Positive displacement pumps

Features and operating principle of a positive displacement pump

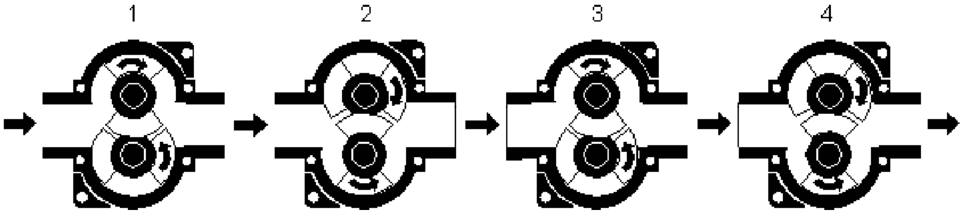
Positive displacement pumps are hydrostatic machines. They operate with a positive transfer and should not work against a closed system.

All rotary pumps are designed after the same principle. Two rotors are arranged on parallel shafts and driven by an external synchronous gear box.

The rotors rotate in opposite directions to each other. Small radial and axial clearences 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.

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



Suction and filling of the upper chamber and simultaneous displacement of the product present in the lower chamber

Displacement of the product present in the upper chamber and simultaneous suction and filling of the lower chamber

Discharge of the product present in the upper chamber and simultaneous displacement of the product present in the lower chamber

Displacement of the product present in the upper chamber and simultaneous discharge of the product present in the lower chamber

Rotary pumps ensure a gentle fluid transfer with minimum stress or damage to the product.

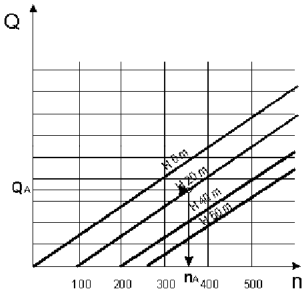
Performance curve (only for water)

With positive displacement pumps the flow rate Q is linear dependent on the pump speed n.

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.

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.

The positive displacement pump is usually operated with a fixed speed drive. The flow rate is constant.



Pump speed

The flow rate can be adjusted to the various operating conditions by changing the pump speed.

Viscosity

The viscosity of the product must be always taken into consideration for the design and selection of the pump type.

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.

Clearance losses

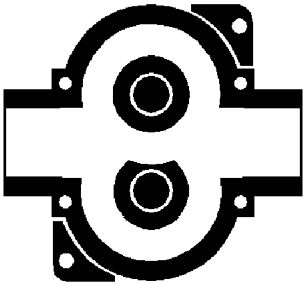
Regardless of the low clearance between the rotor and the pump body, a slip from the pressure side back to the suction side will be generated when waterlike products are transfered.

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.

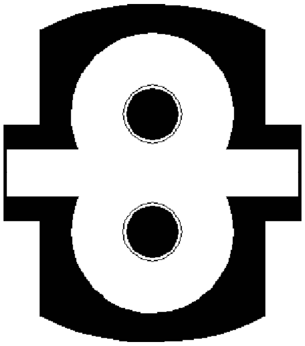
Designs

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

- ***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.



Design versions

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

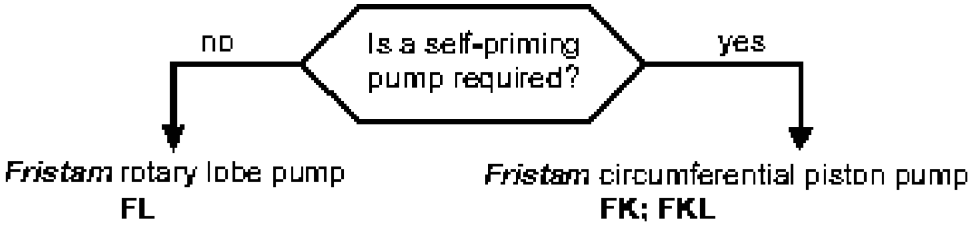
- up to approx. 90 °C using **rotors with standard dimensions**
- up to approx. 150 °C using **rotors with high temperature dimensions.**

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

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

Selection of design

The design selection depends amongst other:

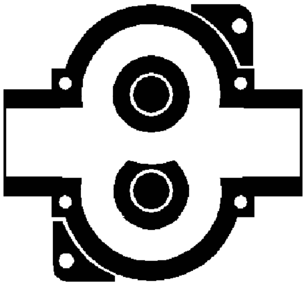


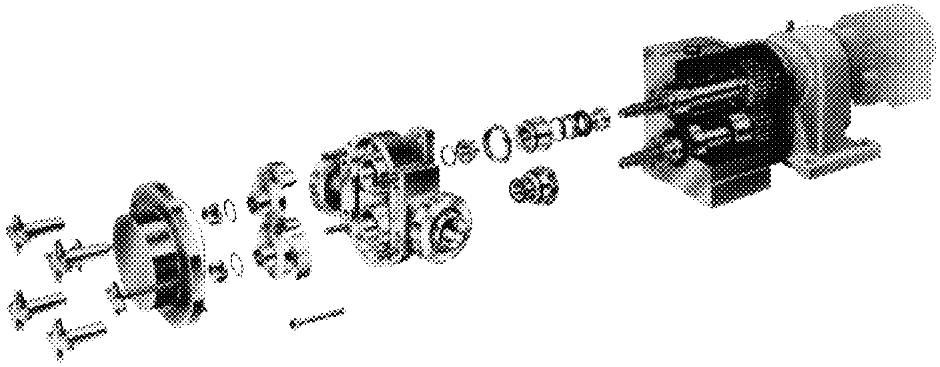
An additional selection criteria is the difference in pressure performance of the various types.

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

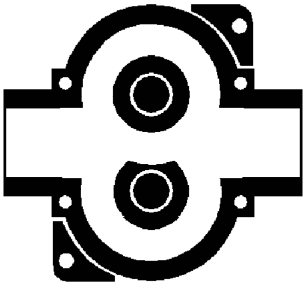
Circumferential piston pumps FK, FKL

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.





Type selection

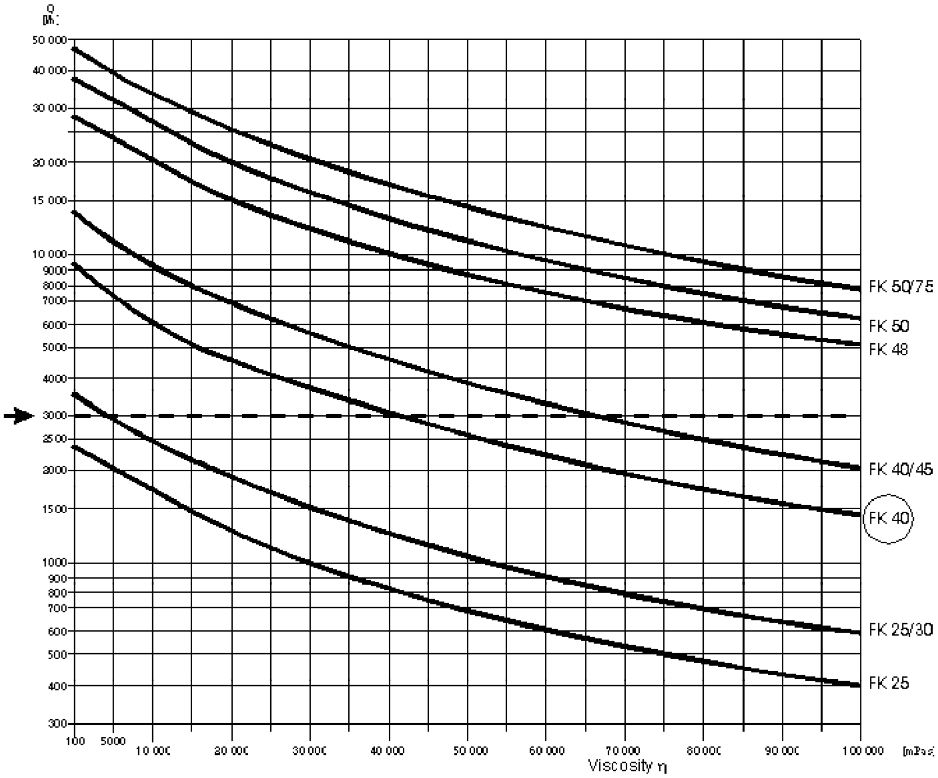


Example:

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

Pump to be used for products with different viscosities.

FK pump basic selection diagram



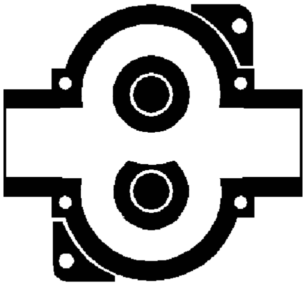
for case 1: water
case 2: 10 mPa s selected: **FK 40**
case 3: 10,000 mPa s≠

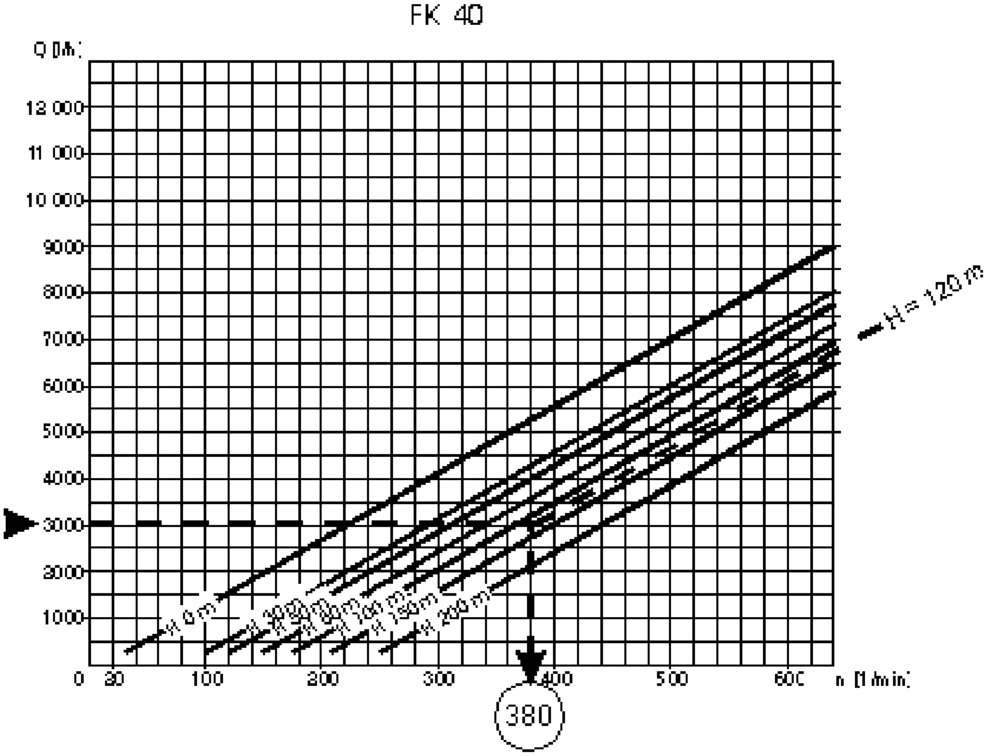
Case 1: viscosity η ∪ 1 mPa s

Example:

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

Step 1:
read speed n [1/min]

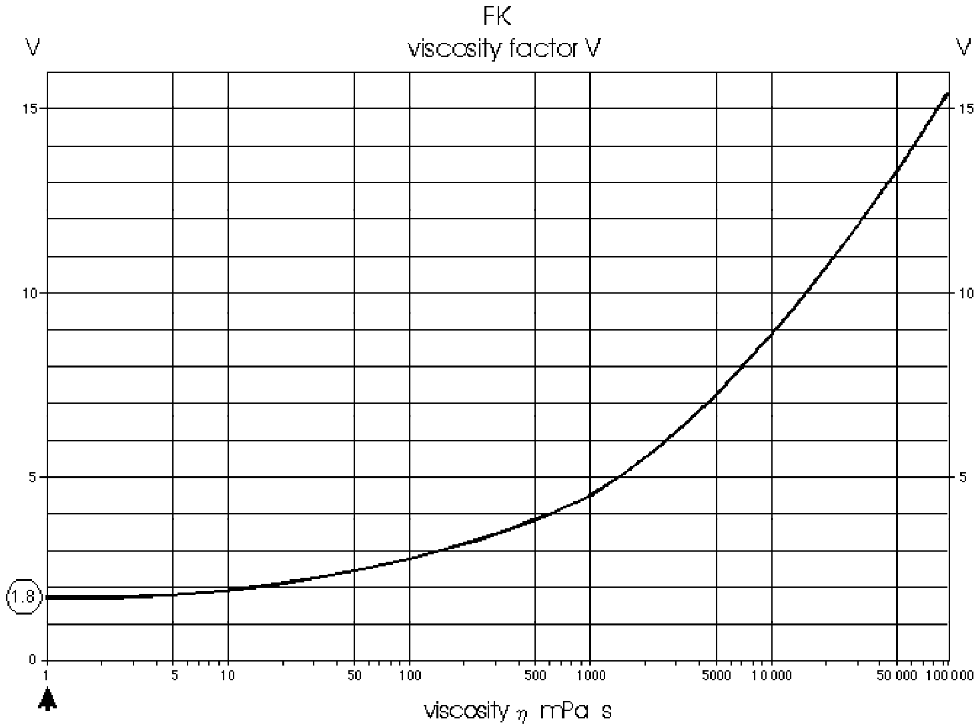




resulting from the diagram: speed n = 380 1/min

Step 2:
define viscosity factor

Case 1: viscosity
η ∪ 1 mPa s



Viscosity factor V = 1.8

Case 1: viscosity η ∪ 1 mPa s

Step 3:

Calculate the power N [kW] required for the pump drive.

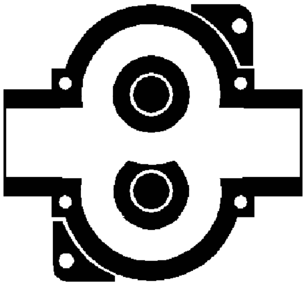
p = pressure [bar]
V = viscosity factor
n = speed [1/min], stated in the diagram
C = flow rate/revolution [l/rev.]

RK	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:

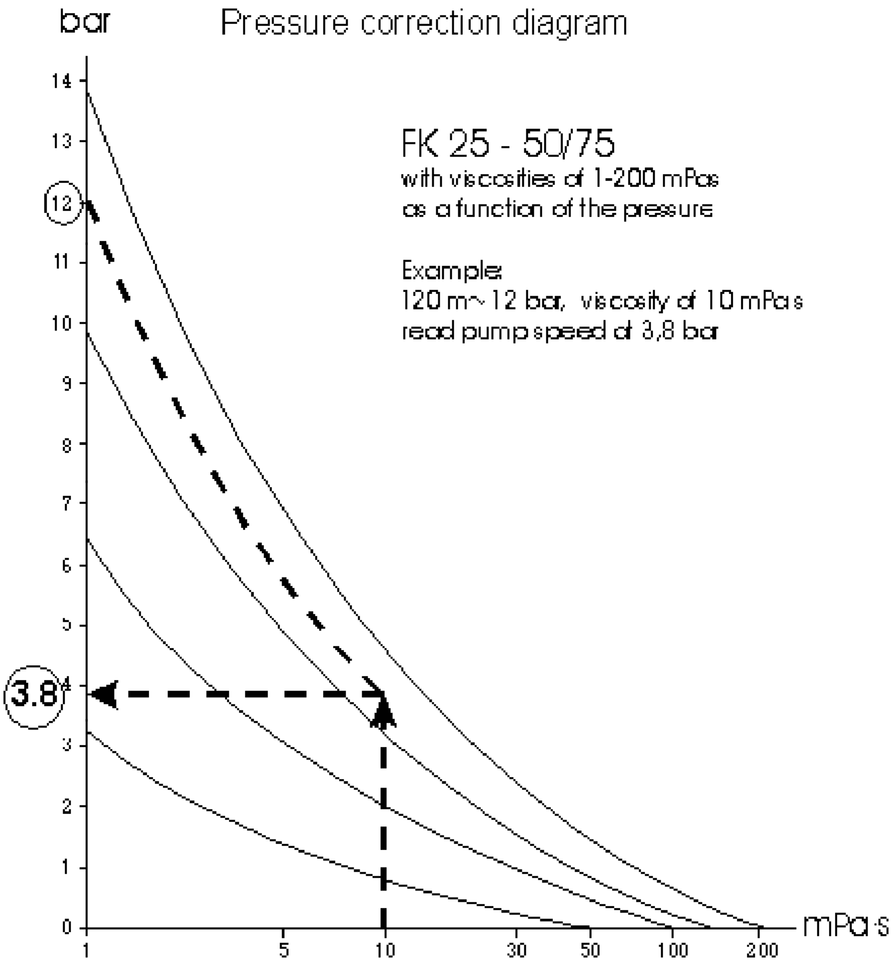
$$N = \frac{(2 \times 12 + 1.6) \times 360 \times 0.26}{1000} = 2.5\,\text{kW}$$

Case 2: viscous product η up to 200 mPa s



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

Step 1:
speed correction

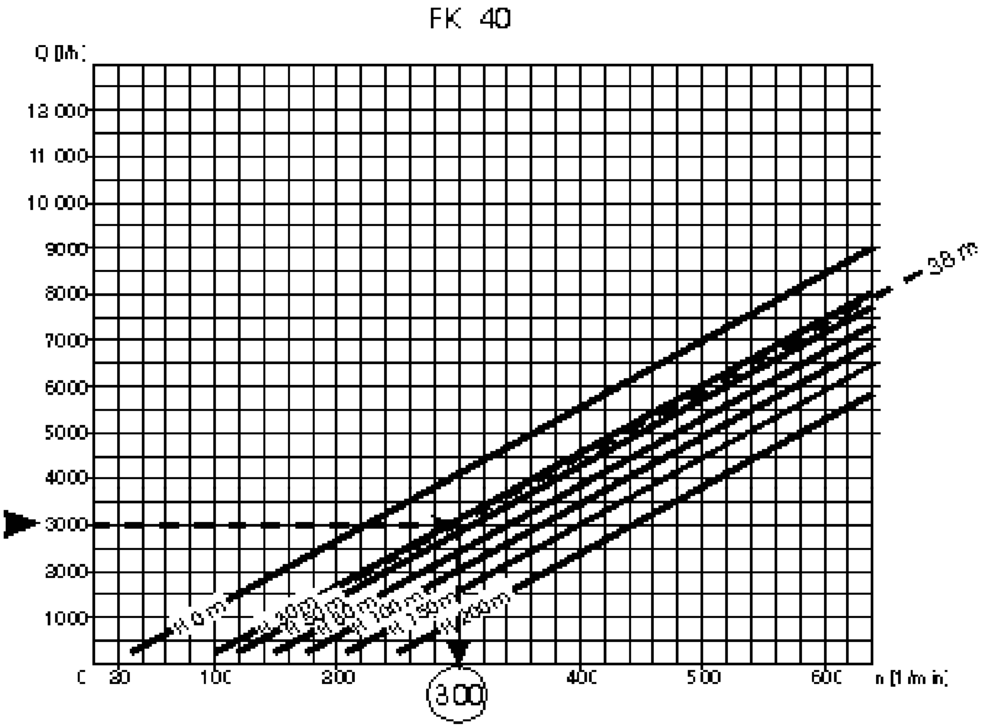


stated in the diagram: p = 3.8 bar.

Define now the speed required for the corrected pressure.

Case 2:
viscous product
η up to 200 mPa s

Step 2:
read speed n [1/min]

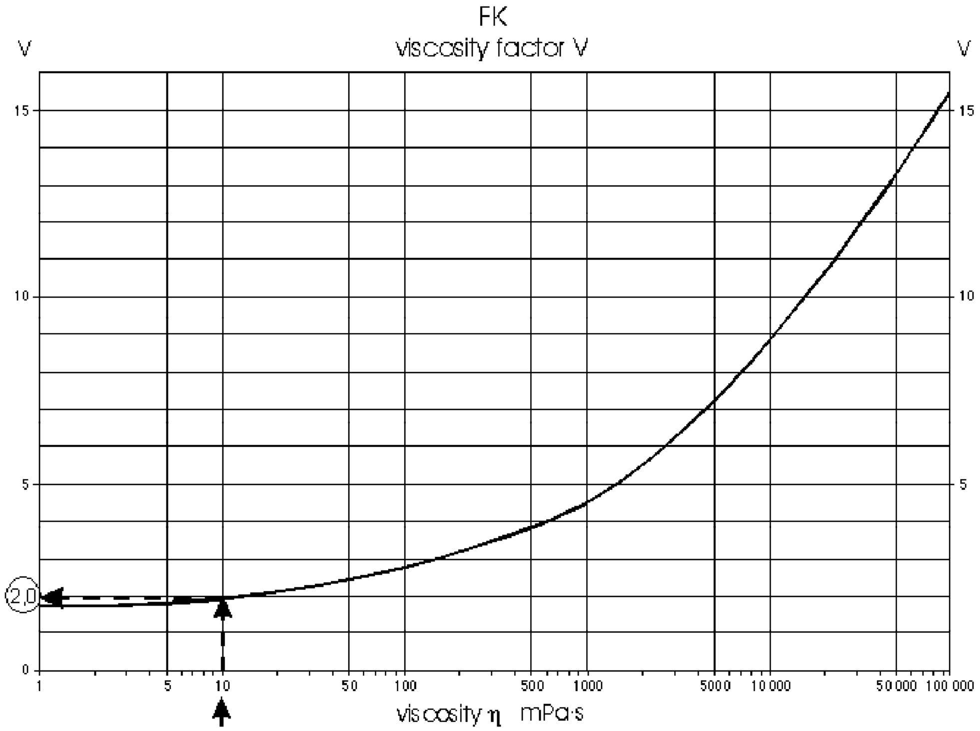


stated in the diagram: speed n = 300 1/min

Step 3:

define viscosity factor

Case 2:
viscous product
η up to 200 mPa s



stated in the diagram: viscosity factor V = 2.0

Case 2: viscous product η up to 200 mPa s

Step 3:

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

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

p = pressure in bar ∪ H/10

V = viscosity factor

n = speed with H = 38 m

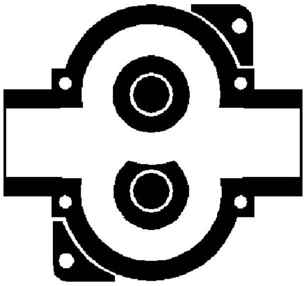
C = flow rate/revolution [l/rev.]

FK	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 :

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

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

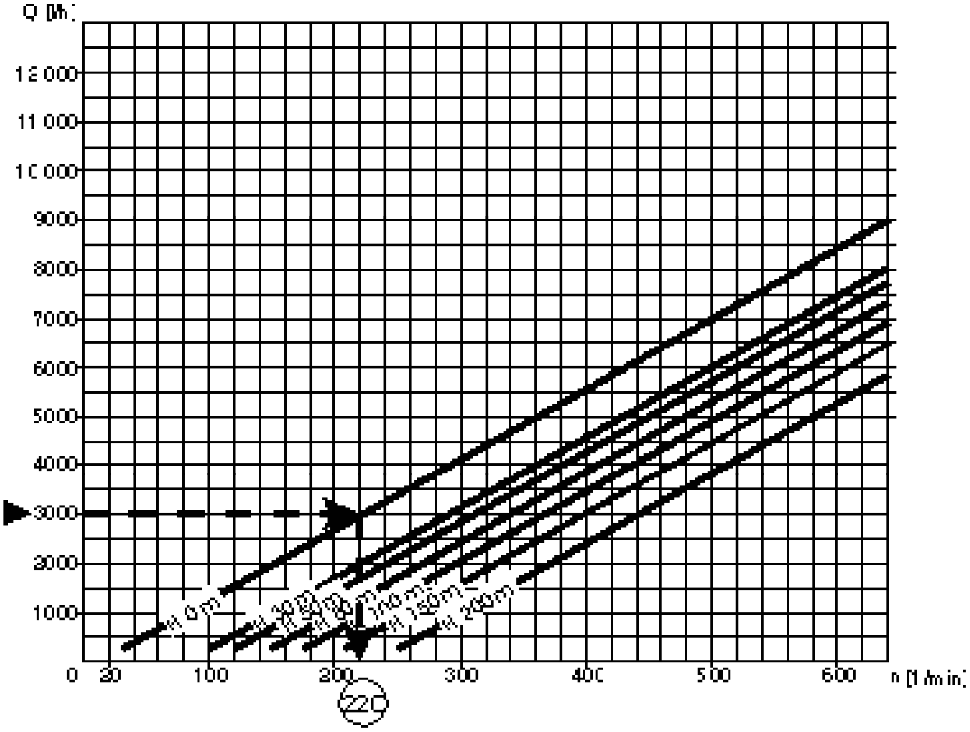


Example:

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

Step 1:
read speed with H = 0, η > 200 mPa s

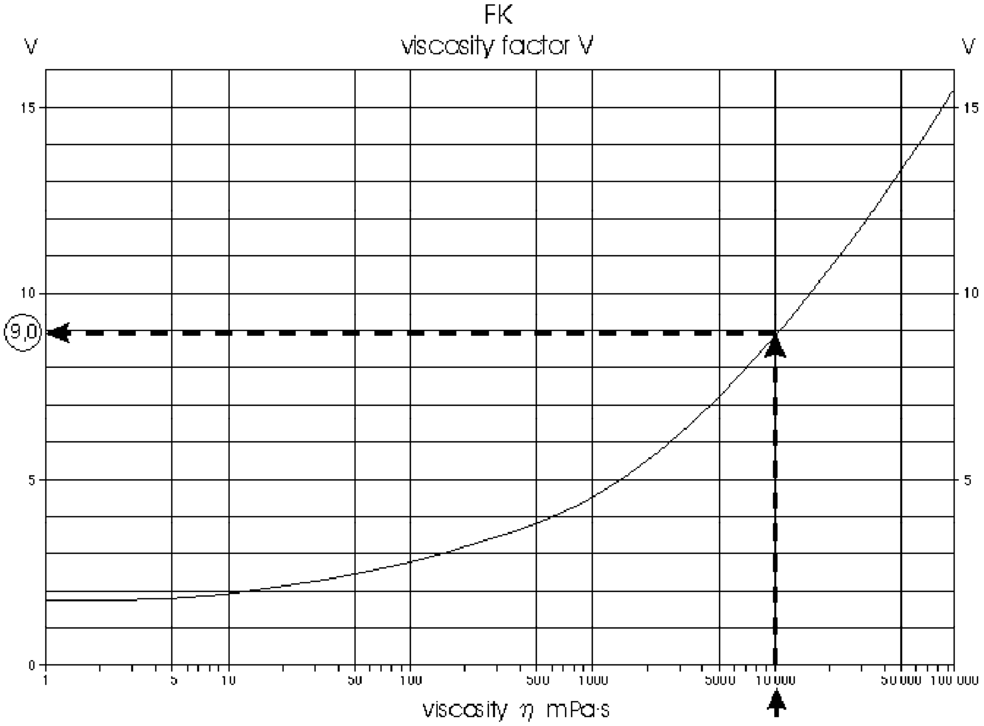
FK 40



Stated in the diagram: n = 220 1/min

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

Step 2:
read viscosity factor V.



stated in the diagram: V = 9.0

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

Step 3:

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

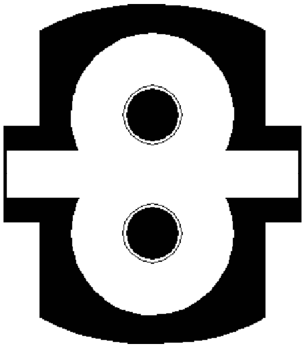
$$N = \frac{(2 \times p + V) \times n \times C}{1000}$$

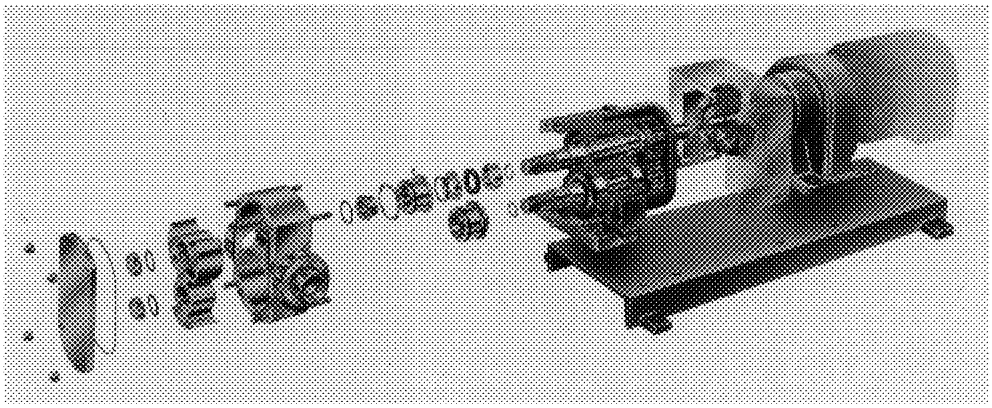
p = pressure [bar] ∪ H/10
V = viscosity factor
n = speed [1/min], stated in the diagram
C = flow rate/revolution [l/rev.]

Example:

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

Rotary lobe pump FL





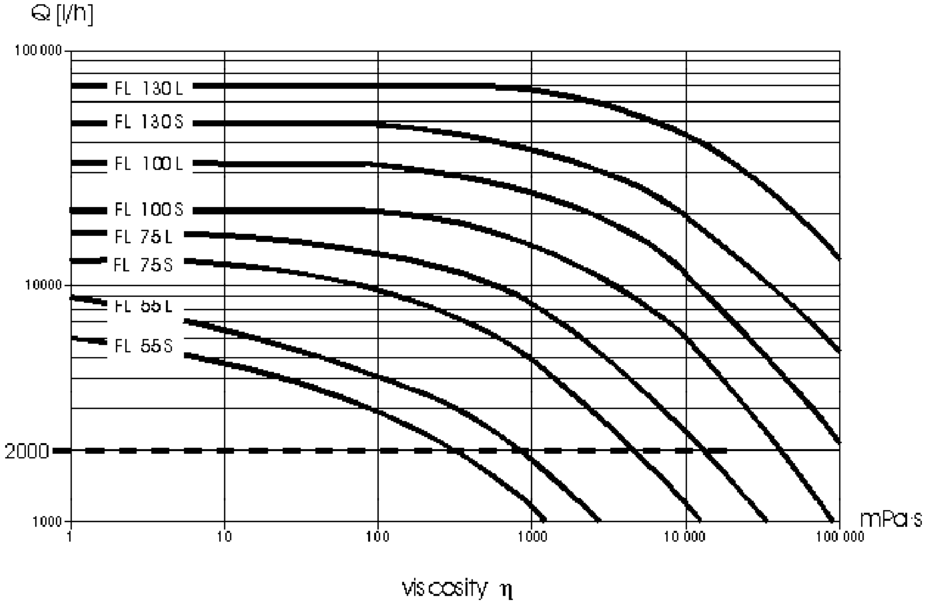
Example:

Flow rate	Q = 2000 l/h
Total head	H = 60 m

Selection

Pump to be used for products with different viscosities.

FL - basic selection diagram

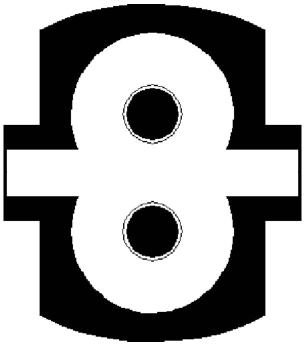


for case number 1: water

case number 2: 10 mPa s | selected: **FL 75 L**

case number 3: 10,000 mPa s ≠

Case 1: viscosity η ∪ 1 mPa s



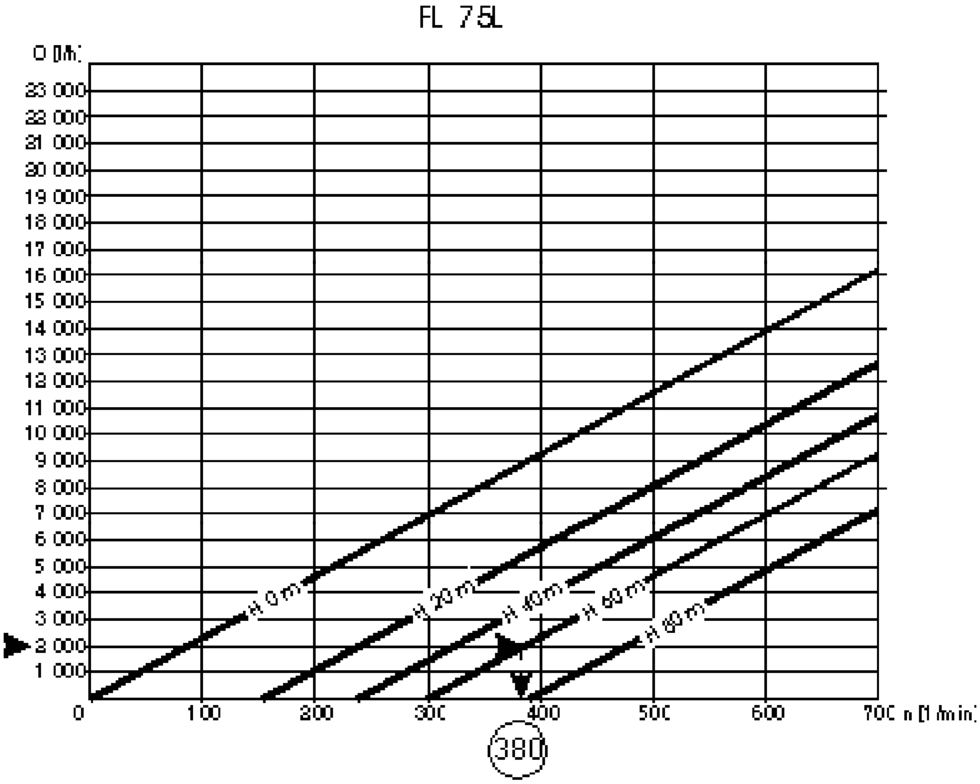
Flow rate Q = 2000 l/h

Total head H = 60 m

η = 1 mPa s (water).

Step 1:

read speed n [1/min] .

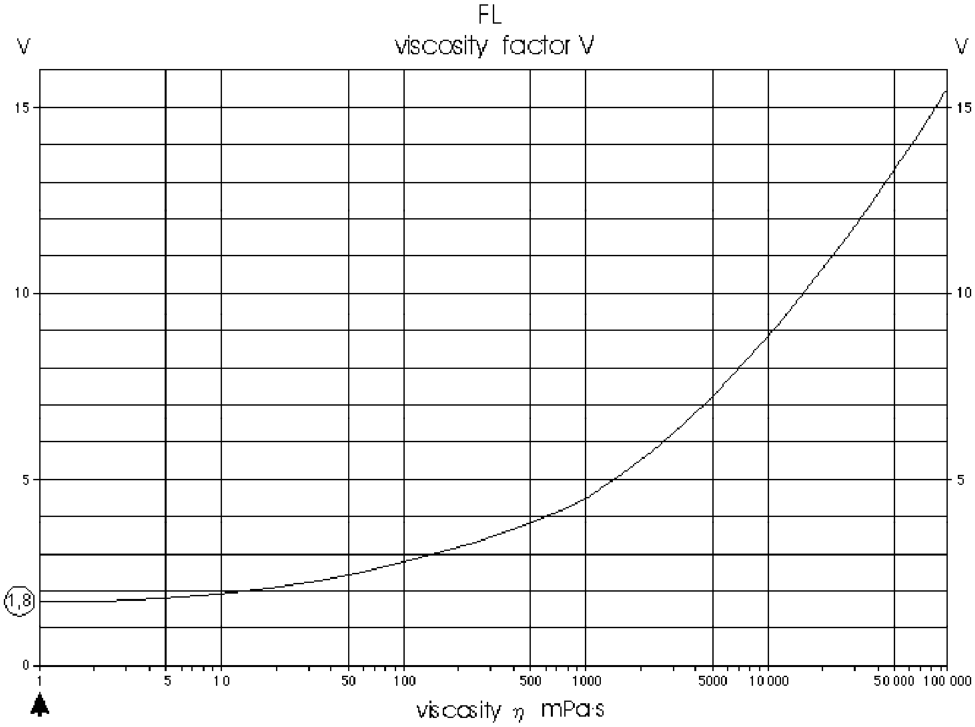


read: speed n = 380 1/min

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

Step 2:

define viscosity factor



stated in the diagram: viscosity factor V = 1.8

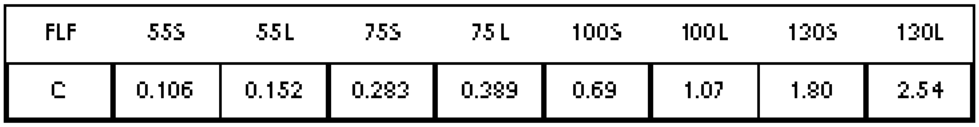
Case 1: viscosity η ∪ 1 mPa s

Step 3:

Calculate the 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
V = viscosity factor
n = speed with H = 0
C = flow rate/revolution [l/rev.]

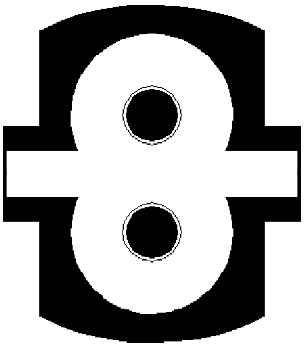


FLF	55S	55L	75S	75 L	100S	100L	130S	130L
C	0.106	0.152	0.283	0.389	0.69	1.07	1.80	2.54

Example:

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

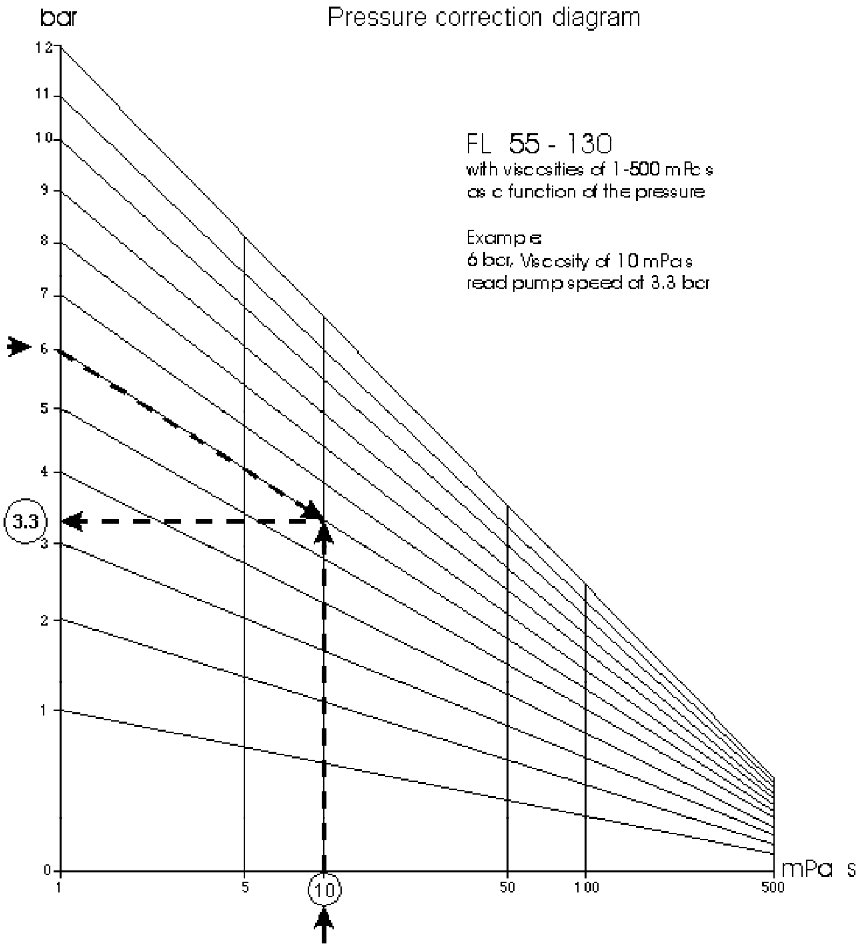
Case 2: viscous product η up to 500 mPa s



Flow rate	Q = 2000 l/h
Total head	H = 60 m
Viscosity	η = 10 mPa s

Step 1:
define correction for the speed

H = 60 m ∪ 6 bar

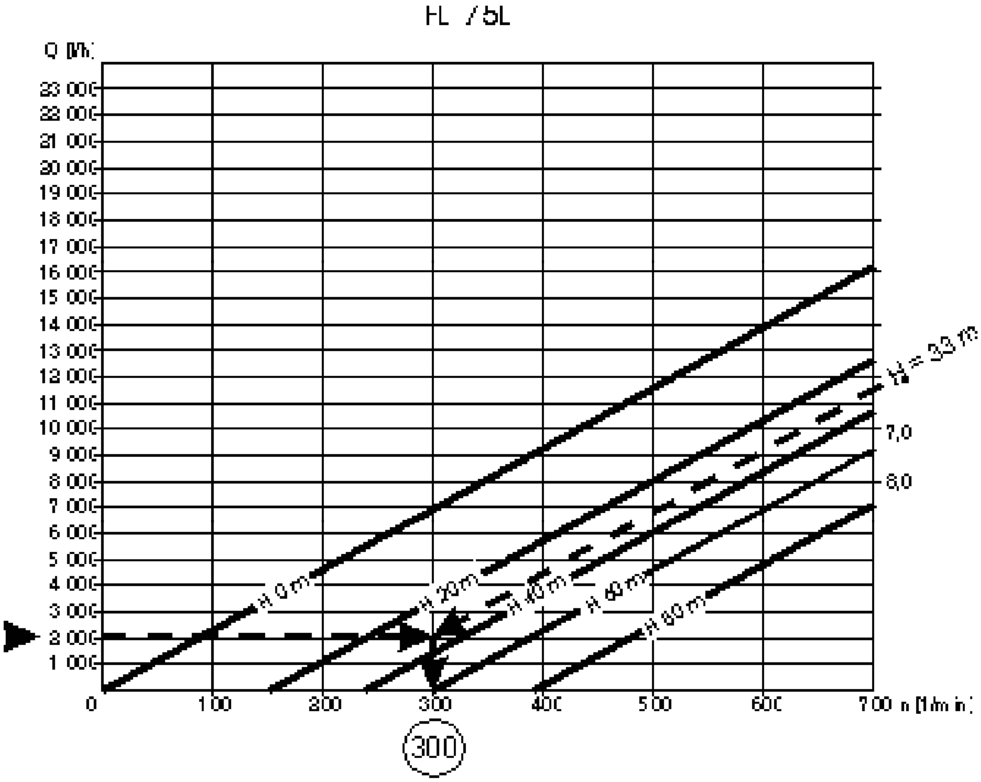


read speed at H = 33 m (equal to p = 3.3 bar)

Case 2:
viscous product
η up to 500 mPa s

Step 2:

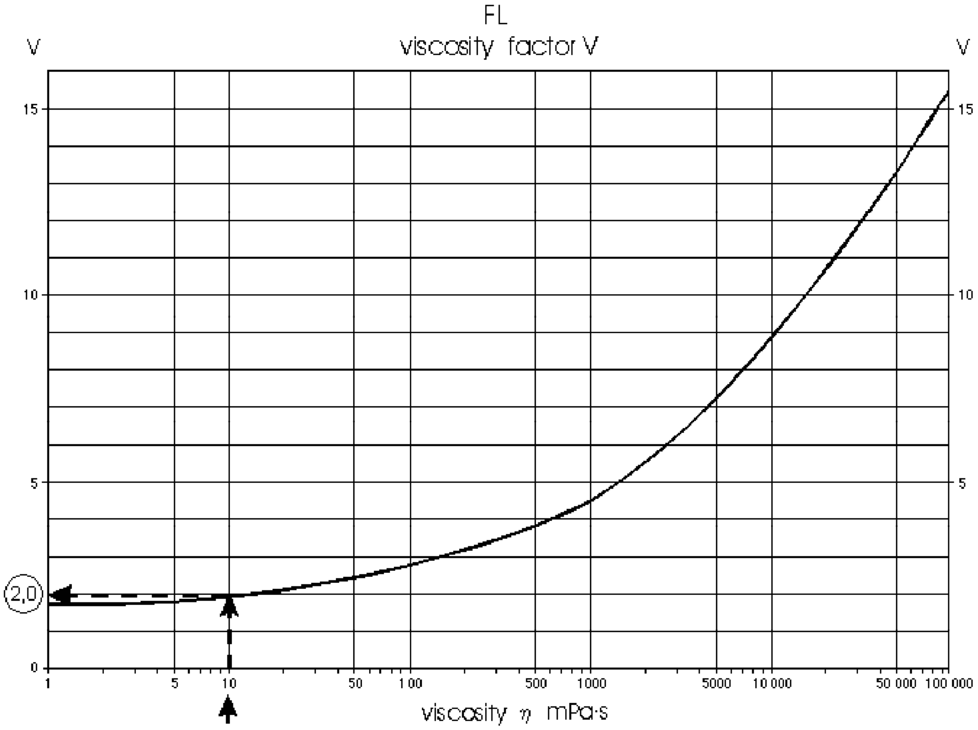
read speed at H = 33 m (∪ 3.3 bar)



read: speed n = 300 1/min

Case 2: viscous product η up to 500 mPa s

Step 3:
define viscosity factor



stated in the diagram: viscosity factor V = 2.0

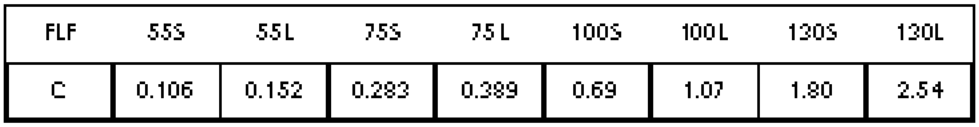
Case 2:
viscous product
η up to 500 mPa s

Step 4:

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
V = viscosity factor
n = speed at H = 0
C = flow rate/revolution [l/rev.]



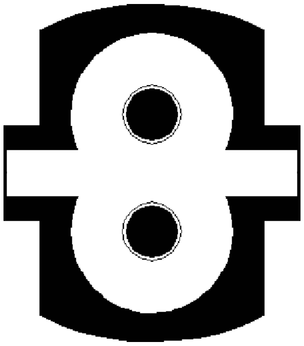
FLF	55S	55L	75S	75 L	100S	100L	130S	130L
C	0.106	0.152	0.283	0.389	0.69	1.07	1.80	2.54

Example :

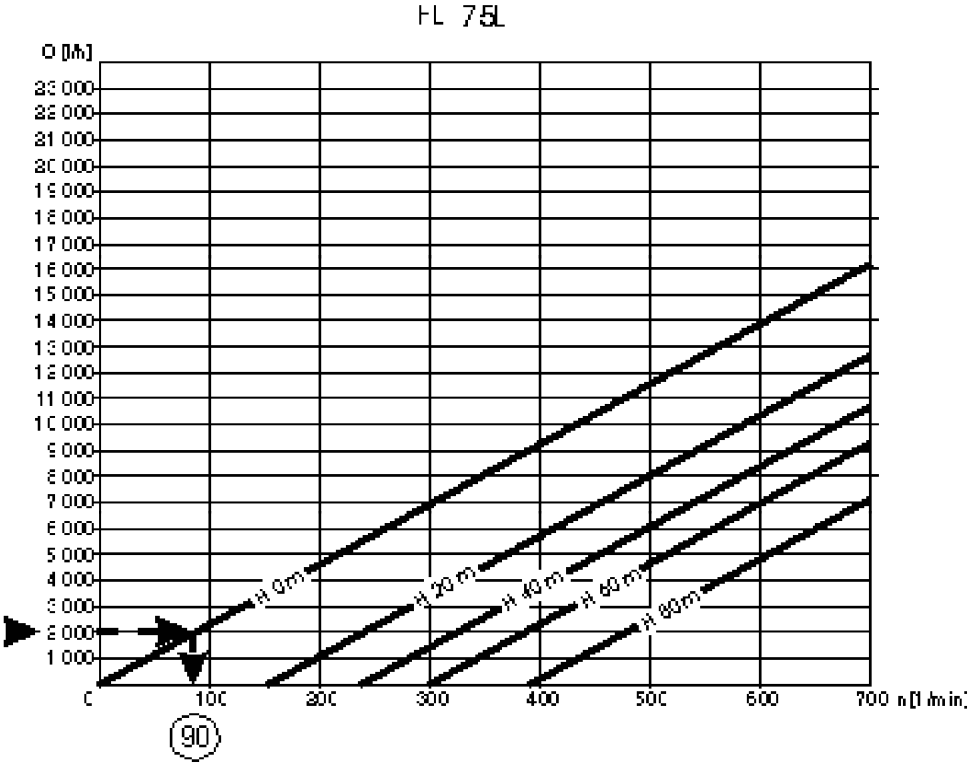
$$N = \frac{(2 \times 6 + 2) \times 300 \times 0.389}{1000} = 1.63 \text{ kW}$$

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

Flow rate	Q = 2000 l/h
Total head	H = 60 m (∪ 6 bar)
viscosity	η = 10,000 mPa s



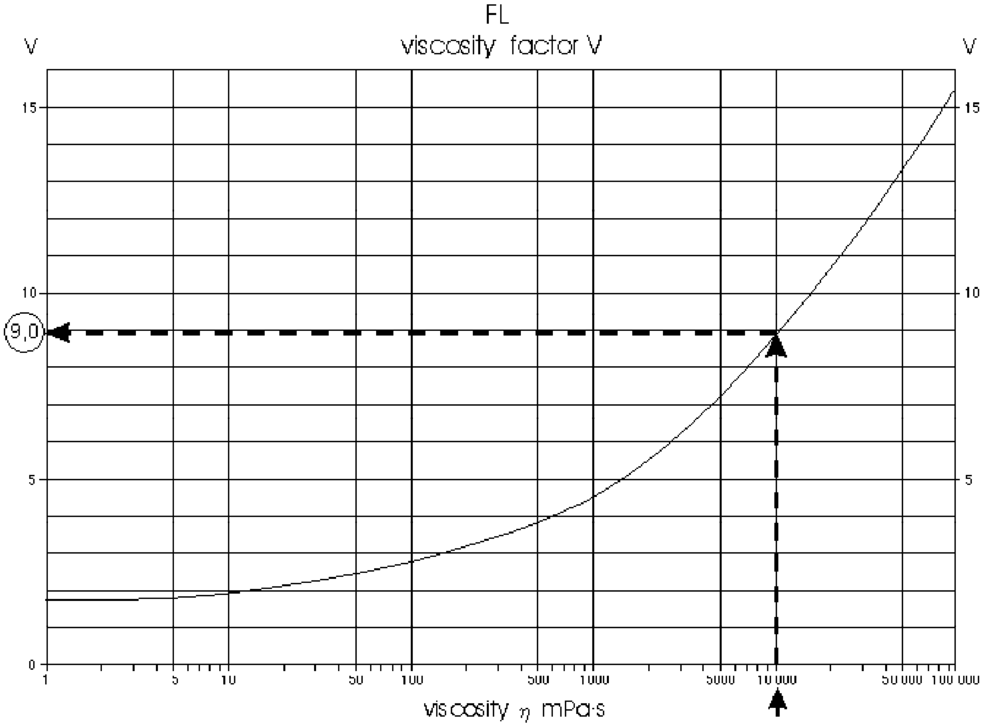
Step 1:
read speed at H = 0 m, as η > 500 mPa s



read: n = 90 1/min

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

Step 2:
define viscosity factor



Viscosity factor V = 9.0

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

Step 3:

calculate absorbed power N [kW].

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

p = pressure in bar ∪ H/10

V = viscosity factor

n = speed at H = 0

C = flow rate/revolution [l/rev.]

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 :

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