

1) $Q = 0.8 \text{ m}^3/\text{s}$
 8-1) Rapid sand filter boxes: $10 \text{ m} \times 20 \text{ m}$
 $q = 110 \text{ m}^3/\text{d} \cdot \text{m}^2$

How many filter boxes are required?

$$Q = 0.8 \frac{\text{m}^3}{\text{s}} \times (60 \times 60 \times 24) \frac{\text{s}}{\text{day}} = 69,120 \frac{\text{m}^3}{\text{d}}$$

$$Q > 42,000 \text{ m}^3/\text{d}$$

$$\Rightarrow N = 0.0195 (69,120)^{0.5} = 5.13 \text{ filter boxes needed.}$$

Filters usually in pairs so let $N = 6$ filters.

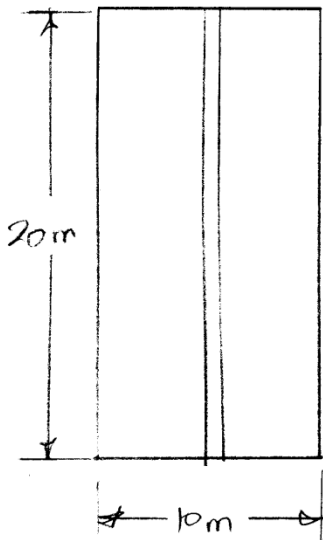
Try 5 filters to handle flow and 1 for redundancy.

$$A = \frac{Q}{Nq} = \frac{69,120 \text{ m}^3/\text{d}}{5 \times 110 \text{ m}^3/\text{d} \cdot \text{m}^2} = 125.7 \text{ m}^2/\text{filter box}$$

Filter box $10 \text{ m} \times 20 \text{ m} = 200 \text{ m}^2$

upper gullet = 0.4 to 2.0 m wide

let upper gullet width = 2.0 m as filter box is large.



One cell used) \Rightarrow

$$4 \text{ m wide} \times 20 \text{ m long} = 80 \text{ m}^2$$

$$2 \text{ cells} \times 80 \text{ m}^2 = 160 \text{ m}^2/\text{filter box}$$

$$L:W \text{ of cell} = 20:4 = 5:1$$

$$160 \frac{\text{m}^2}{\text{filter box}} > 125.7 \frac{\text{m}^2}{\text{filter box}}$$

as this will work.

2) Depth = 0.75 m
 $V_a = 230 \text{ m}^3/\text{d} \cdot \text{m}^2 = 0.00266 \text{ m/s}$
 $S G_{\text{sand}} = 2.80$
 $\phi = 0.80$
 $\epsilon = 0.40$
 $T = 5^\circ\text{C}$; $v = 1.519 \times 10^{-6} \text{ m/s}$

Sieve no.	% Ret.	d_g (m)	Re	C_D	h_L , m
8-12	0.00				
12-16	0.40	0.00141	1.98	14.59	0.001165
16-20	13.10				
20-30	54.50	0.000704	0.9862	24.34	0.531
30-40	30.20				
40-50	1.785	0.000353	0.4945	48.53	0.06916
50-70	0.015				
	100.0				

#12 is 1.68 mm #16 is 1.19 mm

geometric mean dia. $d_g = (d_1 d_2)^{0.5}$
 $= (1.68 \times 1.19)^{0.5} = 2.0 \text{ mm}$
 $= 1.41 \text{ mm} = 0.00141 \text{ m}$

$Re = \frac{\phi d V_a}{v} = \frac{(0.8)(0.00141)(230 \text{ m}^3/\text{d} \cdot \text{m}^2)}{(1.519 \times 10^{-6} \text{ m/s})(86,400 \text{ s/d})} = 1.98$

$C_D = \frac{24}{Re} + \frac{3}{\sqrt{Re}} + 0.34 = 12.12 + 2.13 + 0.34 = 14.59$

h_L for this layer separately = $\frac{1.067 (V_a)^2 (D) C_D}{\phi g (\epsilon)^4 d_g}$

$h_L = \frac{(1.067)(0.00266 \text{ m/s})(0.00266 \text{ m/s})(0.004)(0.75)(14.59)}{(0.80)(9.81 \text{ m/s}^2)(0.40)^4 (0.00141 \text{ m})}$

$= \frac{3.30 \times 10^{-7}}{2.832 \times 10^{-4}} = 0.001165 \text{ m}$

(3)

2) continued

20 is 0.841 mm; # 30 is 0.590 mm

$$d_g = (0.841 \text{ mm} \times 0.590 \text{ mm})^{0.5} = 0.704 \text{ mm} \\ = 0.000704 \text{ m}$$

$$Re = \frac{\phi d v_a}{\nu} = \frac{0.8 \times 0.7}{1.519 \times 10^{-6}}$$

$$Re = \frac{\phi d v_a}{\nu} = \frac{0.8 \times 0.000704 \text{ m} \times 0.00266 \text{ m/s}}{1.519 \times 10^{-6} \text{ m}^2/\text{s}}$$

$$= 0.9862$$

$$C_d = \frac{24}{Re} = 24.34$$

$$h_L \text{ for this layer} = \frac{1.067 (v_a)^2 D C_d}{\phi g (\epsilon)^4 d_s}$$

$$h_L = \frac{1.067 (0.00266 \text{ m/s})^2 (0.545)(0.75)(24.34)}{(0.80)(9.81 \text{ m/s}^2)(0.40)^4 (0.000704 \text{ m})}$$

$$= \frac{7.5111 \times 10^{-5} \text{ m}}{7.4144 \times 10^{-4}} = 0.531 \text{ m}$$

40 is 0.420 mm; # 50 is 0.297 mm; $d_g = 0.353 \text{ mm}$

$$Re = \frac{0.8 \cdot (0.000353 \text{ m})(0.00266 \text{ m/s})}{1.519 \times 10^{-6} \text{ m}^2/\text{s}} = 0.4945$$

$$C_d = \frac{24}{Re} = \frac{24}{0.4945} = 48.53$$

$$h_L = \frac{1.067 (0.00266 \text{ m/s})^2 (0.01785)(0.75 \text{ m})(48.53)}{(0.80)(9.81 \text{ m/s}^2)(0.40)^4 (0.000353)}$$

$$= \frac{4.905 \times 10^{-6}}{7.092 \times 10^{-9}} = 0.6916 \text{ m}$$

(4)

3) $D = 0.75 \text{ m}$
 $V_c = 230 \text{ m}^3/\text{d} \cdot \text{m}^2 = 0.00266 \text{ m/s}$
 $SG_{\text{sand}} = 2.80$
 $\epsilon = 0.4$
 $T = 5^\circ\text{C}$

$$\rho = 999.967 \text{ kg/m}^3$$

$$\rho_{\text{sand}} = (2.80)(999.967 \text{ kg/m}^3) = 2800 \text{ kg/m}^3$$

$$\gamma = 9.807 \text{ kN/m}^3$$

$$\gamma_{\text{sand}} = (2.80)(9.807 \text{ kN/m}^3) = 27.46 \text{ kN/m}^3$$

$$\mu = 1.519 \times 10^{-3} \text{ Pa} \cdot \text{s} = 1.519 \text{ mPa} \cdot \text{s}$$

Sieve no.	% Retained	% Finer	d_g, m
8-12	0.00	100	
12-16	0.40	100	0.00141
16-20	13.10	99.6	0.00100
20-30	54.50	86.5	0.000704
30-40	30.20	32	0.000498
40-50	1.785	1.80	0.000353
50-70	0.015	0.015	0.000250

#16 is 1.19 mm; #20 is 0.841 mm; $d_g = 1.000 \text{ mm}$

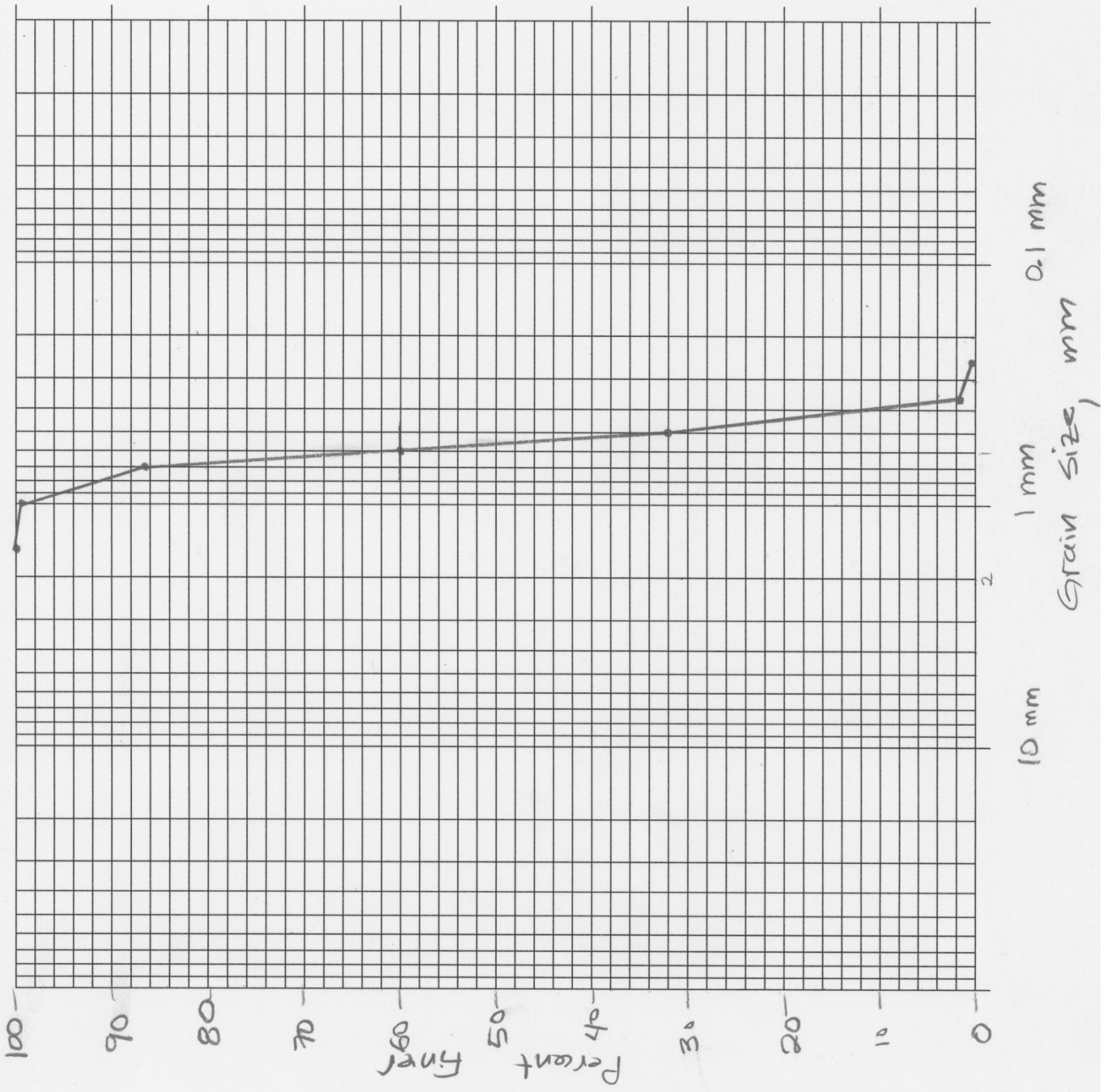
#30 is 0.590 mm; #40 is 0.420 mm; $d_g = 0.4978 \text{ mm}$

#50 is 0.297 mm; #70 is 0.210 mm; $d_g = 0.250 \text{ mm}$

Plot percent finer on semi-log paper (next page)

From graph $d_{60} = 0.60 \text{ mm}$

or simply interpolating between 86.5% and 30%
 to get the 60% finer size gives 0.604 mm
 $\approx 0.60 \text{ mm}$. (5)



(9)

3) continued.

$$v_f = \frac{0.0000839 (d_{60})^{1.82} [\gamma (\gamma_{\text{sand}} - \gamma)]^{0.94}}{\mu^{0.88}}$$

$$v_f = \frac{0.0000839 (0.60)^{1.82} [9.807 (27.46 - 9.807)]^{0.94}}{(1.519)^{0.88}}$$

$$= \frac{0.0000839 (0.3947) [127.07]}{1.4447}$$

$$= 0.002913 \text{ m/s}$$

$$Re_f = \frac{\rho v_f d_{60}}{\mu} = \frac{(999.967 \text{ kg/m}^3) (0.002913 \text{ m/s}) (0.0006 \text{ m})}{0.001519 \text{ Pa}\cdot\text{s}}$$

$$= 1.1506 \quad \left(Pa = \frac{N}{m^2} = \frac{kg \cdot m}{s^2 \cdot m^2} \right)$$

$Re_f < 10$ so K_R not needed

$$v_s = 8.45 v_f = (8.45) (0.002913 \text{ m/s}) = 0.0246 \text{ m/s}$$

$$Re_s = \frac{\rho v_s d_{60}}{\mu} = 8.45 Re_f = 9.722$$

$$n_e = 4.45 Re_s^{-0.1} = 4.45 (9.722)^{-0.1} = 3.5447$$

$$v_f = K_e (E)^{n_e}; \quad K_e = \frac{v_f}{(E)^{n_e}} = \frac{0.002913 \text{ m/s}}{(0.4)^{3.5447}} = 0.075 \text{ m/s}$$

The smallest particle that cannot be washed out by backwashing is 0.00025 m or 0.250 mm

From Fig. 8.7, estimated settling velocity is about $0.034 \text{ m/s} = v_b$

(7)

3) continued

$$V_b = K_e (\epsilon_e)^{n_e}$$

$$\epsilon_e = \left(\frac{V_b}{K_e} \right)^{1/n_e} = \left(\frac{0.034 \text{ m/s}}{0.075 \text{ m/s}} \right)^{1/3.5447} = 0.453^{0.2821}$$

$$= 0.800$$

$$D_e = \frac{D(1-\epsilon)}{1-\epsilon_e} = \frac{0.75(1-0.4)}{1-0.8} = \frac{0.45}{0.2} = 2.25 \text{ m}$$