3. Shell and tube heat exchanger.

i) $U_D = x \times 5.67 \ \frac{J}{m^2 s K}$

ii) $LMTD = \frac{\Delta T_1 - \Delta T_2}{\ln\left(\frac{\Delta T_1}{\Delta T_2}\right)}$

iii) $S = \frac{t_2 - t_1}{T_1 - t_1}$

$R = \frac{T_1 - T_2}{T_2 - T_1}$

$f_t = \underline{\hspace{2em}}$

iv) $f_t \times LMTD = (LMTD)_{act}$

v) $Q_h = m_h \times C_{p_h} \times \Delta T_h$

vi) $Q_h = Q_c$

vii) $m_c = \frac{Q_c}{C_{p_c} \times \Delta T_c}$

viii) $Q = U_D A_o \Delta T_{lm}$

ix) $A_o = \pi d_o L N$

x) Shell ID - Pg 54

store
67

xi) Table 1, 4-15 IS CODE

xii) h_i :

$d_i \rightarrow$ B.W.G / IPS

$$A = \frac{\pi}{4} d_i^2$$

$$V = \frac{m / \text{no. of pass}}{\rho \times A}$$

$$N_{Re} = \frac{\rho d_i V}{\mu} \qquad N_{pr} = \frac{c_p \mu}{k}$$

$$\frac{h_i d_i}{k} = 0.023 (N_{Re})^{0.8} (N_{pr})^{0.33} \left(\frac{\mu}{\mu_w}\right)^{0.14}$$

xiii) h_o

$$\frac{h_o d_o}{k} = 0.2 \left(\frac{G_e d_o}{\mu}\right)^{0.6} (N_{pr})^{0.33} \left(\frac{\mu}{\mu_w}\right)^{0.14}$$

$$G_e = \sqrt{G_c G_b} \qquad D_e = \frac{4\left(p^2 - \frac{\pi d_o^2}{4}\right)}{\pi d_o}$$

$$G_c = \frac{m_h}{S_c} \qquad G_b = \frac{m_h}{S_b}$$

$$S_c = P D_s \left(1 - \frac{d_o}{p}\right) \qquad S_b = f \frac{\pi}{4} D_s^2 - N_b \frac{\pi}{4} d_o^2$$

$$f - 0.1955 \qquad N_b = \frac{\text{no. of tube}}{\text{No. of pass}}$$

xiv) $$\Delta P_{tube} = \frac{f G^2 L N}{2 \rho g d_i} \qquad P_r = \frac{2 N v^2 \rho}{2g} \qquad P = P_r + \Delta P$$

$G = \rho V$ $\quad$ N - no of passes.

xv) $$\Delta P_{shell} = \frac{f G_e^2 N_H}{2 \rho g D_e} \qquad N_H = \frac{\text{length of tube}}{\text{Baffel Pitch}} - 1$$

Case: STHE

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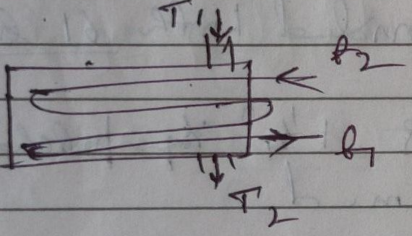
System: Light Distillate – Water

Properties

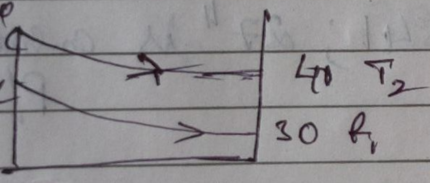
	Light Distillate	Water
C_p	1400	4178
μ	0.4×10^{-3}	0.82×10^{-3}
k	0.096	0.620
ρ	780	995.025
ΔT (80–40) →	40	30–35 ⇒ 5°C
T_{avg}	60°C	32.5°C
N_{pr}	5.833	5.526



$F_T = 0.98$

$R = \frac{80-40}{30-35} = \frac{T_1-T_2}{t_2-t_1} = 8$

$S = \frac{t_2-t_1}{T_1-t_1} = 5/80-30 = 0.1$



$\Delta T_{Lm} = 23.27 = \frac{45-10}{\ln 45/10}$

Light distillate shell side fluid

$\dot m_h = 57000$ kg/h = 15.83 kg/s

$\dot m_h = \cancel{57000\text{ kg}}$/h = kg/s of 15.83 kg/s

$Q = 88.6\times10^4$ W $= \dot m_h C_{p_h} \Delta T$

$\dot m_c = 42.44$ kg/s $= Q/C_{p_c}(\Delta T_c)$

U_D – Ref T10-14

50 – 150 $\frac{Btu}{h\,ft^2\,°F}$; 120 is assumed

Assume 120 × 5.6783 = 681.4 $\frac{W}{m^2K}$

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$A = \frac{Q}{U_D \Delta T_{Ln}}$

$= \frac{\cancel{[illegible]} \; 88.6 \times 10^4}{681.4 \times 22.805} = \cancel{0.127 \times 10 = 2.7}$

$= 57 m^2$

Given $d_o = 25 mm$ & ~~[illegible]~~ $L = 3m$

$\pi d_o L N_t = 57 m^2$

$N_t = \frac{57}{\pi \times 25 \times 10^{-3} \times 3} = 241.99$

$= 242$

For four passes $\Rightarrow$ 244 is used

Since it is 2-4 Shell & Tube HE

Each pass will be provided with 61 tubes

1" OD & $1\frac{1}{4}$" sq. pitch is assumed

Shell ID from P841; 27" is considered

503 Tube/sheet thickness = P/T7

Tube hole dia

No. of baffles =

Thickness of shell = 19mm

Corrosion allowance = 2m

MOC – Cast iron – Permissible fac for 200

ID of shell $= 27" \times \frac{2.54 \times 10^{-2}}{1"} - 2(21 mm)$

$= 0.644 m$

OD_{shell} 27" = 0.68.58 m

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Design verification

$h_i \Rightarrow$

$$\frac{h_i d_i}{k_i} = 0.023 (N_{Re})^{0.81} (N_{pr})^{0.33} \left(\frac{\mu}{\mu_w}\right)^{0.14}$$

$$v = \frac{m}{\rho A_{cs}} = \frac{42.44}{995.025 \times (\frac{\pi}{4} \times 23.75 \times 10^{-3})^2}$$

$= \underline{96.3}$ as per ~~the~~ flow rate

Since, this is to be divided into 61 flows ((no. of tubes) / pass)

$$\frac{96.3}{61} = \underline{1.578} \ m/s$$

$$\therefore N_{Re} = \frac{995.025 \times 23.749 \times 10^{-3} \times 1.578}{0.82 \times 10^{-3}}$$

$= \cancel{17686.41}$ 45473.83

$$h_i \cancel{Mix} = \frac{0.62 \times 0.023 (17686.41)^{0.81} (5.526)^{0.33}}{0.02374} (1)^{0.14}$$

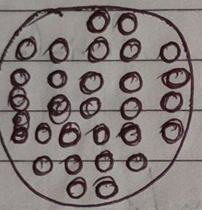
$= 126,618 \times 0.023 = 2912.2 \ W/m^2K$

$h_{io} = 2812 \ W/m^2K$

$h_o \Rightarrow$ For N_{Re} from 2000 – 1,00000

$$\frac{h_o D_e}{k} = 0.36 \left(\frac{D_e G_s}{\mu}\right)^{0.55} \left(\frac{C\mu}{k}\right)\left(\frac{\mu}{\mu_w}\right)^{0.14}$$

Linear & mass velocities of the fluid in shell change continuously across the bundle, since width of the shell & the no. of the tubes vary from zero at the top and bottom to maxima at the centre of shell.



Length of flow area = B
baffle spacing

Tube pitch = Clearence + tube dia

c/s area for flow in in shell side
= bundle c/s flow area

$$a_s = \frac{ID \text{ of shell} \times C' B}{P_T}$$

$\dot{m}_s$ = Mass flow rate

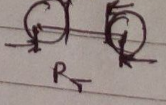
G_s = Mass velocity = $\frac{\dot{m}_s}{a_s}$ kg/s m^2

$G_s = \frac{\dot{m}_s}{a_s}$

$$D_e = \frac{4 \times \text{free area}}{\text{wetted perimeter}}$$

$$D_e = \frac{4\left(P_T^2 - \pi d_o^2/4\right)}{\pi d_o}$$

$P_T = 1.5\, d_o$ & $C' = P_T - d_o$



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B = Baffle spacing

$$h_o = \frac{\cancel{0.096}\ 0.096}{0.043}(62419.61)^{0.55}(5.833)^{1/3}(1)$$

$$h_o = 1742.9\ W/m^2 s$$

$$P_T = 23.75 \times 1.5$$
$$35.625\ mm$$

$$D_e = \frac{4\left(0.035^2 - \left(\frac{\pi \times 0.02375^2}{4}\right)\right)}{\pi \times 0.02375}$$
$$= 0.043\ m$$

$$c' = 35.625 - 23.75$$
$$= 11.875\ mm$$

$$B = 5'' = 5 \times 2.54 \times 10^{-2} = 0.127\ m = 12.7\ cm$$

(Maximum B = 1" ID of shell)

$$\cancel{a_s = \frac{0.644 \times 0.127 \times 11.875 \times 10^{-3}}{35.625 \times 10^{-3} \times 144} = 1.892 \times 10^{-4}\ m^2}$$
$$\cancel{= 272.5 \times 10^{-4}}$$
$$\cancel{= 0.272\ m^2}$$

$$\cancel{G_s = \frac{\dot{m}_s}{a_s} = \frac{1}{\left(\frac{1.892 \times 10^{-4} \times 144}{15.83}\right)} = \left(\frac{1}{1.195 \times 10^{-5}}\right) kg/m^2 s}$$
$$\cancel{580.19 = 83645\ kg/m^2 s}$$

$$\cancel{D_e = 0.043\ m = 0.043\ m}$$

$$\cancel{N_{Re} = \frac{0.043 \times (1/1.195 \times 10^{-5})}{0.4 \times 10^{-3}} = 8988636}$$
$$\cancel{62,448.6}$$

$$a_s = 0.644 \times 0.127 \times 0.011875 / 0.035$$
$$= 0.0272\ m^2$$

$$G_s = \frac{15.83}{0.0272} = 580.19\ kg/m^2 s$$

$$N_{Re_s} = \frac{0.043(580.19)}{0.4 \times 10^{-3}} = 62,419.61$$

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~~Nuzz~~

$$\frac{1}{U_c} = \frac{1}{h_{io}} + \frac{1}{h_o}$$

$$= \frac{1}{2812} + \frac{1}{1742.88}$$

$$= \underline{1075.99} \ W/m^2 K$$

$U_c > U_D$

If U_c is used to find A for same Q

$$A_{new} = \frac{Q}{U_c \, \Delta T_{lm}}$$

A_{new} (36 m²) will be < $A_{used\ for\ design}$ (57 m²)

Means equipment is overdesigned

Design is ok.

Assume 150 Btu/h ft² of Q.

redesign HE

Nozzle Design $\Rightarrow \frac{\pi}{4} d_n^2 = \frac{\dot{m}}{\rho v}$

$v = 4$ m/s

$$d_n = \sqrt{\frac{4}{\pi} \times \frac{\dot{m}}{\rho v}}$$

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Tube side pr drop

$$\cancel{\Delta P = \frac{f\, G_t^2\, L\, N_{pass} \times \text{no. of passes}}{2g\, d_o\, \rho}}\quad n_{(\text{pass no.})}$$

$$\Delta P = \frac{f\, G^2\, (Ln)}{5.22 \times 10^{10}\, D_e\, s\, \phi_i} \qquad \text{psf (Pounds/ft}^2)$$

$Ln \Rightarrow$ Total length of path
$n \Rightarrow$ no. of passes, $L \Rightarrow$ Length of tube

Use

$$= \frac{f\, G^2\, (Ln)}{2g\, \rho\, d_i} = \Delta P_f$$

Entrance loss $= 4\, n\, v^2\, \rho / 2g = \Delta P_e$ (n = No. of passes)

$$\Delta P_{total} = \Delta P_{tube} + \Delta P_e$$

Shell side $\Rightarrow$ $\Delta P_s = \dfrac{f\, G^2\, D_s\, (N+1)}{2g\, D_e\, \rho}$

N = No. of crosses
= Tube length / baffle spacing