Solution 10.1

See section 10.4.3, Figure 10.16 and example 10.1

Solution 10.2

Section 10.4 Solid- Liquid Separation

Figure 10.10 Solid-liquid separation techniques

Solids 10%, particle size 0.1mm = $0.1 \times 10^{-3} \times 10^{6} = 100$ microns

Possible separators: filters and centrifuges, cyclones, classifiers

Reject filters, classifiers and cyclones, material likely to be sticky and flammable

Consider centrifuge, Section 10.4, solid bowl batch or continuous likely to be most suitable for the duty.

Sigma theory

Overflow 1000 kg/h, $\rho_s = 1100$ kg/m^3, $\rho_{mix} = 860$ kg/m^3, $\mu_L = 1.7$ mNm^{-2}s , solids 10%

Density of solids is given, density of clarified liquid overflow needed. Specific volumes are additive, see chapter 8, section 7.1 .

$$1/860 = 1/\rho_L \times 0.9 + 1/1100 \times 0.1$$

$$\rho_L = 840 \text{ kg/m}^3$$

$\Delta\rho = 1100 - 860 = 240$ kg/m^3

$u_g = (240 \times (0.1 \times 10^3)^2 9.8)/(18 \times 107 \times 10^{-3} = 0.000769,$ 7.7 x 10-4 m/s (10.2)

$Q/\Sigma = 2 \times 0.000769 = 1.53 \times 10^{-3}$ (10.3)

$Q = 1000 / 840 = 1.19$ m^3/h

From table 10.6 a solid bowl/basket centrifuge should be satisfactory. A Continuous discharge type should be selected. The centrifuge could be housed in a casing purged with nitrogen.

Solution 10.3

Data

Flow-rate 1200 l/m, recovery 95% greater than 100 mμ

Density of solid 2900 kgm^{-3}

Properties of water: viscosity 1300×10^{-6} Nm^{-2} s at 10 ^{o}C, 797×10^{-6} Nm^{-2} s at 30 ^{o}C;

density 999.7 kgm^{-3} at 10 ^oC, 995.6 kgm^{-3} at 30 ^oC.

Design for both temperatures.

At 10 ^oC

$$(\rho_S - \rho_L) = 2900 - 999.7 = 1900.3 \ kgm^{-3}, \ 1.9 \ gm^{-3}$$

From Fig. 10.22, for 95% recovery greater than 100 μm., d_{50} = 64 μm

From Fig. 10 23 for, a liquid viscosity of 1.3 mNm^{-2} s, D_c = 110 cm

At 30 ^oC

$$(\rho_S - \rho_L) = 2900 - 995.6 = 1904.4 \ kgm^{-3}$$

liquid viscosity = 0.8 mNm^{-2} s

D_c = 150 cm

Take the larger diameter and scale the cyclone using the proportions given in Fig. 10.24.. See section 10.4.4, example 10.2 .

Solution 10.4

See section 10.8.3 and example 10.4 .

Solution 10.5

I will treat this as a simple separation of water and acrylonitrile. In practice acrylonitrile will be soluble to some extent in water and water in acrylonitrile. Also, the azetropic composition will not be that given in the problem specification.

The design of liquid-liquid separators, decanters, is covered in section 10.6.1 and illustrated in example 10.3.

Take the acrylonitrile as the continuous phase.

Physical properties

Viscosity of acrylonitrile, estimated using the correlation given in Appendix D,

Log μ = 343.31(1/293 – 1/210.42) , μ = 0.5 mN m^{-2}s

Density of acrylonitrile = 806 kg/m^3

Water density = 998 kg/m^3

Decanter sizing

Take the droplet size as 150 μm

Then the settling velocity, $u_d = \frac{(150 \times 10^{-6})^2 \times 9.8(998 - 806)}{18 \times 0.35 \times 10^{-3}}$ (10.7)

$= 0.0067$ m/s $= 6.7 \times 10^{-3}$ m/s

Greater than 4.0×10^{-3}, so use 4.0×10^{-3} m/s

Feed rate 300 kg/h, very small so use a vertical separator

Acrylonitrile flow-rate = $300 \times 0.95 = 285$ kg/h

Volumetric flow-rate, $L_c = 285/(806 \times 3600) = 9.82 \times 10^{-5}$ m^3/s

Continuous phase velocity must be less than the droplet settling velocity, which determines the cross-sectional area required,

$$A_i = (9.82 \times 10^{-5})/(4.0 \times 10^{-3}) = 0.0246 \text{ m}^2$$

So, decanter diameter $= \sqrt{[(4 \times 0.0246)/\Pi]} = 0.18$ m

Take height as twice diameter = $0.18 \times 2 = 0.36$ m

Take dispersion band as 10% of vessel height = 0.036 m

Droplet residence time = $0.036/4 \times 10^{-3} = 9$ sec, low

The decanter is very small, due to the low flow-rate. So increase to, say, diameter 0.5 m and height 1.0 m to give a realistic size.

Check residence time for larger decanter,

Total volumetric flow = $285/(806 \times 60) + 15/(998 \times 60) = 0.00614$ m^3/min

Volume of decanter = $1 \times 0.5^2 \times \Pi/4 = 0.194$ m3

Residence time = 0.194/0.00614 = 32 min. More than sufficient for separation, 5 to 10 minutes normally reckoned to be adequate.

Piping arrangement.

Keep velocity in feed pipe below 1 m/s.

Volumetric flow rate = 0.00614/60 = $0.000102 m^3/s$

area of pipe = 0.000102/1.0 = 0.000102 m^2 ,

diameter = $\sqrt{[}$ (4 x 0.000102)/Π] = 0.0114 m = 12mm

Take the interface position as halfway up the vessel and the water take off at 90% of the height, then

z_1 = 0.9m, z_3 = 0.5m

z_2 = (0.9 - 0.5)806/998 + 0.5 = 0.82m (10.5)

say 0.8m

Solution 10.6

See the solution to problem 10.5 and example 10.3

Solution 10.7

See section 10.9.2 and example 10.5

Solution 10.8

See section 10.9.2 and example 10.5