EQUIPMENT DESIGN

LECTURE 8 - 9
PUMPS & PIPING SYSTEMS - 3

Net positive suction Head (NPSH)

The pressure at the inlet to a pump must be high enough to prevent cavitation occurring in the pump. Cavitation occurs when bubbles of vapour, or gas, form in the pump casing. Vapour bubbles will form if the pressure falls below the vapour pressure of the liquid.

The net positive suction head available *($NPSH_{avail}$) is the pressure at the pump suction,* above the vapour pressure of the liquid, expressed as head of liquid.

The net positive head required *($NPSH_{reqd}$) is a function of the design parameters of* the pump, and will be specified by the pump manufacturer. As a general guide, the NPSH should be above 3 m for pump capacities up to 100 m3/h, and *6 m above this capacity.* Special impeller designs can be used to overcome problems of low suction head; see Doolin (1977).

The net positive head available is given by the following equation:

$$NPSH_{avail} = P/\rho + H - P_f/\rho - P_v/\rho \qquad (5.7)$$

where $NPSH_{avail}$ = net positive suction head available at the pump suction, m,
P = the pressure above the liquid in the feed vessel, N/m^2,
H = the height of liquid above the pump suction, m,
P_f = the pressure loss in the suction piping, N/m^2,
P_v = the vapour pressure of the liquid at the pump suction, N/m^2,
ρ = the density of the liquid at the pump suction temperature, kg/m^3.

The inlet piping arrangement must be designed to ensure that $NPSH_{avail}$ exceeds $NPSH_{reqd}$ under all operating conditions.

Example 5.4

Liquid chlorine is unloaded from rail tankers into a storage vessel. To provide the necessary NPSH, the transfer pump is placed in a pit below ground level. Given the following information, calculate the NPSH available at the inlet to the pump, at a maximum flow-rate of 16,000 kg/h.

The total length of the pipeline from the rail tanker outlet to the pump inlet is 50 m. The vertical distance from the tank outlet to the pump inlet is 10 m. Commercial steel piping, 50 mm internal diameter, is used.

Miscellaneous friction losses due to the tanker outlet constriction and the pipe fittings in the inlet piping, are equivalent to 1000 equivalent pipe diameters. The vapour pressure of chlorine at the maximum temperature reached at the pump is 685 kN/m^2 and its density and viscosity, 1286 kg/m^3 and 0.364 $mNm^{-2}s$. The pressure in the tanker is 7 bara.

Solution

Friction losses

Miscellaneous losses $= 1000 \times 50 \times 10^{-3} = 50$ m of pipe

Total length of inlet piping $= 50 + 50 = 100$ m

Relative roughness, e/d $= 0.046/50 = 0.001$

Pipe cross-sectional area $= \frac{\pi}{4}(50 \times 10^{-3})^2 = 1.96 \times 10^{-3}$ m^2

Velocity, u $= \frac{16{,}000}{3600} \times \frac{1}{1.96 \times 10^{-3}} \times \frac{1}{1286} = 1.76$ m/s

Reynolds number $= \frac{1286 \times 1.76 \times 50 \times 10^{-3}}{0.364 \times 10^{-3}} = 3.1 \times 10^5$ (5.4)

Friction factor from Figure 5.7, $f = 0.00225$

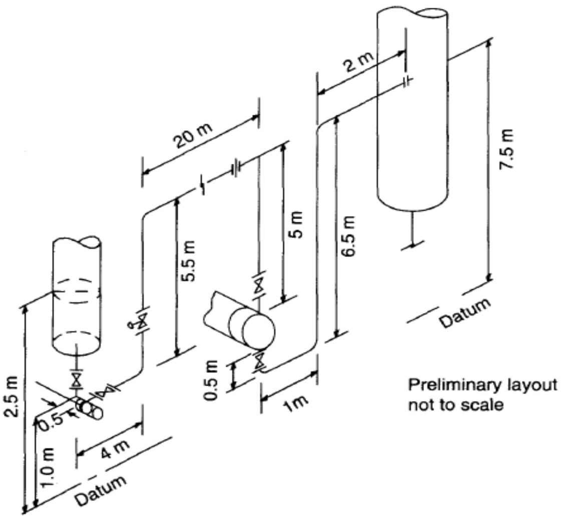
$$\Delta P_f = 8 \times 0.00225 \frac{(100)}{(50 \times 10^{-3})} \times 1286 \times \frac{1.76^2}{2} = 71{,}703 \text{ N/m}^2 \quad (5.3)$$

$$\text{NPSH} = \frac{7 \times 10^5}{1286 \times 9.8} + 10 - \frac{71.703}{1286 \times 9.8} - \frac{685 \times 10^{-3}}{1286 \times 9.8} \quad (5.7)$$

$$= 55.5 + 10 - 5.7 - 54.4 = \underline{\underline{5.4 \text{ m}}}$$

Example 5.8

Calculate the line size and specify the pump required for the line shown in Figure 5.15; material ortho-dichlorobenzene (ODCB), flow-rate 10,000 kg/h, temperature 20°C, pipe material carbon steel.



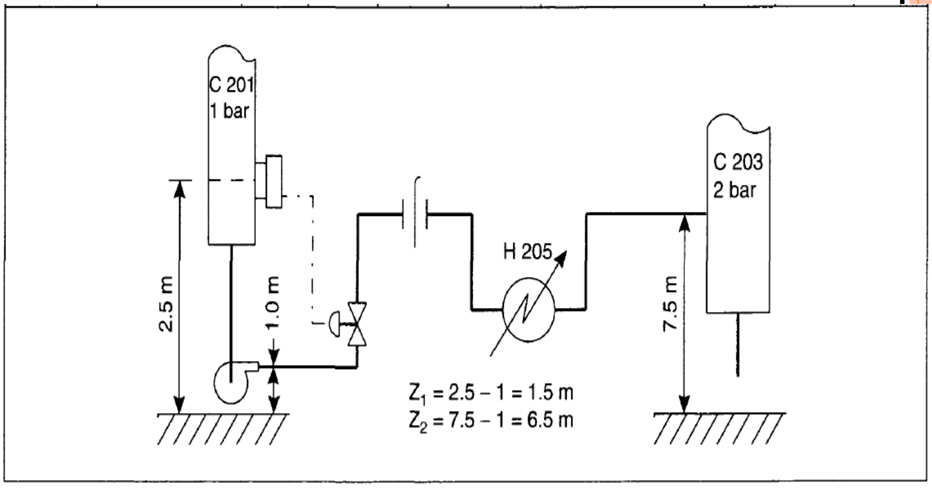


Table 5.4. Line calculation form (Example 5.4)

Pump and line calculation sheet									
Job no.	Sheet no.	By RKS, 7/7/79				Checked			
4415A	1								
Fluid		ODCB			DISCHARGE CALCULATION				
Temperature °C		20			Line size mm		40		
Density kg/m^3		1306				Flow	Norm.	Max.	Units
Viscosity mNs/m^2		0.9			u_2	Velocity	1.7	2.0	m/s
Normal flow kg/s		2.78			Δf_2	Friction loss	1.0	1.5	kPa/m
Design max. flow kg/s		3.34			L_2	Line length	54	—	m
					$\Delta f_2 L_2$	Line loss	54		kPa
SUCTION CALCULATION						Orifice	15	22	kPa
Line size mm		40			30%	Control valve	140	200	kPa
	Flow	Norm.	Max.	Units		*Equipment*			
u_1	Velocity	1.7	2.0	m/s		(a) Heat ex.	70	100	kPa
Δf_1	Friction loss	1.0	1.5	kPa/m		(b)	—	—	kPa
L_1	Line length	3.4	—	m		(c)	—	—	kPa
$\Delta f_1 L_1$	Line loss	3.4	5.1	kPa		(6) Dynamic loss	279	403	kPa
$\rho u_1^2/2$	Entrance	1.9	2.7	kPa					
(40 kPa)	Strainer	—	—	kPa	z_2	Static head	6.5	—	m
	(1) Sub-total	5.3	7.8	kPa	$\rho g z_2$		85	85	kPa
						Equip. press (max)	200	200	kPa
z_1	Static head	1.5	1.5	m		Contingency	None	None	kPa
$\rho g z_1$		19.6	19.6	kPa		(7) Sub-total	285	285	kPa
	Equip. press	100	100	kPa	(7) + (6)	Discharge press.	564	685	kPa
	(2) Sub-total	119.6	119.6	kPa	(3)	Suction press.	114.3	111.8	kPa
						(8) Diff. press.	450	576	kPa
(2) − (1)	(3) Suction press	114.3	111.8	kPa					
	(4) VAP. PRESS.	0.1	0.1	kPa	(8)/ρg		34	44	m
(3) − (4)	(5) NPSH	114.2	111.7	kPa	Valve/(6)	Control valve			
(5)/ρg		8.7	8.6	m		% Dyn. loss	50%		

Table 5.5. Pump Specification Sheet (Example 5.8)

	Pump Specification
Type:	Centrifugal
No. stages:	1
Single/Double suction:	Single
Vertical/Horizontal mounting:	Horizontal
Impeller type:	Closed
Casing design press.:	600 kPa
design temp.:	20°C
Driver:	Electric, 440 V, 50 c/s 3-phase.
Seal type:	Mechanical, external flush
Max. flow:	7.7 m^3/h
Diff. press.:	600 kPa (47 m, water)