HEAT EXCHANGER

CHE391 Innovation Lab: Group T06

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OBJECTIVE OF THE EXPERIMENT

- The objective of the experiment is to maintain a constant temperature (already specified) for a reactor, for a given feed at a given temperature. This is to be achieved by heating one of the inlet streams.

- The motive is to analyze the effectiveness of the heat exchanger by calculating the number of transfer units (NTU), and suggest methods to optimize the performance of the heat exchanger.

BRIEF OVERVIEW

In a chemical reactor that is being operated at a constant temperature, the temperature of the reactor is maintained at a fixed value throughout the reaction. This is often done to control the rate of the reaction, improve the yield of the desired product, and minimize unwanted side reactions.

One way to maintain a constant temperature in a reactor is to heat one of the (inlet) streams being fed into the reactor. This can be done by passing the stream through a heat exchanger before it enters the reactor. By heating one of the streams being fed into the reactor, it is possible to achieve and maintain a desired temperature throughout the reaction.

SCHEMATIC

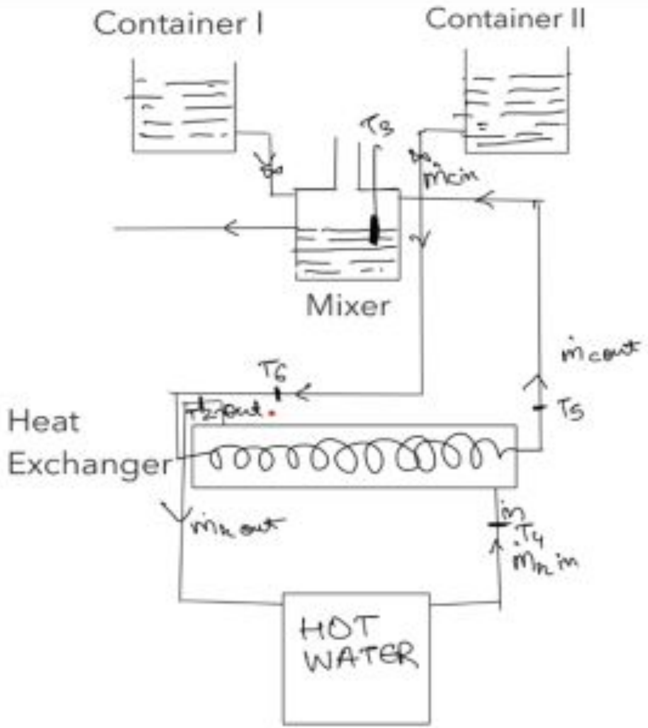


Fig: Line Diagram for setup

APPARATUS AND SETUP

The set-up consists of the heat exchanger apparatus and includes two heaters. For our innovation lab, the use of a single heater was sufficient.

The apparatus also had two glass containers that were regularly filled with water, and coloring agents ($KMnO_4$ and blue ink) were added to differentiate between the two of them. A large quantity of distilled water was also required for the experiment.

ESSENTIAL FORMULAE

Heat transferred from the hot fluid and delivered to the cold fluid:

$$\dot{Q}_c = \dot{m}_c * c_{pc} * (T_{c,out} - T_{c,in})$$

$$\dot{Q}_h = \dot{m}_h * c_{ph} * (T_{h,in} - T_{h,out})$$

Average heat transfer can be written as:

$$\dot{Q}_{avg} = UA_s \Delta T_m$$

$$\dot{Q}_{avg} = (\dot{Q}_c + \dot{Q}_h)/2$$

The temperature difference at the ends of the heat exchanger is:

$$\Delta T_1 = T_{h,in} - T_{c,out}$$

$$\Delta T_2 = T_{h,out} - T_{c,in}$$

Log mean temperature for the heat exchanger is:

$$\Delta T_m = (\Delta T_1 - \Delta T_2)/\log(\Delta T_1/\Delta T_2)$$

Number of Transfer Units are:

$$\mathbf{NTU = UA_s/(\dot{m}_c * c_{pc})}$$

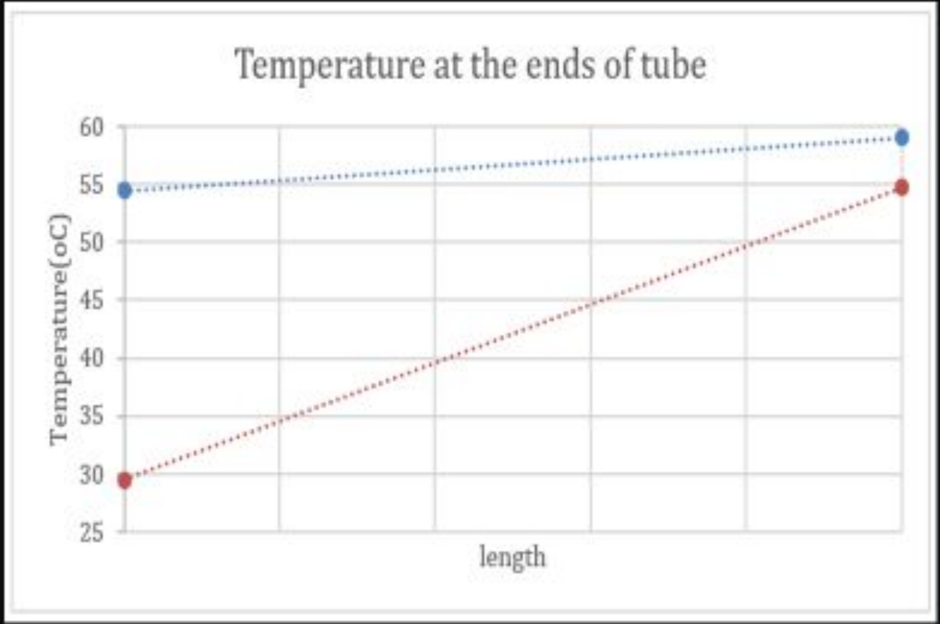
OBSERVATIONS AND RESULTS

ṁh(g/s)	12
ṁc(g/s)	1.8
Cp(J/K-g)	4.18

	Container 1		Hot Water		Reactor Temp										
	inlet	outlet	inlet	outlet	inside										
Time(min)	T6(°C)	T5(°C)	T4(°C)	T2(°C)	T3 (°C)	ΔT1(°C)	ΔT2(°C)	ΔTm(°C)	Qc(W)	Qh(W)	Qavg(W)	UA(W/K)	Tmax(°C)	Qmax(°C)	NTU
0	29.6	29.6	29.6	29.6	29.6	0	0	--	0.0	0.0	0.0	--	0	0.0	--
30	29.7	55.0	59.4	57.1	44.9	4.4	27.4	29.0	190.4	115.4	152.9	5.28	29.7	223.5	0.70
60	29.4	55.7	59.2	55.6	39.25	3.5	26.2	26.0	197.9	180.6	189.2	7.29	29.8	224.2	0.97
70	29.6	55.8	59.2	55.3	38.2	3.4	25.7	25.4	197.1	195.6	196.4	7.74	29.6	222.7	1.03
80	29.5	55.2	58.8	55.3	38.8	3.6	25.8	26.0	193.4	175.6	184.5	7.11	29.3	220.5	0.94
90	29.5	54.7	59.0	54.4	37.8	4.3	24.9	27.0	189.6	230.7	210.2	7.78	29.5	222.0	1.03
100	29.7	55.1	59.4	54.4	38.75	4.3	24.7	26.9	191.1	250.8	221.0	8.22	29.7	223.5	1.09

TEMPERATURE AT TUBE ENDS

Tube end	Hot	Cold
1	54.4	29.5
2	59	54.7



METHODS TO OPTIMIZE NTU VALUE

1. The flow rate of the HOT WATER should be increased (or that of the cold water should be decreased.)

2. Choosing a more efficient heat exchanger design can also improve the overall heat transfer rate. The gap between the spirals of the heat exchanger can be increased. Increasing the length and the surface area of the heat exchanger will also be beneficial.

3. Adding a small amount of a suitable additive to the hot water can improve the thermal conductivity of the water, which can increase the heat transfer rate.

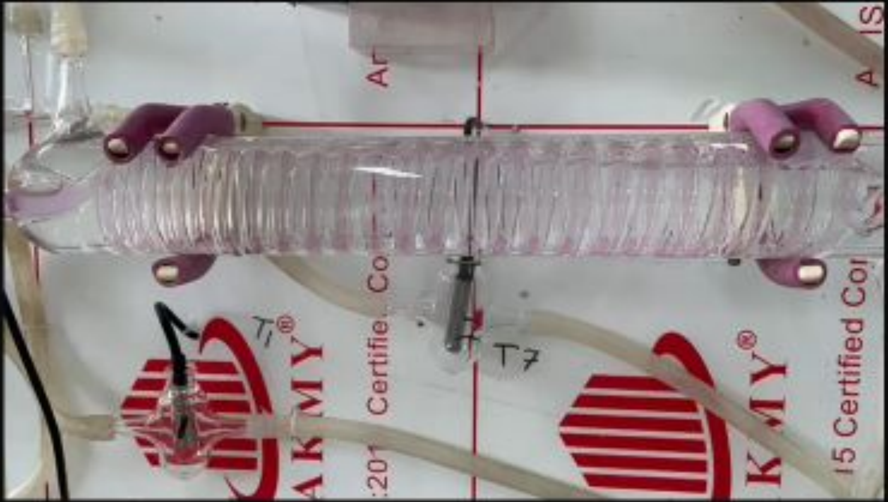
4. The thermal conductivity of the pipe can be improved by using a different material. Additional insulation can be added, so that more heat is transferred to the cold liquid.

CONCLUSION

- NTU for the heat exchanger is 1.0.
- Overall heat transfer coefficient*surface area of the spiral tube is somewhere between 7-8 W/K.
- It takes around 1 hour for the set up to reach a steady state. This is because the hold-up volume in the reactor heats up slowly.

ERRORS

- Air entrapment in the pipes and heat exchanger was a concern. It decreases the mass flow rate.



ERRORS

- Since water is flowing because of the potential caused due to height difference, the water level of container has to be maintained. For this purpose, the containers were filled at regular intervals of time.
- Values at 90 degrees caused air entrapment; hence values forming 180 degrees with pipes were used.
- The heat exchanger was not entirely filled with water. This caused a decrease in the rate of heat transfer.
- Instrumental errors and human errors may also lead to distortion of accurate results. These can be minimized by using calibrated and precise instruments, and working with caution.
- Insulation of the pipes was required, as the warmth of the water could be felt through them.

THANK YOU!