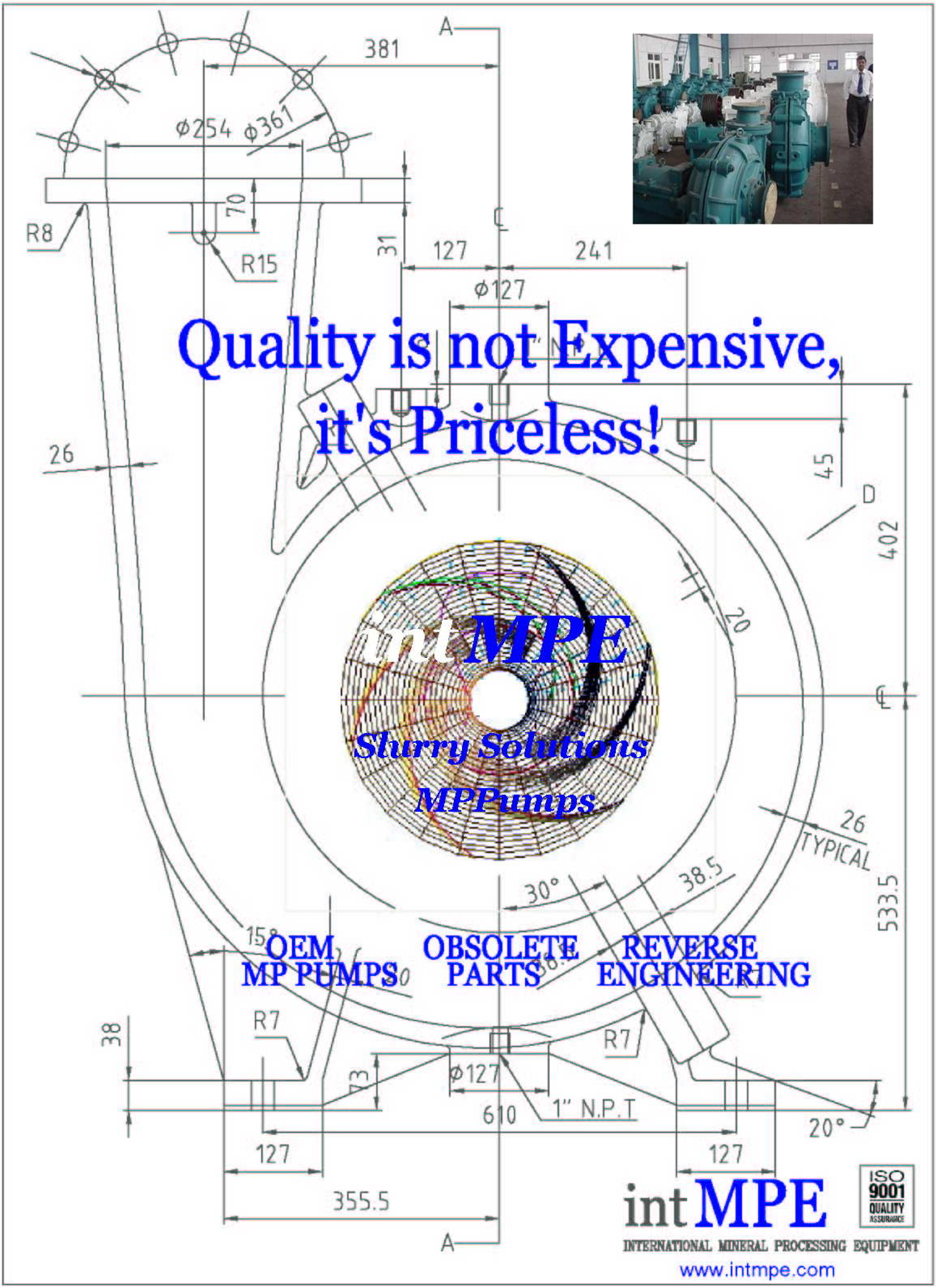

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Step by step calculation

See page 2 for values used in the example.

1. Determine SG/density of the liquid. If the density is unknown, it can be determined by using the formula or nomograph.

Pages 3, 4

2. Calculate the critical velocity using the table and curve. Choose a pipe diameter so that the pipe velocity is higher than the critical velocity. If the velocity is too low, losses, wear and also the risk of blockage increase.

Page 5

3. Calculate the total discharge head, which is the sum of the static discharge head, the losses in the pipe system, and the pipe discharge pressure (if required).

Page 6

The losses in the pipe system consist of friction losses and losses caused by fittings like pipe bends and valves etc. The friction losses can be established using the diagram. If the concentration is more than 15% by volume, the value should be adjusted using the correction factor diagram. For slurry pumping, pipe bends with a large radius and valves with free through flow should be selected. In this way, losses in fittings can be neglected when estimating the total losses.

Page 7

4. The required duty point has now been established. If the solid concentration exceeds 15% by volume, the discharge head of the pump must be reduced. By dividing the duty head with the reduction factor, the equivalent clean-water pump head is obtained.

5. The pump can now be selected based on the flow and head values above.

Page 8

The type of installation conditions in question should also be considered. Overall operating expenses, including wear, maintenance and energy consumption are equally important points to be considered.

6. Corresponding power consumption, clean-water versus slurry.

Page 9

The power curves for the pumps are based on clean water and these must then be multiplied by the specific gravity of the slurry to obtain the corresponding value for slurry pumping. Normally variations in the slurry can be expected and the motor should therefore be relatively large. Flygt recommends a motor with a 20% excess power margin for slurry applications.

Example

Calculate the size of a pump in a coal mine, pumping coal slurry from the mine.

Data from customer:

Voltage	**380 V, 50 Hz**
Water temp	**max 40°**
Concentration of solids by volume	**C_v = 30%**
Density of solids: 1800 kg/m³	**SG_s = 1,8**
Requested flow:	**Q = 50 l/s**
Geodetic head:	**H = 22 m**
Pipe diameter:	**150 mm**
Pipe length:	**L = 50 m**
Size of solids:	**d_{85} = 1**

These values are used in the example on the following pages.

1 Specific gravity (SG) of slurry

Determine the specific gravity of the slurry. Use the formula below or the nomograph on the next page.

Specific gravity is the density of a particular material normalised by the density of water.

Example: Density of sand is normally 2600 kg/m^3. SG of sand is then 2,6.

$$SG_{sl} = 1 + C_v(SG_s - 1)$$

or

$$SG_{sl} = \frac{SG_s}{SG_s - C_m(SG_s - 1)}$$

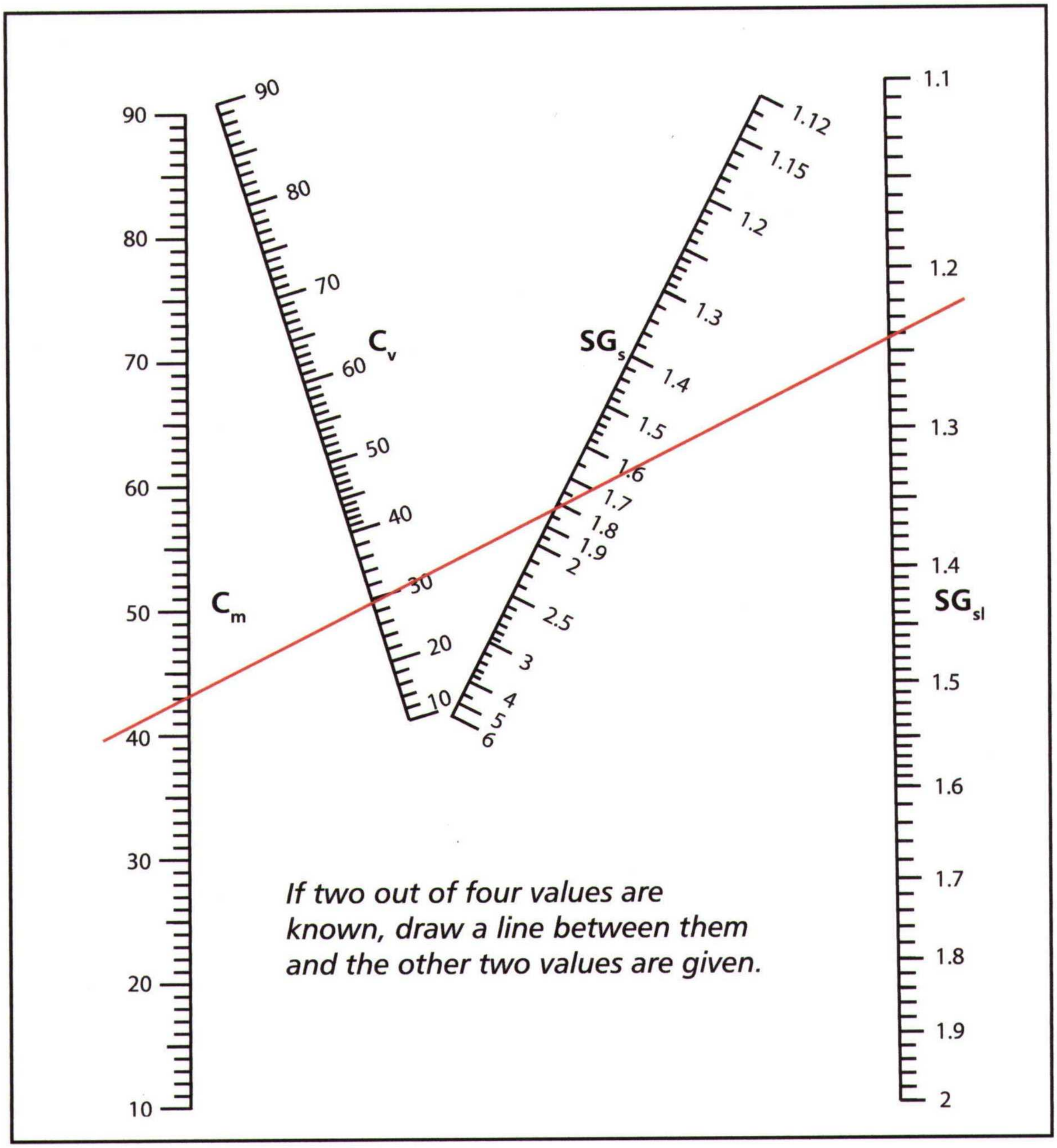
SG_{sl} = Specific gravity of the slurry
SG_s = Specific gravity of the solids
C_v = Concentration of solids by volume
C_m = Concentration of solids by weight

Example

Calculate the specific gravity (SG) of the slurry

$$SG_{sl} = 1 + 0{,}3(1{,}8 - 1) = 1{,}24$$

You can also use the nomograph on the next page.



Nomograph showing the relationship of concentration to specific gravity in aqueous slurries.

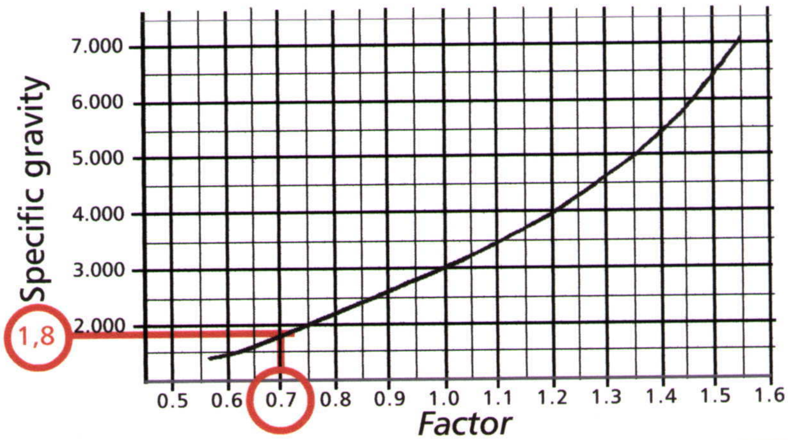
❷ Critical velocity

Calculate the critical velocity using the table and curve below. Choose a pipe diameter so that the pipe velocity is less than the critical velocity. If the velocity is too low, the losses, wear and also the risk of blockage will increase

Critical velocity (V_{cr}) m/s (for d_{85} and SG=3)

Pipe size		Mesh 65	48	32	24	16	9	<4
mm	inch	mm 0.2	0.3	0.5	0.7	1.0	2.0	>5
25	1	1.3	1.4	1.4	1.4	1.4	1.4	1.4
50	2	1.3	1.7	1.8	1.8	1.8	1.8	1.8
75	3	1.6	1.8	1.9	1.9	1.9	1.9	1.9
100	4	1.7	1.9	2.0	2.1	2.1	2.1	2.1
150	6	1.7	2.0	2.1	2.4	2.4	2.4	2.4
200	8	1.8	2.0	2.3	2.5	2.5	2.5	2.5
300	12	1.8	2.1	2.4	2.7	2.8	3.0	3.0
400	16	1.8	2.1	2.5	2.8	2.9	3.1	3.6

As the SG of the solids is below 3, a correction of the value must be done according to the diagram below.



Example

Check that the velocity in the pipe is above the critical velocity.
Pipe diameter: 150 mm
Size of solids: d_{85} = 1
V_{cr} = 2,4 m/s

Correction factor
Density of solids: 1800 kg m³ = SG_s = 1,8 = factor 0,7

Critical velocity
V_{cr} = 2,4 x 0,7 = 1,7 m/s

Actual velocity $V = \frac{Q}{A^*} = \frac{50 \times 10^{-3}}{3{,}14 \times 0{,}075^2}$ = 2,8 m/s

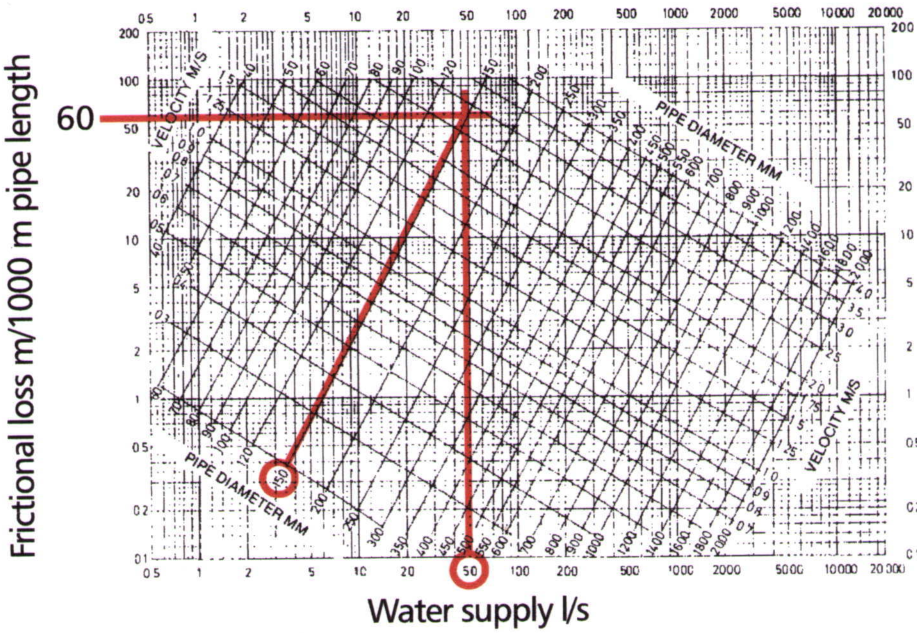
*A is the pipe area

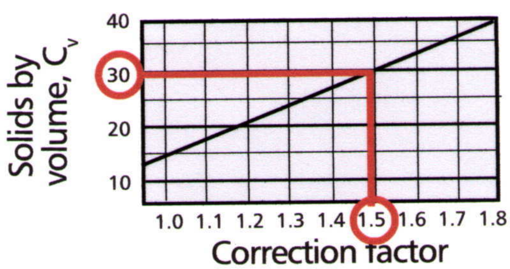
2,8 m/s > 1,7 m/s Well above!

❸ Total discharge head

Determine the <u>total discharge head</u>, by adding the friction losses to the geodetic head.

The table shows the frictional losses for clean water and the value must be multiplied with a correction factor for slurry.





Example

<u>Friction losses</u>

For steel pipe with a roughness factor 0,2, diameter 150 mm and flow rate, Q=50 l/sec, the top diagram gives friction losses for clean water: 60 m/1000m= 0,06 m/m_{pipe}

For pipe length 50 m: 50 x 0,06 = 3m

<u>Correction factor</u>

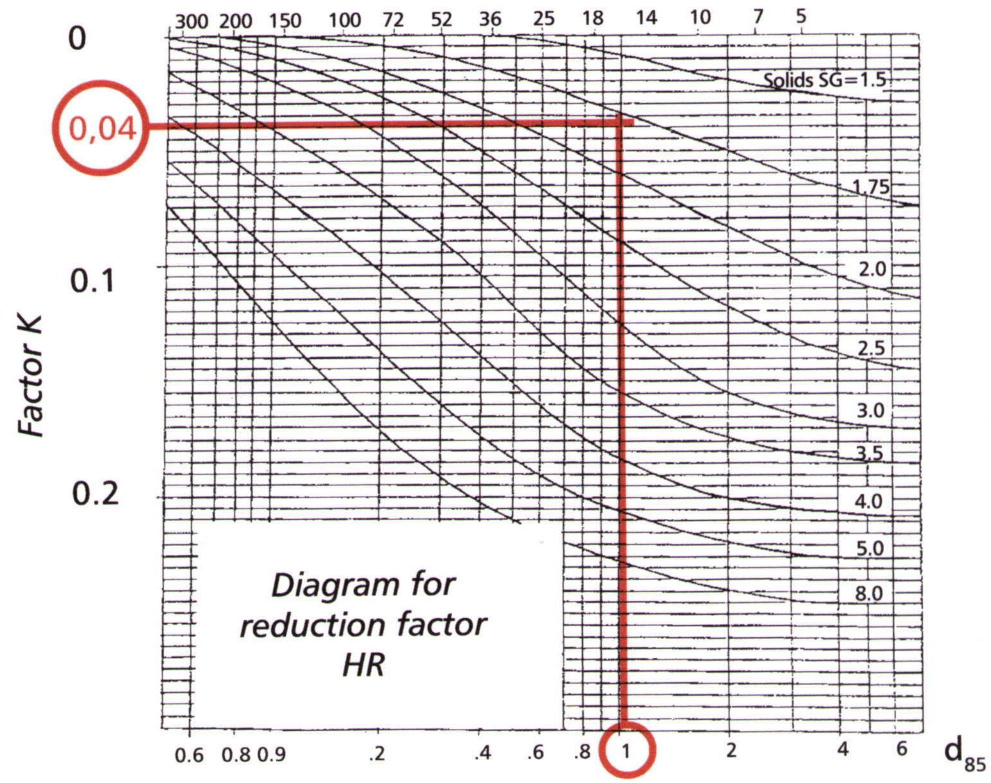
Correction factor for slurry C_v 30% = 1,5

<u>Head</u>

H_{frsl} = 3 x 1,5 = 4,5 m ; H_{totsl} = 4,5 + 22 = 26,5 m

4 Clean-water pump head

The diagram below gives the reduction factor HR for calculation of the equivalent clean water head, H_{cw}, since the performance curves are for clean water.



Example

Reduction factor HR

With d_{85} = 1 and SG_s = 1,8 the diagram gives K = 0,04

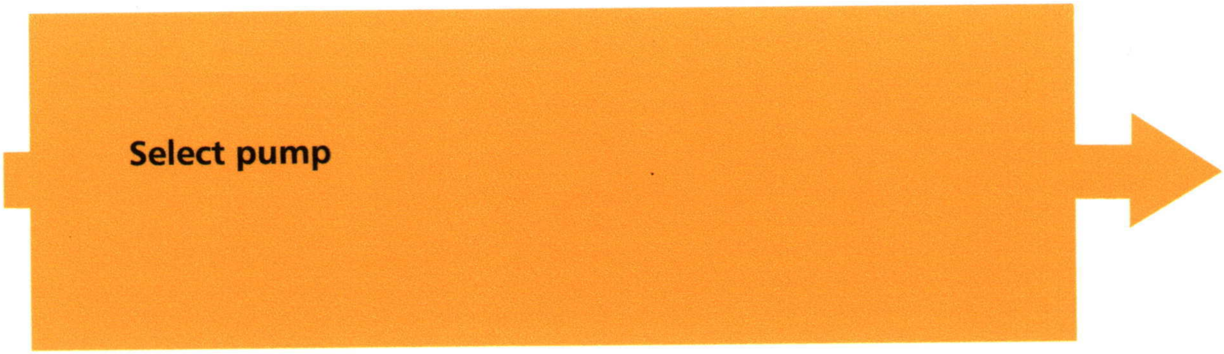
$$HR = 1 - K \times \frac{C_v}{20} = 1 - 0,04 \times \frac{30}{20} = 0,94$$

$$H_{cw} = \frac{H_{totsl}}{0,94} = \frac{26,5}{0,94} = 28,2 \text{ m}$$

Choose a pump with a clean water curve for duty point: H_{cw}=28,2 m (H_{sl}=26,5) and Q=50 l/s.

❺ Select pump

The pump is selected based on the flow and head values. The type of installation conditions in question should also be considered. Overall operating expenses, including wear, maintenance and energy consumption are equally important points to be considered.



6 Corresponding power consumption, clean-water vs slurry

The power curves for the pumps are based on clean water and these must then be multiplied by the specific gravity of the slurry to obtain the corresponding value for slurry pumping.

Pump	Poles	Rated shaft power, kW	$P_{shaft\ duty\ point}$	$P_{shaft\ max(432)}$
5150	4	30,0	22,5	25
	4	37,0	22,5	25
	4	45,0	22,5	25

Example

Check motor power

Check that the pump motor has a power margin to handle the higher density.

The table shows that the maximum permitted shaft power for the chosen motor is between 30 and 45 kW and the performance curve shows that we need 22,5 kW shaft power for clean water at the requested duty point.

$$SG_{sl} \times P_{incw} = P_{insl}$$

$$1{,}24 \times 22{,}5 = 27{,}9 \text{ kW}$$

The value is well below the maximum permitted input power at the requested duty point, but check that the value is below the power limit for the whole curve in case there are variations in the pumped head.

$P_{shaft\ max}$ = 25 kW for the chosen curve. $P_{inmaxsl}$ = 25 x 1,24 = 31 kW

There is still a sufficient power margin.

Select Pump with 37 kW motor.