Group-S

Grp-S

INDIAN INSTITUTE OF TECHNOLOGY

8.5/10

DATE 8|08|23

SHEET NO. 1

Design of double pipe heat exchanger:

(Hot) Engine oil

$T_{H in}$ = 120°C.

$T_{H out}$ = 65°C x = 5 kg/s, $\Delta P_{allowable}$ = 80 kPa

$T_{H,avg} = \frac{120+65}{2} = 92.5°C$

R_o, fouling resistance = 0.00018 m2K/W

Physical properties : SAE 15W-40.

Heat capacity of oil, C_o = 1.958 KJ/kg.

viscosity, μ_o = 13.77×10^{-3} Pas

thermal conductivity k_o = 0.145 W/m.K.

density, ρ_o = 0.8336 g/cm3

(Cold) Seawater   Reference: Figshare.

$T_{c,in}$ = 30°C, $T_{c,out}$ = 45°C, $T_{c,avg}$ = 37.5°C

$\Delta P_{,allowable}$ = 65 kPa

R_w = 0.0001 m2K/W

Physical properties,

C_w = ~~4.18~~ ~~4179~~ 4.179 KJ/kg

μ_w = 0.000685 Pa.s.

k_w = 0.63.

ρ_w = 993.18 kg/m3.

Given, thermal conductivity for exchanger material = 52 W/mK

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DOUBLE PIPE HEAT EXCHANGER DATA SHEET

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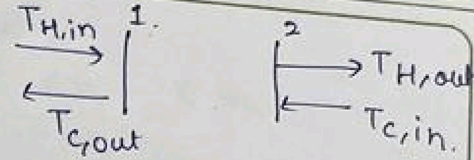
SHEET NO. 2.

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



$$= \cancel{35} \frac{(120-45)-(65-30)}{\ln\left(\frac{75}{35}\right)} = \underline{52.48^\circ C}$$

Let, mass flow rate of seawater be x kg/s.

$$Q_H = Q_C$$

$$5 \times C_o \Delta T_H = x C_w \Delta T_c$$

$$x = \frac{5 \times 55 \times C_o}{4.18 \times 15}$$

$$= \underline{8.59} \text{ kg/s}$$

∴ mass flow rate of water is greater than oil, so seawater should be kept inside and oil should be outside. Also cooling water should be inside because cooling water fouls severely. It is easier to clean / replace inner pipe because it can be removed easily, as compared to cleaning the annulus region which has a very small thickness.

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DOUBLE PIPE HEAT EXCHANGER DATA SHEET

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SHEET NO 3

Standard dimensions of the pipe,

$L = $ ~~6 feet = 1.83 m.~~ 6 m.

$D_i = 22.63$ mm.

$D_o = 28.17$ mm.

$D_{i_o} = 52.48$ mm.

For the inner pipe. (seawater is inside).

$$a_i = \frac{\pi D_i^2}{4} = 402.2156 \times 10^{-6} \, m^2$$

$$G_i = x/a_i = 21{,}556.705 \, Kg/m^2 s$$

$$Re_i = \frac{G_i D_i}{\mu_w} = \underline{7.05 \times 10^5}$$

$\therefore$ we observed that the flow is turbulent

$$h_i = \frac{K\,0.027}{D_e} Re^{0.8} \, Pr^{0.33} \left(\frac{\mu}{\mu_w}\right)^{0.14}, \quad Pr = \left(\frac{C_p \mu}{K}\right) = \underline{4.54}$$

ϕ = viscosity correction factor = 1.

$$h_i = 0.751 \times 47{,}703.61 \times (4.54)^{0.33}$$

$$= 0.751 \times 47{,}703.61 \times 1.647$$

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HEAT EXCHANGER DATA SHEET

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SHEET NO 4

$h_i = 5.9 \times 10^4$

For oil in outside region,

$D_e = D_{io} - D_o = 24.31$ mm

$a_o = \frac{\pi (D_{io}^2 - D_o^2)}{4} = 1539.8 \times 10^{-6} m^2$

$G_o = 5/a_o = 3,247.17$

$Re_o = \frac{G_o D_e}{\mu_o} = 5,782.658$

∴ We can observe that the flow is ~~turbulent~~ transition.

Assuming $\phi_o = 1$

$h_o = \frac{K}{D_e} 0.116 \left[(Re)^{2/3} - 125 \right] (Pr)^{0.33} \left[1 + (D_i/L)^{2/3} \right]$

$= 0.6918 \times [195.31] \underbrace{(185.94)^{0.33}}_{5.707} [1.024]$

$= \cancel{811.9724}$ 753.031

Now, the wall temperature, T_w,

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EXCHANGER DATA SHEET

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SHEET NO. 5

$$T_w = \frac{h_i T_{i,avg} + h_o (D_o/D_i) T_{o,avg}}{h_i + h_o (D_o/D_i)}$$

$$= \frac{5.9 \times 10^4 \times 310.5 + 753.03 (1.245)(365.5)}{5.9 \times 10^4 + 753.03 (1.245)}$$

$= \cancel{38.4264}$ 310.364 K = 37.36 °C

→ for oil.

μ_w at T_w = 108.583×10^{-3}

viscosity at wall temp. T_w

$$\phi_i = (\mu/\mu_w)^{0.14} = 2.0134.$$

h_i (actual) = $h_i \phi_i$ = 1.186×10^5

→ for seawater.

$$\left(\frac{\mu}{\mu_w}\right)^{0.14} \approx 1.$$

$$\frac{1}{U_o} = \frac{1}{h_o} + \frac{D_o}{h_i D_i} + \frac{D_o \ln(D_o/D_i)}{2K} + 0.00018 \times \frac{D_o}{D_i} + 0.0001$$

U_o = ~~0.0012~~. ~~403.19~~ 657.82

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So,

$$Q = U_0 A_0 \, LMTD$$

$$5 C_H \Delta T_H = U_0 \pi D_0 l \times 52.48$$

$$l = \frac{5 C_H \Delta T_H}{U_0 \pi D_0 \times 52.48}$$

$$= 154.23 \text{ m}$$

$\therefore$ No. of hair pins $= \frac{l}{12} = \frac{12.85}{\cancel{25.7}} \approx 13.$ ~~26~~ hairpins

for the inner pipe,

$$\Delta P_i = H_{fi} \times \rho_i g.$$

friction factor, $f_i = 0.0043$.

$$H_{fi} = \frac{4 f_i G_i^2 L}{2 \times g \times \rho_w^2 \times \phi_i} \approx 2.429 \text{ m}$$

$$\Delta P_i = \rho_w g H_{fi}$$

$$= 23.665 \text{ KPa}.$$

for the outer pipe,

$$f_o = .$$

$$= 0.0099.$$

$$H_{fo} = \frac{4 f_o G_o^2 L}{2 \times g \rho_o^2 \phi_o} = \underline{\underline{0.91\ m}}$$

oil velocity, $v_o = G_o/\rho_o$

$$= 3.89\ m/s.$$

$$H_{fo,\, bend} = \frac{(2N_{Hairpins} - 1)v_o^2}{2g} = (19.28)\, m$$

$$\Delta P_o = (H_{fo} + H_{fo\,bend})\, \rho_o g.$$

$$= (0.91 + 19.28)\, \rho_o g.$$

$$= \underline{\underline{165.106\ kPa}}.$$ $\Delta P_o > 65\, kPa$

Result:

After taking different combinations of inner and outer pipe dimensions.

final dimension choosen are

outer pipe $\rightarrow D_{io} = 154.051\ mm$ (Nominal pipe size = 6)

Inner pipe $\begin{cases} D_o = 88.9\ mm \\ D_{ii} = 77.9272\ mm \end{cases}$ [Nominal pipe size = 3]

No. of Hairpins = 9

$\Delta P_o = 40.84\ kPa$

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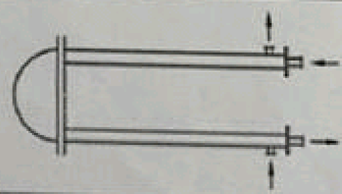
DOUBLE PIPE HEAT EXCHANGER DATA SHEET

UNITS OF MEASUREMENT : (SI)

1	Service Of Unit:					
2	Site: Chemical Engineering Department		No Of Units: 4			
3	Size	Type	Manufacturer Group 5		Item No:	
4	Surface/Unit (Eff.) m²	Arrangement Shell Parallel	Series: Tube		Parallel:	Series Yes
5	PERFORMANCE OF ONE UNIT		Section/Unit		Surface/Section (Eff.) m²	
6	Fluid Allocation		SHELL SIDE		TUBE SIDE	
7	Fluid Name		Engine oil		Seawater	
8	Fluid Quantity, Total	Kg/hr	18000		30,924	
9		Kg/hr				
10	Vapor (In/Out)	Kg/hr				
11	Liquid	Kg/hr	18000	18000	30,294	30,299
12	Steam	Kg/hr				
13	Water	Kg/hr				
14	Non-Condensale (Mw)	Kg/hr				
15	Temperature	°C	120	65	20	45
16	Density (Vapor/Liquid)	Kg/m³	833.16	833.16	998.18	993.18
17	Viscosity (Vapor/Liquid)	cP	0.137	0.137	0.000685	0.000685
18	Molecular Weight	Kg/Kmol				
19	Specific Heat (Vapor/Liquid)	KJ/Kg°C	1.958	1.958	4.179	4.179
20	Thermal Coductivity (Vapor/Liquid)	W/m°C	0.145	0.145	0.63	0.63
21	Surface Tension	Dyn/cm				
22	Boiling Point	°C				
23	Latent Heat	KJ/Kg				
24	Inlet Pressure	barg				
25	Velocity	m/s	3.89			
26	Pressure Drop, Allowable/Calculated	bar				
27	Fouling Resistance (Min.)	m² °C/W	0.00018		0.0001	
28	Heat Exchanged	MW		MTD (Corrected) (Weighted)		°C
29	Transfer Rate	W/m² °C				

				SHELL SIDE	TUBE SIDE	Sketch
29	CONSTRUCTION OF ONE SHELL					
30						
31	Design Pressure		barg			
32	Design Temperature Max/Min		°C	120/65	45/30	
33	Corrosion Allowance		mm			
34	Insulation THK. In/Out		mm			
35	Connections	In				
36	Size &	Out				
37	Rating					



38	Tube No. O.D. (mm); Thk. mm (Ave/Min)	Length mm;	Pitch mm;	Flow Angle	Deg
39	Tube Type	Material			
40	Fins: No. Height mm; Thk. mm	Type		Material	
41	Shell O.D. mm; Thk. mm	Material			
42	Tube Sheet - Stationary	Impingement Protection			
43	Baffles-Cross Type %Cut	Spacing:c/c	mm;	Inlet	mm
44	Shell Return Bend - Housing Material	Cover Material			
45	Tube Side Closure - Type			Material	
46	External Return Bend: OD mm; Thk. mm;			Material	
47	Gasket - Shell Side	Tube Side			
48	Code Requirements	Stamp NO			
49	Double Pipe Type? Yes	Multi Tube Type?			
50	Remarks:				
51					
52					
53					

Rev.	Date	Description	App.1	App.2	App.3