Department of petroleum Engineering

UNIT V: CH 8591 HEAT TRANSFER

② water enters a counter flow double pipe heat exchanger at 15°C, flowing at the rate of 1300 kg/hr. It is heated by oil [$C_p = 2000$ J/kg.k] flowing at the rate of 550 kg/hr from an inlet T of 94°C. for an area of $1 m^2$ and $U = 1075$ $W/m^2 k$. find the heat transfer rate and outlet temp of water & oil.

Given Data: Sp. heat of oil = 2000 J/kg.K

Sp. heat of water = 4187 J/kg.k

Overall HT coeff = 1075 $W/m^2 K$

$T_w = 15°C = 288$ K

$T_{oil} = 94°C = 367$ K

Solution:

The heat capacity rates are

Water :
$$\dot{m}_c C_{pc} = \frac{1300}{3600} \times 4187 = 1511.97 \text{ W/K}$$

Oil :
$$\dot{m}_h C_{ph} = \frac{550}{3600} \times 2000 = 305.55 \text{ W/K}$$

The heat capacity rate of hot fluid (oil) is smaller than that of H_2O.

Given $U = 1075$ $W/m^2 K$ $A = 1 m^2$

$$NTU = \frac{UA}{(\dot{m} c_p)_{small}} = \frac{UA}{\dot{m}_h C_{ph}} = \frac{1075 \times 1}{305.55}$$

$$\boxed{NTU = 3.52}$$

①

$$C = \frac{\dot{m}_h C_{ph}}{\dot{m}_c C_{pc}} = \frac{305.55}{1511.97} = 0.20$$

for counter current flow.

The effectiveness of the HE is given by

$$\varepsilon = \frac{1 - e^{-NTU\,(1-c)}}{1 - c \cdot e^{-NTU\,(1-c)}}$$

$$\varepsilon = \frac{1 - e^{-3.52\,(1-0.2)}}{1 - 0.2 \times e^{-3.52\,(1-0.02)}}$$

$$\boxed{\varepsilon = 0.9515}$$

For $m_h\, C_{ph}$ small, the effectiveness is given by

$$\varepsilon = \frac{T_1 - T_2}{T_1 - t_1}$$

$$0.9515 = \frac{367 - T_2}{367 - 288}$$

$$= 291.83\ k$$

outlet Temp of oil $\boxed{T_2 = 18.83^\circ C}$

The heat balance over the exchanger is given by

$$Q = \dot{m} C_{pc} (t_2 - t_1) = \dot{m}_h C_{ph} (T_1 - T_2)$$

$$C = \frac{m_h C_{ph}}{m_c C_{pc}} = \frac{t_2 - t_1}{T_1 - T_2}$$

$$0.20 = \frac{t_2 - 288}{367 - 291.83}$$

$$t_2 = 303.03 \text{ K}$$

outlet temp of H_2O $$\boxed{t_2 = 30.03^{\circ}C}$$

The rate of heat transfer is

$$Q = m_h C_{ph} (T_1 - T_2)$$

$$= \frac{550}{3600} \times 2000 \times [367 - 291.83]$$

$$= 22968. \text{ J/s}$$

$$\boxed{Q = 22968 \text{ W}}$$

3. Differentiate square pitch & triangular pitch.

The shortest centre-to-center distance between the adjacent is called as. Tube pitch.

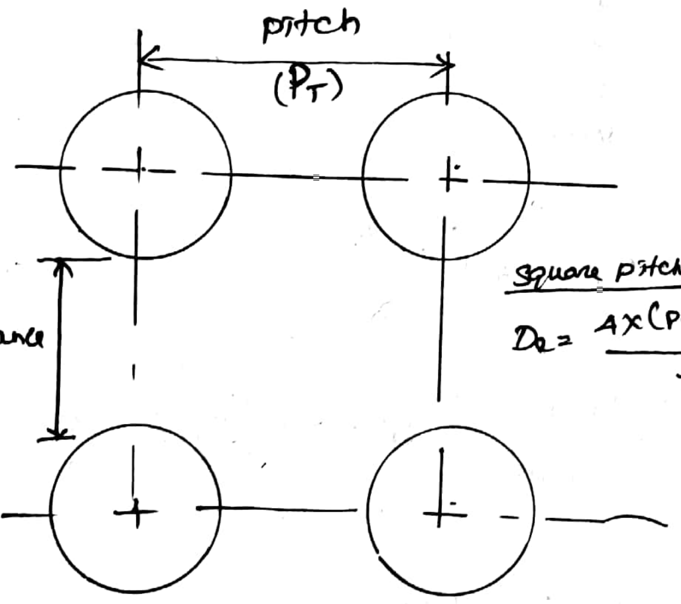
The shortest distance b/w two tube is called as clearance.

The minimum pitch is 1.25 times the outside diameter of tube.

The clearance should not be less than 0.25 time the outside diameter of tube, the minimum clearance being 4.76 mm.

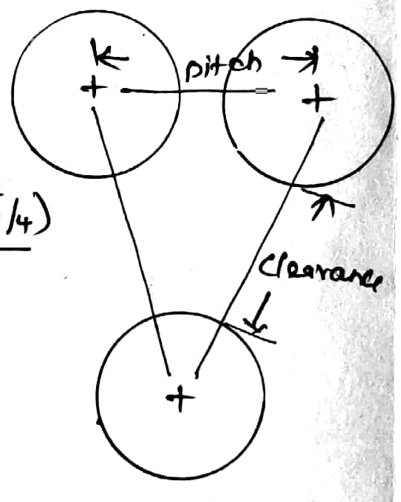
For a triangular pitch

$$D_e = \frac{4\times\left[\frac{1}{2}P_T\times 0.86\,P_T - \frac{1}{2}\pi d_o^2/4\right]}{1/2\times\pi d_o}.$$



Square pitch

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



Square pitch

Triangular pitch

The tubes are commonly laid out either on a square pitch or on an equilateral triangular pitch as shown in Figure.

The advantages of the square pitch is that permits external cleaning of the tubes and causes a low pressure drop on the shell side.

If the fluids are very clean, a triangular pitch is used.

The triangular pitch arrangements incorporates larger number of tubes in a given shell diameter than with square pitch & usually creates large turbulence in the shell side fluid.

3. Differentiate single & multi pass shell & Tube HE.

Single pass	Multipass.
Heat Exchanger is simple in construction	is Complex in construction
flow may parallel or Counter current	The flow is parallel as well as counter current
It is relatively inexpensive	~~Heat~~ It is relatively expensive
HT - coefficient are relatively low	HT coefficients High.

Single pass	Multipass
For a given duty, floor space requirement is large	For a given duty, floor space requirement is low.
Frictional losses are low	very High
HT rate are low	Heat Transfer rates are high
Fluids flow once through HE.	fluid flow ~~flows through~~ no. of times through exchanger depends on passes.

3. Guidelines of directing fluid

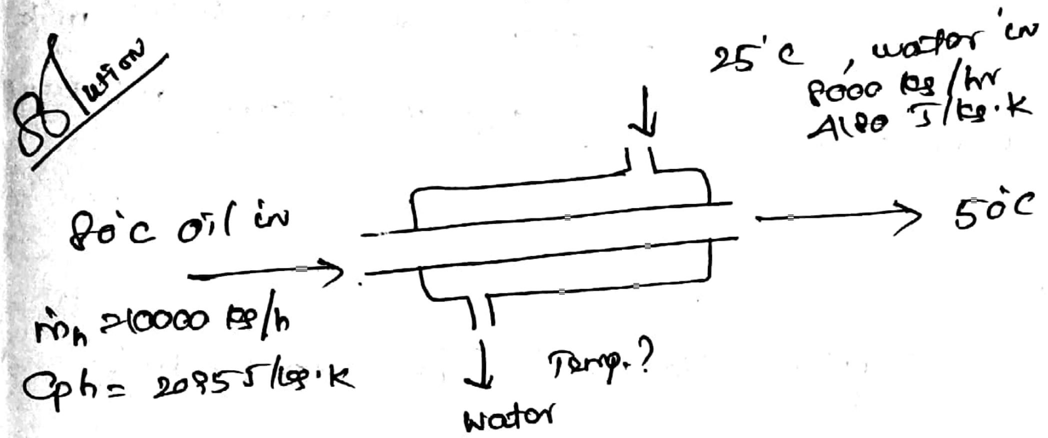
Fluids used for heating and cooling in the process include gases, water and steam, organic mineral oils, organic synthetic oil, inorganic molten salts and molten metals such as Na & K. The types of fluids are

Water (Temp B/w 0-100°C)
Gases (100°C)
Organic fluids (300-400°C)
Diphenyl & diphenyl oxide (400°C)
Silicones as thermic fluid (−40 to 370°C)
Molten salts (>250°C)

④ In a double pipe heat Exchanger, 10,000 kg/hr of an oil having specific heat of 2095 J/kg·K is cooled from 80°C to 50°C by 8000 kg/hr of water entering at 25°C. Find the heat transfer area for which U = 300 W/m²K. Compare the performance of cocurrent & counter current double pipe HE.

Take cp of H_2O = 4180 J/kg·K

Solution



The outlet temp of cold fluid (H_2O) is not given

WKT,

$$Q = \dot{m}_h C_h (T_{hi} - T_{ho}) = \dot{m}_c C_h (T_{co} - T_{ci})$$

$$(10000)(2095)(80-50) = (8000)(4180)(T_{co} - 25)$$

$$\boxed{T_{co} = 43.8^\circ C}$$

Heat transfer rate $Q = m \cdot c_p \cdot \Delta T$

$$= (10000)(2095)(80-50)$$

$$= \frac{10000}{3600} \times (2095) \times (30)$$

$$\boxed{Q = 174.58 \text{ kW}}$$

WKT

$$Q = UA\Delta T$$

For counter current. $\boxed{A = 19.20 \text{ m}^2}$

$\boxed{A = 26.03 \text{ m}^2}$ For cocurrent

① A Shell and tube heat exchanger is to be provided with tubes of 31mm OD 27mm ID 4m long. It is required for heating from 295k (22°c) to 318k (45°c) with the help of condensing steam at 393 k (120°c) on the outside of the tubes. Determine the no of tubes required if water flow rate is 10 kg/s. The heat transfer coeff on the steam side & water side are 6000 W/m²k & 850 W/m²k respectively. Neglect all other resistance.

Solution:

water flow rate $= \dot{m}_w = 10$ kg/s.

Q:

$$Q = \dot{m}_w C_{pw} (T_2 - T_1)$$

$$= 10 \times 4.187 \times (318 - 295)$$

$$= 963 \text{ KJ/s.} \Rightarrow 963 \times 10^3 \text{ J/s}$$

$$\Rightarrow 963 \times 10^3 \text{ W}$$

$$393 \text{ K} \xrightarrow{\text{steam}} 393 \text{ K}$$

$$295 \text{ K} \xrightarrow{\text{water}} 318 \text{ K}$$

$$\Delta T_1 = 393 - 295 = 98 \text{ K}$$

$$\Delta T_{lm} = \frac{\Delta T_1 - \Delta T_2}{\ln(\Delta T_1/\Delta T_2)} = \frac{98 - 75}{\ln(98/75)}$$

$$= 86 \text{ K}$$

$$\boxed{h_i = 850 \text{ W/m}^2\text{K}}$$

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⑤ A shell and tube HE with one shell and pass and two tube passed is used to cool oil from 120°c (t_1°c) to 50°c [t_2°c] which flows through tubes. Cooling water flows through shell side and enters at 20°c [T_1] and leaves at 40°c [T_2] correction factor [F] is obtained using $R = \frac{[T_1 - T_2]}{t_2 - t_1}$, $P = \left[\frac{t_2 - t_1}{T_1 - t_1}\right]$ and reading the corresponding F value, If U = 400 W/m²K and heat load is 300 kW. Calculate area required for heat exchange using the appropriate data of the table.

R	4.0	1.5	0.286
P	0.2	0.4	0.7
F	0.85	0.82	0.8

Given

$T_1 = 20°C$ $\qquad t_1 = 120°C$

$T_2 = 40°C$ $\qquad t_2 = 50°C$

$U = 400 \ W/m^2 K$

$Q = 300 \ kW = 300 \times 10^3 \ W$

To Find: $A = ?$

$$R = \frac{T_1 - T_2}{t_2 - t_1} = 0.286$$

$$P = \frac{t_2 - t_1}{T_1 - t_1} = 0.7$$

From table,

$$F = 0.8$$

$$\Delta T_{LMTD} = \frac{\Delta T_1 - \Delta T_2}{\ln(\Delta T_1/\Delta T_2)}$$

$$\Delta T_1 = t_1 - T_2 = 120 - 40 = 80$$

$$\Delta T_2 = t_2 - T_1 = 50 - 20 = 30$$

$$\Delta T_{LM} = \frac{80 - 30}{\ln(80/30)}$$

$$= 50.97 \times F$$

$$= 50.97 \times 0.8$$

$$\boxed{\Delta T_{LM} = 40.78}$$

$$A = \frac{Q}{U(\Delta T)_{LMTD}}$$

$$= \frac{300 \times 10^3}{400 \times 40.78}$$

$$\boxed{A = 18.39\ m^2}$$

⑤ A counter flow concentric tube HE is used to cool engine oil ($C_p = 2130$ J/kg·K) from 160°C to 60°C with water, available at 25°C as the cooling medium. The flow rate of cooling water through the inner tube of 0.5 m dia is 2 kg/s while the flow rate of oil through the outer annulus OD = 0.7 m is also 2 kg/s.

If the value of the overall heat transfer coeff is 250 W/m²K, how long must the heat exchanger be to meets the cooling requirement?

Sol

$$Q = \dot{m} c_h (T_{hi} - T_{ho})$$

$$= 2 \times 2130 \times (160 - 60)$$

$$\boxed{Q = 426000 \text{ W}}$$

$$Q = \dot{m}_c C_c (T_{co} - T_{ci})$$

$$T_{co} = \frac{Q}{\dot{m}_c C_c} + T_{ci}$$

$$= \frac{426000}{2 \times 4186} + 25$$

$$\boxed{T_{co} = 75.88^\circ C}$$

$U_o = ?$

$$h_{io} = h_i \times \frac{ID}{OD}$$

$$= 850 \times \frac{0.027}{0.031}$$

$$= 740.3 \ W/m^2K$$

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

$$= \frac{1}{6000} + \frac{1}{740.3}$$

$$\boxed{U_o = 659 \ W/m^2.K}$$

To find A in

$$Q = U_o A_o \Delta T_{lm}.$$

$$A_o = n \pi d_o L$$

$$A_o = 963 \times 10^3 / 659 \times 86$$

$$\boxed{A_o = 17 m^2}$$

$$n = 17 (\pi \times 0.031 \times 4)$$

$$\boxed{n = 43.64}$$

$Q = UA \, \Delta T_{lm}$

$$\Delta T_{Lm} = \frac{\Delta T_1 - \Delta T_2}{\ln(\Delta T_1 / \Delta T_2)}$$

$$= \frac{84.12 - 35}{\ln\left(\frac{84.12}{35}\right)} = 56.01°C$$

$\Delta T_1 = T_{hi} - T_{co} = 160 - 75.88 \Rightarrow 84.12$

$\Delta T_2 = T_{ho} - T_{ci} = 60 - 25 \Rightarrow 35$

Length of HE:

$Q = U(\pi D_i L) \, \Delta T_{LM}$

$A = \pi D_i L$
$= 2\pi r_i L$

$$\therefore L = \frac{Q}{U \pi D_i \Delta T_{lm}}$$

$$= \frac{426000}{250 \times \pi \times 0.5 \times 56.01}$$

$$\boxed{L = 19.37 \text{ m}}$$