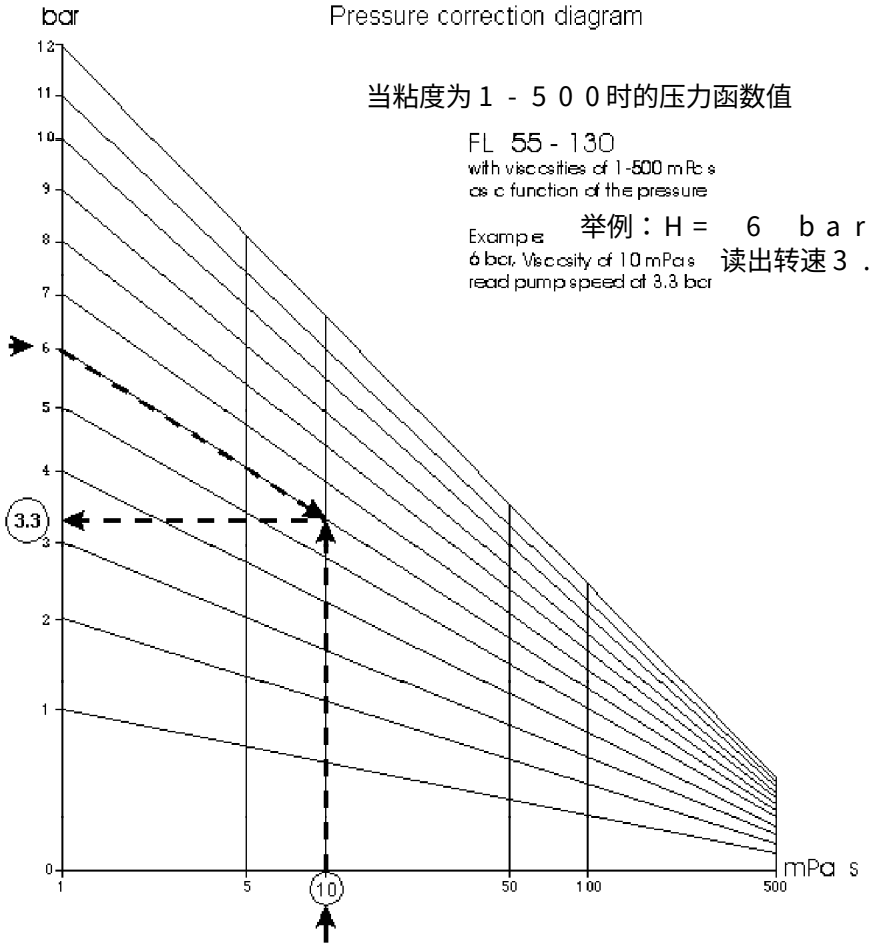
Case 2:	Flow rate	Q = 2000 l/h 流量Q = 2 0 0 0 L / H
viscous product	Total head	H = 60 m 总压头H = 6 0 M
η up to 500 mPa s	Viscosity	η = 10 mPa s 粘度1 0 M P A S

Step 1: 定义修正的转速
define correction for the speed

H = 60 m ∪ 6 bar

压力修正表

Pressure correction diagram



当粘度为1 - 5 0 0时的压力函数值

FL 55 - 130
with viscosities of 1-500 mPa s
as a function of the pressure

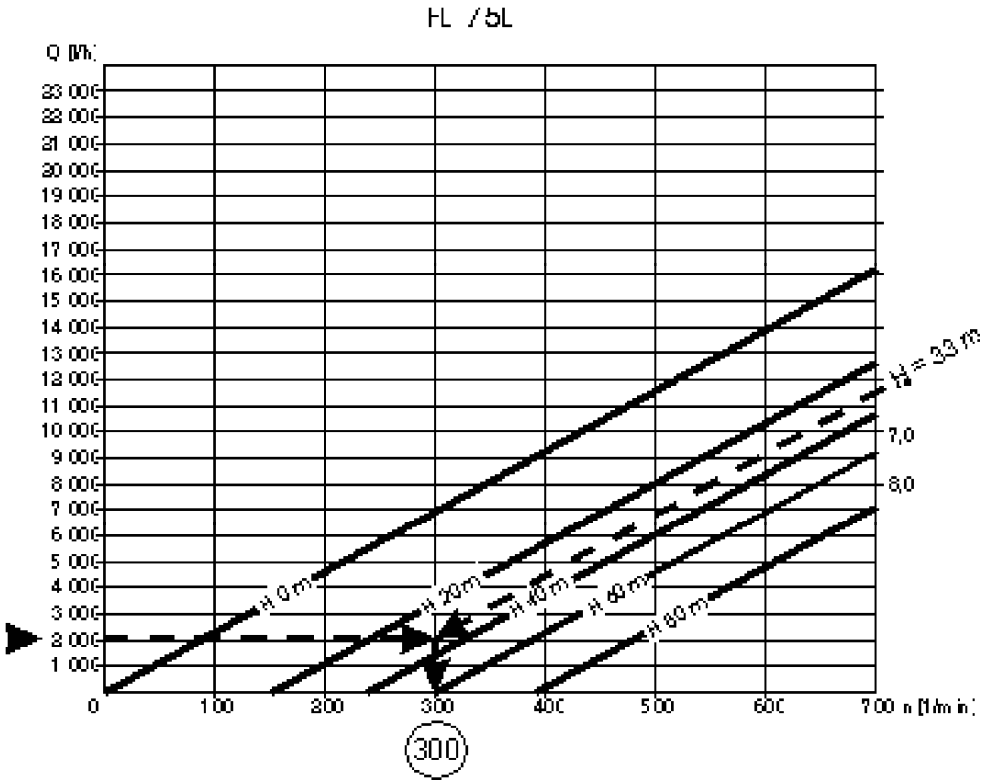
Example:
6 bar, Viscosity of 10 mPa s
read pump speed at 3.3 bar

举例：H = 6 b a r η = 1 0 mPa s
读出转速3 . 3 b a r

read speed at H = 33 m (equal to p = 3.3 bar)
在H = 3 3 M时读出转速

Step 2: 读出H = 3 3 M时的转速
read speed at H = 33 m (∪ 3.3 bar)

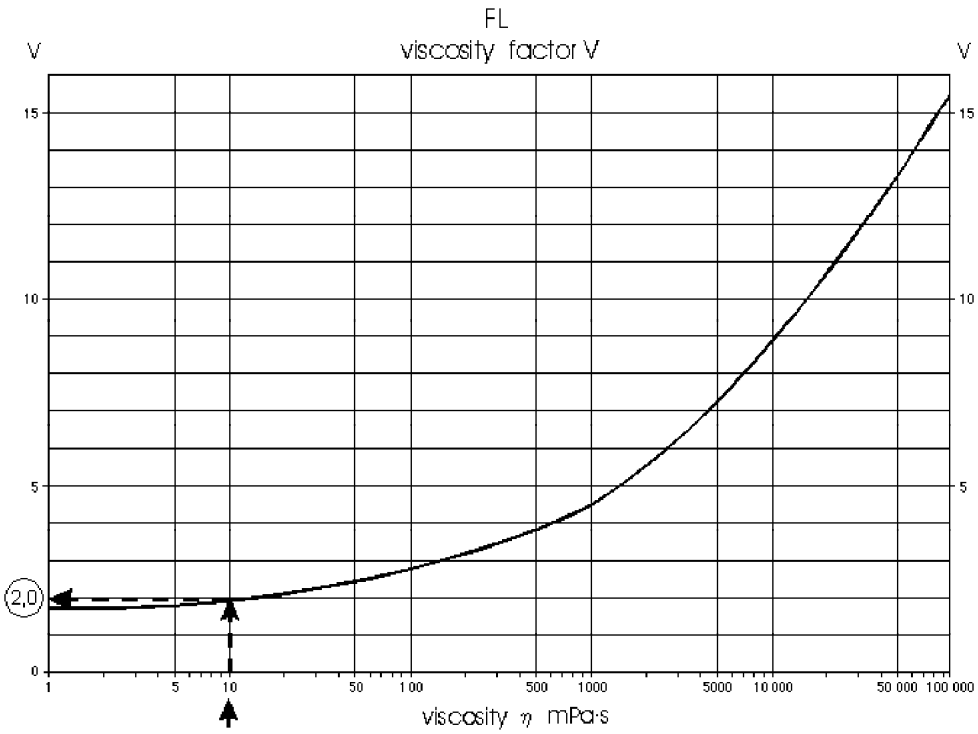
Case 2:
viscous product
η **up to 500 mPa s**



read: speed n = 300 1/min
读出转速N = 3 0 0

Case 2: viscous product η up to 500 mPa s

Step 3: 定义粘度系数
define viscosity factor



stated in the diagram: viscosity factor V = 2.0
根据表得出粘度系数 V = 2 . 0

Case 2:
viscous product
η up to 500 mPa s

Step 4: 计算电机功率选择马达

Calculate absorbed power N [kW] to select the pump drive.

$$N = \frac{(2 \times p + V) \times n \times C}{1000}$$

p = pressure in bar ∪ H/10 压力
V = viscosity factor 粘度系数
n = speed at H = 0 从表中选出的转速
C = flow rate/revolution [l/rev.] 流量 / 每转

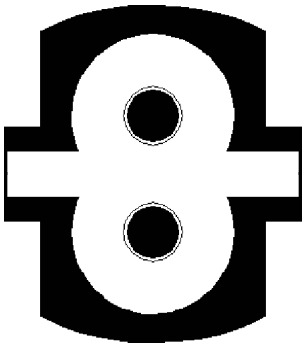
FLF	55S	55L	75S	75L	100S	100L	130S	130L
C	0.106	0.152	0.283	0.389	0.69	1.07	1.80	2.54

Example :

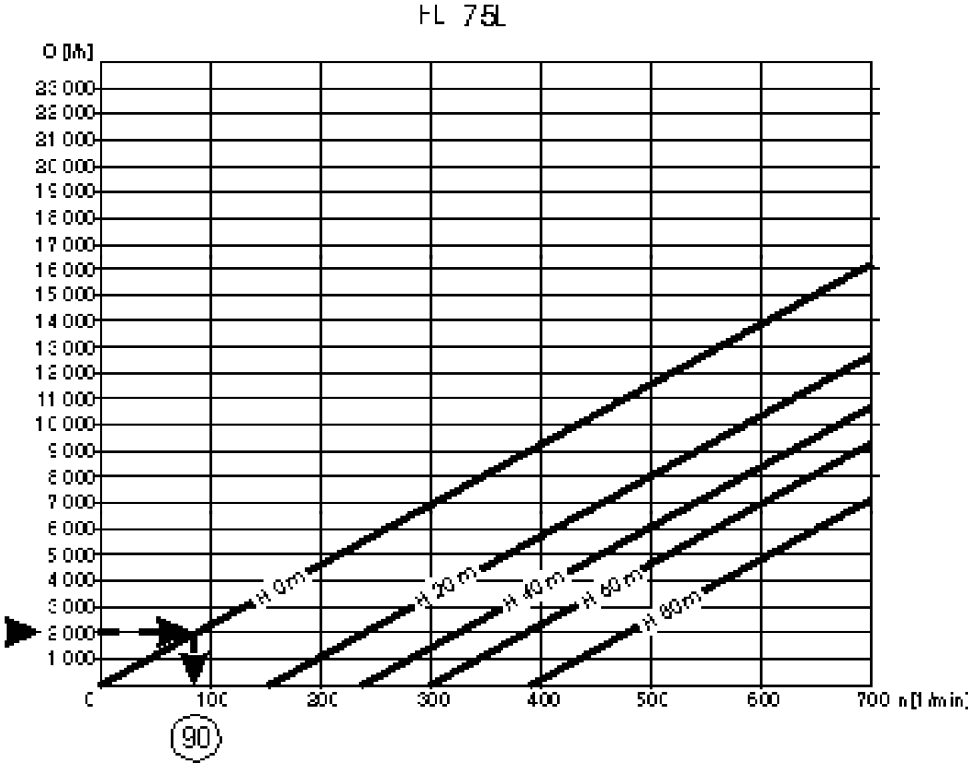
$$N = \frac{(2 \times 6 + 2) \times 300 \times 0.389}{1000} = 1.63\ kW$

Case 3:
viscous product
η = 500–100,000 mPa s

Flow rate	Q = 2000 l/h	流量Q = 2 0 0 0
Total head	H = 60 m (∪ 6 bar)	总压头H = 6 0
viscosity	η = 10,000 mPa s	粘度系数1 0 0 0 0



Step 1: 当粘度系数> 5 0 0 mPa s读出H = 0的转速
read speed at H = 0 m, as η > 500 mPa s

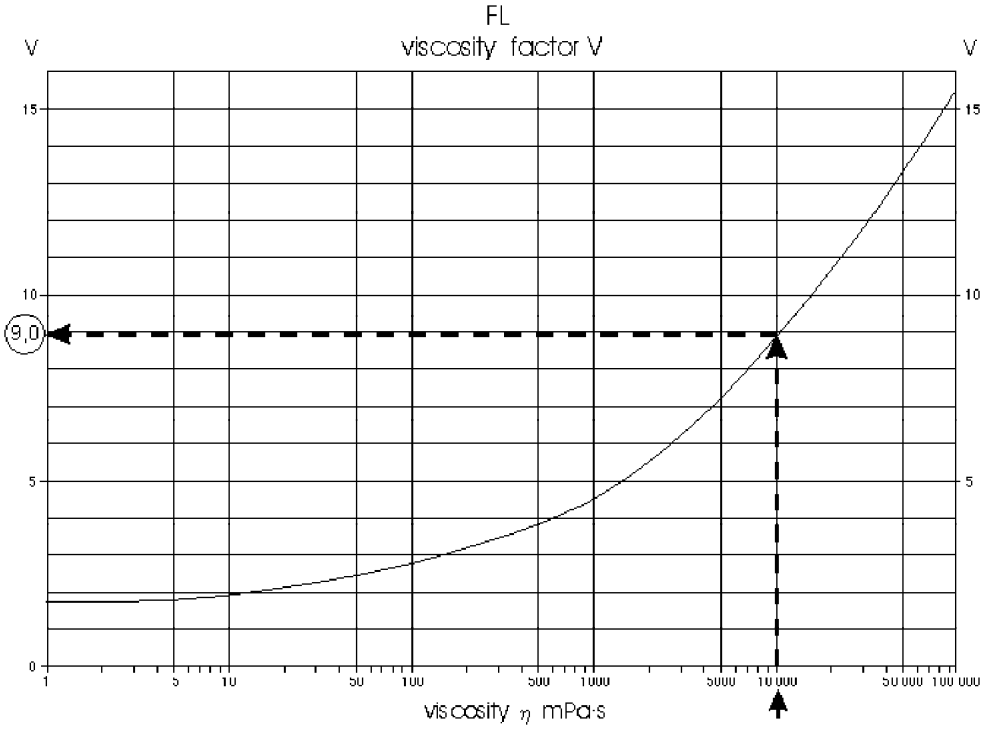


read: n = 90 1/min

Step 2: 定义粘度系数
define viscosity factor

Case 3:
viscous product
η = 500–100,000 mPa s

F L粘度系数V



Viscosity factor V = 9.0
粘度系数V = 9 . 0

Case 3:
viscous product
η = 500–100,000 mPa s

Step 3: 计算出功率 N
calculate absorbed power N [kW].

$$N = \frac{(2 \times p + V) \times n \times C}{1000}$$

p = pressure in bar ∪ H/10 压力
V = viscosity factor 粘度系数
n = speed at H = 0 当 H = 0 的转速
C = flow rate/revolution [l/rev.] 流量 / 每转

FLF	55S	55L	75S	75L	100S	100L	120S	120L
C	0.106	0.152	0.283	0.389	0.69	1.07	1.80	2.54

Example :

$$N = \frac{(2 \times 6 + 9) \times 90 \times 0.389}{1000} = 0.74 \text{ kW}$$