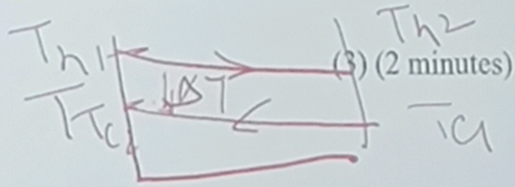
Time: 40 minutes $m_c C_{pc}$ **Full Marks: 45**

Multiple-choice questions may have more than one correct answer

1. The assumptions of LMTD concept are – (3) (2 minutes)



(a) Constant specific heat of both fluids

(b) Constant pressure drop of both fluids

(c) Constant overall heat transfer coefficient

$\frac{d\Delta T}{\Delta T}$

(d) No heat loss to the surroundings.
Answer: (a), (c), (d)

2. Identify the conditions for which LMTD will not be affected by the flow direction of the two streams. (3) (2 minutes)

Answer: (a), (c), (d)

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(3) (~~2 minutes~~)

a) Toluene at 70⁰C is cooled to 55⁰C using water at 30⁰C where the maximum permissible rise in temperature for the cooling water is 15⁰C

b) Toluene liquid at 80⁰C is vaporised by saturated steam at 100⁰C

c) Toluene at 30⁰C is heated to 70⁰C using saturated steam at 100⁰C

d) Water at 30⁰C is heated to 70⁰C using saturated steam at 100⁰C

Answer: b), c), d)

3. In a concentric pipe hear exchanger, fins - (3) (

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(3) (2 minutes)

a) increase heat transfer coefficient of the outer fluid
b) increase heat transfer coefficient of the inner fluid
c) ~~c)~~ increase pressure drop in the annulus.
d) increase pressure drop in the inner pipe.

U max $\frac{1}{h_1 A_1} \sim$

$Q = U A_1 LMTD$

Ans- a),c)

4. When and why are fins adopted?

(1+3) (4 minutes)

When h1<<h2 to ensure h1A1≈h2A2. This ensures maximum U and minimum A.

5. While heating kerosene using flue gas, identify the most suitable configuration and flow arrangement of the double pipe heat exchanger. (**Justify your answer**)(3)(2 minutes)

a) Gas on the annular side with fins on the inner side of the inner tube

b) Gas on the annular side with fins on the outer side of the inner tube

c) Gas on the annular side with fins on the inner side of the outer tube

d) Gas on the inner side with the fins on the inner side of the inner tube

Answer: b
h (gas) << h (kerosene).
So hA gas needs to be increased because U max for hiAi close to hoAo
Accordingly A for gas side should be higher.
Since it is easier and practical to install fins on outer side of inner tub

d) Gas on the inner side with the fins on the inner side of the inner tube

Answer: b

h (gas) << h (kerosene).

So hA gas needs to be increased because U max for hiAi close to hoAo

Accordingly A for gas side should be higher.

Since it is easier and practical to install fins on outer side of inner tube, Gas flows on annular side with fins on outer side of inner tube

6. In a double pipe hairpin exchanger, where the inner pipes are connected in series, the bend pressure loss is usually negligible for the inner pipe but may be significant for the annuli. Why

(3) 2 mins

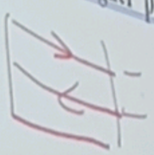
Annuli connected by a pair of 90^0 elbows which offer much higher pressur compared to smooth return bends of the inner pipe.

pressure loss is usually negligible for the inner pipe but may be significant for the annuli. Why?

(2) 2 mins

Annuli connected by a pair of 90^0 elbows which offer much higher pressure drop compared to smooth return bends of the inner pipe.

Cocurrent



7. In a double pipe heat exchanger, hot water at 50000 kg/h is cooled from 95°C to 80°C using cooling water @ 50000 kg/h available at 30°C. The exchanger is wrongly designed for cocurrent flow. Estimate (i) the heat transfer area calculated in design and (ii) the % extra area provided due to the wrong design. Specific heat capacity for both streams =4.2kJ/kg. K and the overall heat transfer coefficient may be assumed as 2270 W/m^{2}K (5) (5 mins)

(i) 7.95m^2

(ii) Countercurrent area =7.71m^2, % extra area = 3.1%

8. A countercurrent double pipe heat exchanger, with an inner tube of inner diameter 40 mm and outer tube of inner diameter 60 mm. is used to cool dilute brine [properties almost similar to

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(i) 7.95m^2

(ii) Countercurrent area =7.71m^2, % extra area = 3.1%

8. A countercurrent double pipe heat exchanger, with an inner tube of inner diameter 40 mm and outer tube of inner diameter 60 mm. is used to cool dilute brine [properties almost similar to water, i.e. viscosity = 6.89×10^{-4} Pa-s, density = 1000 kg/m^3, specific heat = 4.2kJ/kg(^{0}C)] from 85^{0}C to 50^{0}C using cooling water at 30^{0}C which exits at 45^{0}C. The mass flow rates of the brine and water are 200 kg/s and 460 kg/s respectively. Assuming (i) negligible wall thickness of both inner and outer pipe (ii) the fouling factor of water and brine are similar, discuss the placement of the two fluids and estimate the Reynolds number of the inner fluid.

(3+2) (5 mins)

Inner fluid – brine since lower flow rate through smaller cross-sectional area from

6. A countercurrent double pipe heat exchanger, with an inner tube of inner diameter 40 mm and outer tube of inner diameter 60 mm. is used to cool dilute brine [properties almost similar to water, i.e. viscosity = 6.89×10^{-4} Pa-s, density = 1000 kg/m^3, specific heat = 4.2kJ/kg(^{0}C)] from 85^{0}C to 50^{0}C using cooling water at 30^{0}C which exits at 45^{0}C. The mass flow rates of the brine and water are 200 kg/s and 460 kg/s respectively. Assuming (i) negligible wall thickness of both inner and outer pipe (ii) the fouling factor of water and brine are similar, discuss the placement of the two fluids and estimate the Reynolds number of the inner fluid.

(3+2) (5 mins)

Inner fluid – brine since lower flow rate through smaller cross-sectional area from pressure drop considerations. Rei = 11611

Outer fluid – water

3- for selecting inner fluid and 2 for calculating Rei

Rei

$Re_o = \dfrac{D_{eq} G}{\mu}$

$D_{eq} = D_2 - D_1$

9. For the same exchanger specified in Q8, estimate the number of hair pins required assuming Prandtl number of water and brine to be 4.254 and 3.3 respectively and thermal conductivity of the two liquids to be 0.65W/m(K) and 0.7 W/m(K) respectively. Tubes of 12 m length are available for fabricating the heat exchanger.

(15) (15 mins)

Calculate Rei (done), Reo (2), Nui, Nuo (2+2), hi, <u>ho</u> (1+1); U (2), LMTD (1), <u>A</u>(2) N(2)

Reo = 13352.68

Nui= 71.796, hi= 1256.43 W/m^2 K

$D_2 - D_1$ μ

V h_i h_o

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Calculate Rei (done), Reo (2), Nui, Nuo (2+2), hi, ho (1+1); U (2), LMTD (1), A(2) N(2)

$Q = UA\,LMTD$

Reo = 13352.68

Nui= 71.796, hi= 1256.43 W/m² K

Nuo= 87.3, ho= 2839.85 W/m² K

U = 871 W/m² K

LMTD = 28.85 ⁰C

A = 1170 m²

N= 388