NANYANG TECHNOLOGICAL UNIVERSITY

SCHOOL OF MECHANICAL AND AEROSPACE ENGINEERING

E3.5/E3.1AE HEAT EXCHANGER

HEAT TRANSFER LAB

VENUE: N3-B2A-01

NAME OF STUDENT: _Eugene Low________________ LAB SUB-GROUP:_____TM01____

MATRIC NO:_____________U1922005K________________ DATE: _____25/03/21_______

NAME OF SUPERVISOR: _________Asst Prof Hou Han Wei_______________________________

GRADE: ____________________________

NOTE: THIS TITLE PAGE SHOULD BE ATTACHED TO ALL REQUIRED MATERIAL FOR THIS EXPERIMENT BEFORE SUBMISSION.

Table 1 Parallel flow and Counter flow

Test	Parallel flow	Counter flow
Metal wall at inlet, T_1 (°C)	55.8	62.7
Metal wall at exit, T_2 (°C)	55.8	47
Hot stream at inlet, T_3 (°C)	66	66.2
Hot stream 1st intermediate, T_4 (°C)	62.1	63.7
Hot stream 2nd intermediate, T_5 (°C)	59.6	61.1
Hot stream at exit, T_6 (°C)	58	57.3
Cold stream entry/exit, T_7 (°C)	31.3	51.2
Cold stream intermediate, T_8 (°C)	40.8	45.3
Cold stream intermediate, T_9 (°C)	46.4	39.1
Cold stream entry/exit, T_{10} (°C)	50	31.2
Hot water flow rate, $\dot{m}_h$ (kg/s)	0.05	0.05
Cooling water flow rate, $\dot{m}_c$ (kg/s)	0.02	0.02
Heat transfer rate from hot water, $\dot{Q}_h$ (W)	1672	1860.1
Heat transfer rate to cold water, $\dot{Q}_c$ (W)	1563.32	1672

Table 2 Effect of fluid velocity on the convective heat transfer coefficients (Counter flow)

Test	1 (100%)	2 (80%)	3 (60%)	4 (40%)	5 (20%)
Metal wall at inlet, T_1 (°C)	65.7	65.4	65.6	66.1	67
Metal wall at exit, T_2 (°C)	56.6	55.5	54.5	52.7	48.3
Hot stream at inlet, T_3 (°C)	66.6	66.6	67.3	68.4	71.4
Hot stream 1st intermediate, T_4 (°C)	66.1	66	66.4	67.1	68.5
Hot stream 2nd intermediate, T_5 (°C)	65.4	65	65.2	65.3	64.8
Hot stream at exit, T_6 (°C)	64	63.4	63.1	62.5	60.1
Cold stream entry/exit, T_7 (°C)	58.5	57.9	57.6	57	54.7
Cold stream intermediate, T_8 (°C)	52.7	52	51.5	50.6	47.8
Cold stream intermediate, T_9 (°C)	42	41.5	41.1	40.4	38.5
Cold stream entry/exit, T_{10} (°C)	29	29	29	29	29
Hot water flow rate, $\dot{m}_h$ (kg/s)	0.167	0.1333	0.1	0.0667	0.0333
Cooling water flow rate, $\dot{m}_c$ (kg/s)	0.016	0.016	0.016	0.016	0.016
Overall heat transfer coefficient, U (W/m^2 K)	3428.5	3311.7	3140.8	2785.9	2358.3
Average convective heat transfer coefficient inside the inner tube, h_h (W/m^2 K)	22539	19215	15804	12180	8033.8
Average convective heat transfer coefficient in the annulus between the tubes, h_c (W/m^2 K)	4192.2	4142.1	4087.3	3960.4	3568.4

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School of Mechanical and Aerospace Engineering

EXPERIMENT: E3.5/E3.1AE - HEAT EXCHANGER

LOG SHEET

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Lab Sub-Group: TM01; Degree Programme: MAE

Date: 25/03/21 Time: am / ~~pm~~ *

Submitted to: Prof/~~Mr/Ms~~ * Hou Han Wei

6.1 Parallel and counter flow

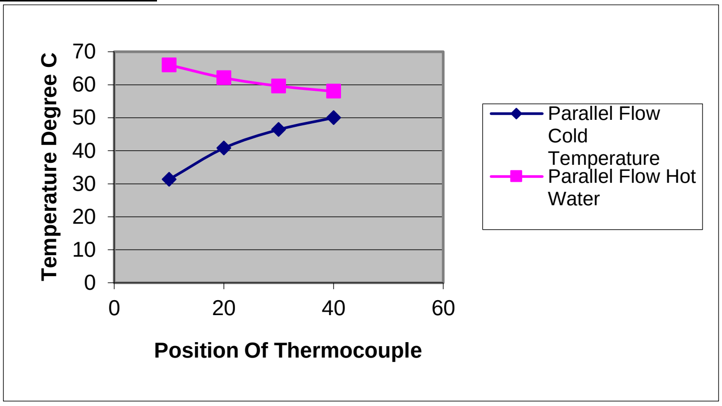

Fig 1: Temperature of metal wall for parallel flow

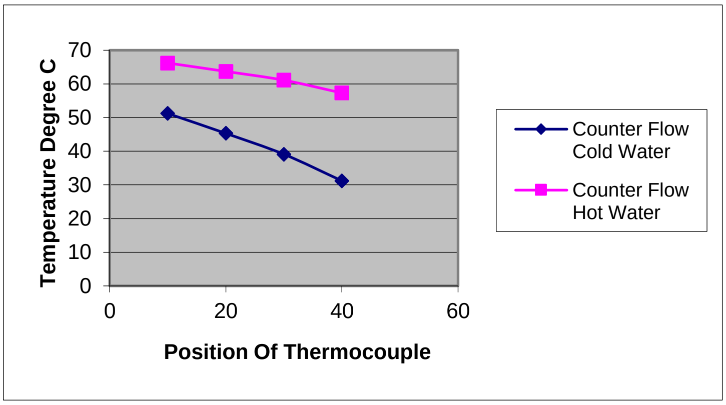

Fig 2: Temperature of metal wall for counter flow

From fig 1 and fig 2, we can determine that the rate of heat transfer for the counter flow is more efficient than parallel flow. For counter flow, Q_h and Q_c are higher, and the temperature difference are more uniform compared to parallel flow. This also minimises thermal stresses in the pipe.

The discrepancies of the rate of heat transferred could be due to:

1. Heat lost to surroundings by radiation due to poor insulation of the experimental set-up.
2. Experimental issue such as insufficient time for the time reading to stabilise. The fluctuation of readings may require the result to be approximated, hence causing it to be inaccurate.
3. Filing effect as the experimental set-up was used for long period of time. This filing effect will act as thermal resistor, therefore causing result to be inaccurate.

6.2 Effect of fluid velocity on the convective heat transfer coefficients and the overall heat transfer coefficient

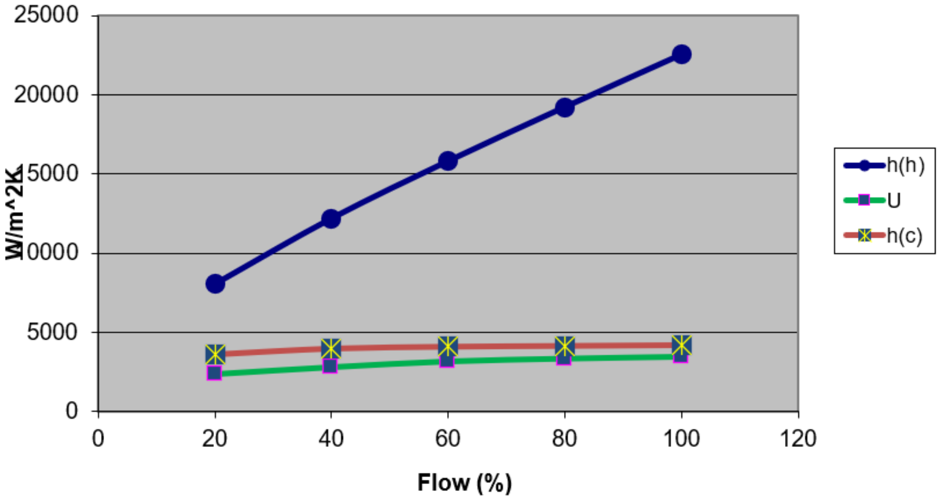

Fig 3: Varying velocity against heat transfer coefficients

As flow rate increases, all the values of heat transfer coefficients increase. However from the graph, we can see that the hot water coefficient h_h increases much more significantly as only the flow rate of the hot water is increased.

As velocity increase, the flow of fluid changes from laminar to turbulent flow. As flow changes to turbulent, secondary flow such as eddie flow will be generated, causing the fluid particles to flow in random directions. This will allow the fluid to have an additional way to lose heat via convection internally more effectively. Hence, causing the heat transfer coefficient for h_h to increase much drastically.

6.3 Sample calculations

$$\dot{Q}_h = \dot{m}_h c_p (T_3 - T_6)$$
$$= 50(4.18)(66-58)$$
$$= 1672 \text{ W}$$

$$\dot{Q}_c = \dot{m}_c c_p (T_{10} - T_7)$$
$$= 20(4.18)(50-31.3)$$

$= 1563.32$ W

<u>For velocity at 60%:</u>

$$U = \frac{\dot{Q}_h}{\frac{(T_3\text{-}T_7)\text{-}(T_6\text{-}T_{10})}{\ln\frac{T_3\text{-}T_7}{T_6\text{-}T_{10}}} A_m} \quad , \qquad A_m = 0.0288\ m^2$$

= (100)(4.18)(67.3-63.1)/[{[(67.3-57.6)-(63.1-29)]/ln[(67.3-57.6)/(63.1-29)]}(0.0288)]
= 3140.7819
= 3140.8

$$h_h = \frac{\dot{Q}_h}{\frac{(T_3\text{-}T_1)\text{-}(T_6\text{-}T_2)}{\ln\frac{T_3\text{-}T_1}{T_6\text{-}T_2}} A_h} \quad , \qquad A_h = 0.0261m^2$$

= 1755.6/[{[(67.3-65.6)-(63.1-54.5)]/ln[(67.3-65.6)/(63.1-54.5)]}(0.0261)]
= 15803.55803
= 15804

$$h_c = \frac{\dot{Q}_c}{\frac{(T_1\text{-}T_7)\text{-}(T_2\text{-}T_{10})}{\ln\frac{T_1\text{-}T_7}{T_2\text{-}T_{10}}} A_c} \quad , \qquad A_c = 0.031m^2$$

= 16(4.18)(57.6-29)/[{[(65.6-57.6)-(54.5-29)]/ln[(65.6-57.6)/(54.5-29)]}(0.031)]
= 4087.283441
= 4087.3

6.4 <u>Observations</u>

As we did not conduct the experiment itself, we cannot observe any possible experimental uncertainties associated with the measuring instrument or sensor. However, we know that when measuring the rate of heat transfer, some amount of time is required for the readings to stabilise. This could be one possible experimental uncertainty associated with the sensor. Other possible discrepancies have been explained in 6.1 and 6.2 respectively.

6.5 <u>Bonus question</u>

Why do you think the heat transfer coefficient U does not increase as much as the heat transfer coefficient h_h?

$$U = \frac{1}{\frac{1}{h_h} + \frac{\Delta x}{kA} + \frac{1}{h_c}}$$

Similar to the reason why convection is the main source of heat transfer. As U is related with h_h, when value of h_h increases, $\frac{1}{h_h}$ will become smaller and smaller. As the value becomes smaller, it can be approximate to be 0 and hence negligible for the calculation of U.