

## **Heat transfer through heat exchanger**

### **1. Aim of the experiment**

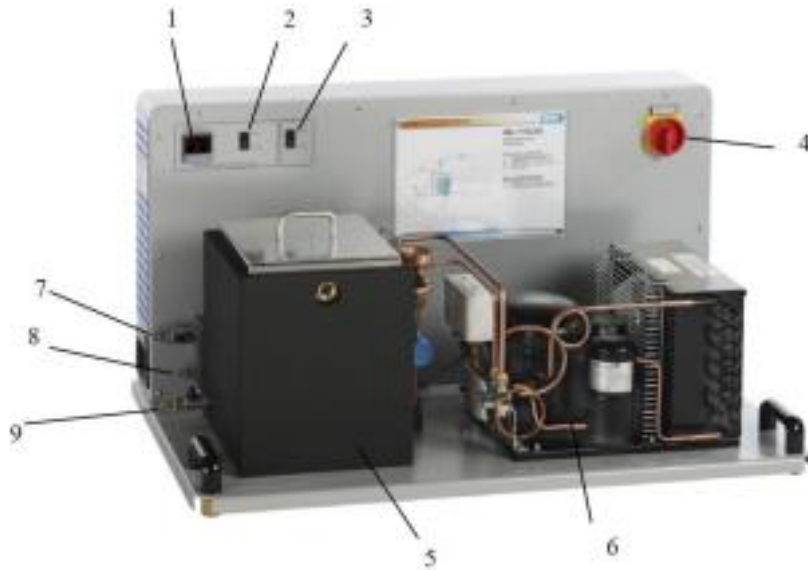
To determine the overall heat transfer coefficient of a tubular heat exchanger using LMTD and AMTD methods for parallel and counter flow configurations.

### **2. Theory**

The role of a heat exchanger is to transfer thermal energy between two or more fluids. Depending upon the flow directions of fluid, there are mainly two types flow configuration, i.e., parallel flow and counterflow. In parallel flow the flow of hot and cold fluids occurs in same direction while in counter flow the flow direction is opposite. In the determination of the overall heat transfer coefficient ( $U$ ), the mean temperature difference is essential and can be obtained by either of the two methods, i.e., Arithmetic Mean Temperature Difference (AMTD) and Logarithmic Mean Temperature Difference (LMTD). LMTD method is most useful for the case of determining the overall heat transfer coefficient based on inlet and outlet temperatures when the temperature difference between hot and cold fluid is large.

### **3. Description of the apparatus**

The apparatus consists of a main service unit, a heat exchanger unit and chiller unit. The service unit as shown in figure (1) consists of a base plate, over which heat exchanger is placed. On the left side of the service unit is a control and display panel unit which contains a mains switch, a heater switch, a pump switch, a heater temperature control unit which is used to set temperature of water in heater tank, a temperature display unit which records inlet and outlet temperatures of hot and cold fluids i.e.,  $T_{h,in}$ ,  $T_{h,out}$ ,  $T_{c,in}$  and  $T_{c,out}$ . On the right side of the service unit is a heater tank, a connecting block which connects to the chiller unit and flow control valves, which are used to set flow rates of hot water ( $\dot{V}_h$ ) and cold water ( $\dot{V}_c$ ). It also contains couplings to connect the flow pipes to the heat exchanger. The hot water tank contains a thermocouple, a heater coil and a level switch indicator which helps to maintain the correct level of water in the tank.



Figure

1:

- |                            |                                  |
|----------------------------|----------------------------------|
| 1 Temperature control unit | 6 Compressor of the chiller      |
| 2 Cooling switch           | 7 Water outlet with flow limiter |
| 3 Pump switch              | 8 Water inlet                    |
| 4 Main switch              | 9 Drain valve                    |
| 5 Water storage tank       |                                  |

#### Service unit

In this experiment, two types of heat exchangers can be used, namely tubular heat exchanger and shell and tube heat exchanger. Tubular heat exchanger essentially consists of two concentric tubes as shown in figure (2). The shell and tube heat exchanger consists of tube bundle and an encasing shell as shown in figure (3). In this experiment we will be conducting experiment using tubular heat exchanger.

Figure 2: Tubular heat exchanger



Figure 3: Shell and tube heat exchanger



The chiller unit as shown in figure (4) consists of a main switch, a cooling switch, a pump switch, a temperature control unit which is used to set the cold water temperature, a water storage tank, water inlet and outlet valves, a drain valve and a refrigeration system.

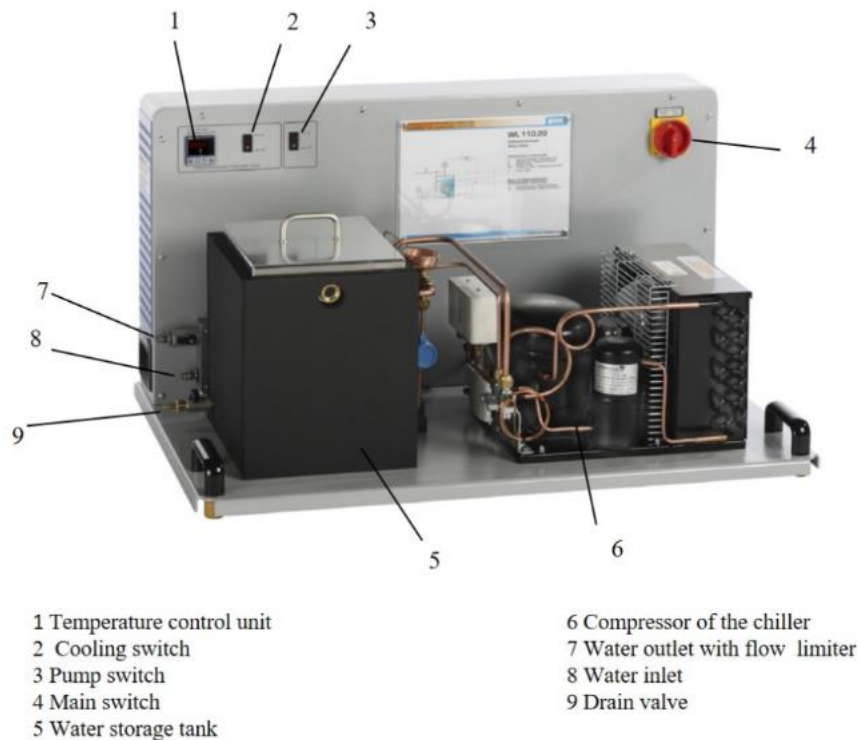


Figure 4 : Chiller unit

#### 4. Experimental procedure

1. Ensure that Mains switch given on the panel is at OFF position . 2. Ensure that the flow and drain valves are in off position.
3. Fill water in chiller unit water tank until water level can be seen from the sight glass.
4. Switch on the chiller unit main switch.
5. Switch on the pump and cooling switch.
6. Set the temperature at a desired set point temperature (say 10°C) 7. Let the water attain the set point temperature.
8. Secure the selected heat exchanger on the base plate of the service unit. 9. Based on the type of flow configuration, parallel or counter flow, ensure the appropriate connection of couplings.
10. Switch on the main switch in the service unit.
11. Check the water level indicator

a) If the hot water tank is empty: Add water until the low level is reached (level switch trips and the low water warning lamp goes out. Then add 0.5 L of water with a beaker.

b) If the hot water tank is filled but with an unknown volume above the low level: Partially drain the hot water tank until the low level is reached (level switch trips and the low water warning lamp lights up). Then add 0,5ltr of water with a beaker.

12. Start the PC. Start the data acquisition program.

13. Open the cold-water feed at the cold-water mains.

14. Open the regulator valve for cold water.

15. Open the regulator valve for hot water.

16. Start the pump in the service unit.

17. Ensure that water flow is not obstructed by air bubbles.

18. Set the desired hot water set point temperature (say 40 °C)

19. Set the desired cold and hot water flow rate using the regulator valves. 20. Turn on the heater (H) in the service unit.

21. Wait until steady state has been reached and record the temperature values and flow rates.

22. Same procedure can be used for other flow configuration and heat exchanger. **5. Closing**

### **Procedure**

1. Turn off the heater.

2. Then stop the pump.

3. Close the regulator valves.

4. Turn off the cooling switch

5. Turn off the pump in the chiller unit.

6. Close the flow valves.

7. Switch off the mains of both units.

## 6. Observation

### 1. Steady state temperature readings for Parallel flow configuration

Set Temperatures	$T_{h,in}$ (°C)	$T_{h,out}$ (°C)	$T_{c,in}$ (°C)	$T_{c,out}$ (°C)	$\dot{V}_h$	$\dot{V}_c$
Heater = 40°C Chiller = 10°C	43	38.3	21.2	28	0.73	0.53
Heater = 50°C Chiller = 10°C	52.6	45.8	22.9	32.9	0.74	0.5
Heater = 60°C Chiller = 10°C	61	52.2	24.5	37.4	0.75	0.5

### 2. Steady state temperature readings for counter flow configuration

Set Temperatures	$T_{h,in}$ (°C)	$T_{h,out}$ (°C)	$T_{c,in}$ (°C)	$T_{c,out}$ (°C)	$\dot{V}_h$	$\dot{V}_c$
Heater = 40°C Chiller = 10°C	43.3	37.5	21.1	26.5	0.68	0.74
Heater = 50°C Chiller = 10°C	52.4	44.3	23.6	30.7	0.69	0.72
Heater = 60°C Chiller = 10°C	59.9	50	26.6	34.7	0.73	0.72

## 7. Specifications and data

Mean Area, of tubes,  $A_m = 0.025 \text{ m}^2$

## 8. Calculation

$$Q_i = \rho \dot{V}_i (T_{i,in} - T_{i,out})$$

$$Q_i = U_{AMTD,i} A_m (\text{AMTD})$$

$$Q_i = U_{LMTD,i} A_m (\text{LMTD})$$

Where,

i = h, for hot fluid

i = c, for cold fluid

$Q_i$  = heat transfer rate for fluid 'i'

$\rho$  = density of water

$U_{AMTD,i}$  = heat transfer coefficient based on AMTD for fluid 'i'

$U_{LMTD,i}$  = heat transfer coefficient based on LMTD for fluid 'i'

Overall heat transfer coefficient;

a) Based on AMTD,  $U_{AMTD,i} = \frac{U_{AMTD,h} + U_{AMTD,c}}{2}$

b) Based on LMTD,  $U_{LMTD,i} = \frac{U_{LMTD,h} + U_{LMTD,c}}{2}$

### 1) Parallel Flow

HOT	COLD	HOT	COLD
$\rho$	$\rho$	Qh	Qc
992.25	999.77	3404.40975	-3603.17108
988.02	999.77	4971.71664	-4998.85
983.13	999.77	6488.658	-6448.5165

	TD	HOT	COLD	U
AMTD	16.05	8484.51028	8979.86562	8732.18795
	21.30	9336.55707	9387.511737	9362.034404
	25.65	10118.76491	10056.16608	10087.4655
LMTD	15.34	8878.298902	9396.644997	9137.47195
	20.15	9871.458619	9925.332535	9898.395577
	24.04	10796.70924	10729.91637	10763.31281

### 2) Counter Flow

HOT	COLD	HOT	COLD
$\rho$	$\rho$	Qh	Qc
992.25	999.77	3913.434	-3995.08092
988.02	999.77	5522.04378	-5110.82424
983.13	999.77	7105.08051	-5830.65864

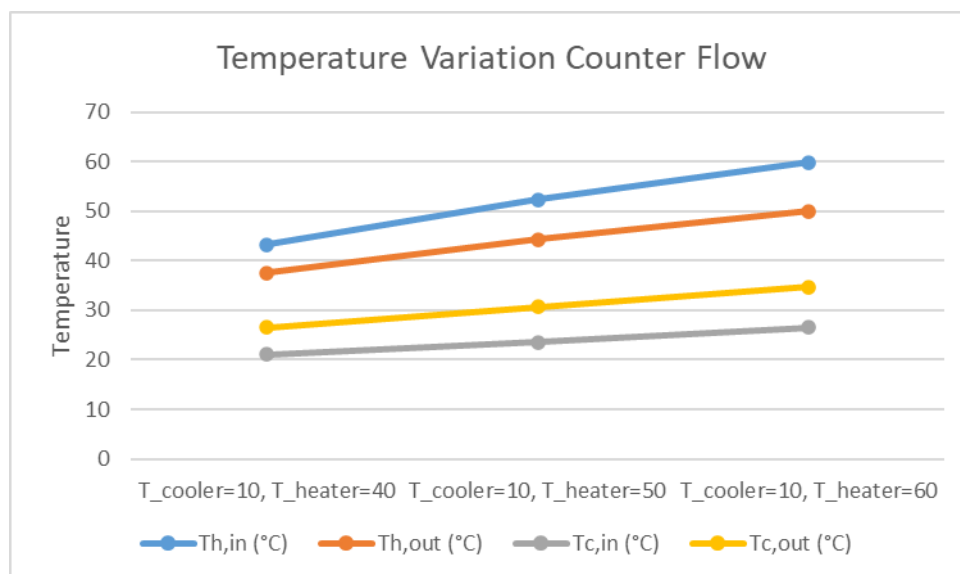
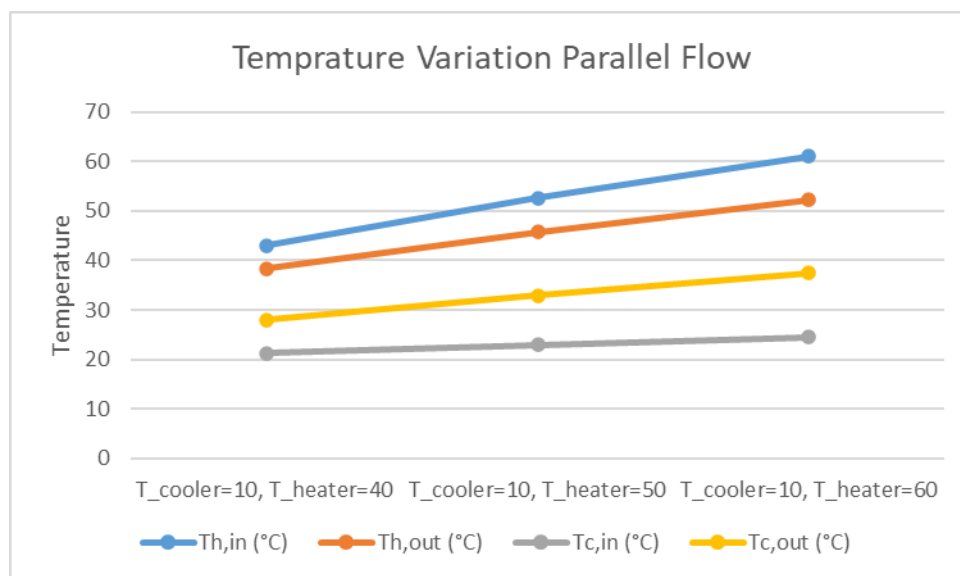
	TD	HOT	COLD	U
AMTD	16.60	9429.961446	9626.701012	9528.331229
	21.20	10418.95053	9643.064604	10031.00757
	24.30	11695.60578	9597.792	10646.69889
LMTD	16.60	9430.417767	9627.166853	9528.79231
	21.20	10420.88301	9644.853178	10032.8681
	24.29	11700.95797	9602.184181	10651.57107

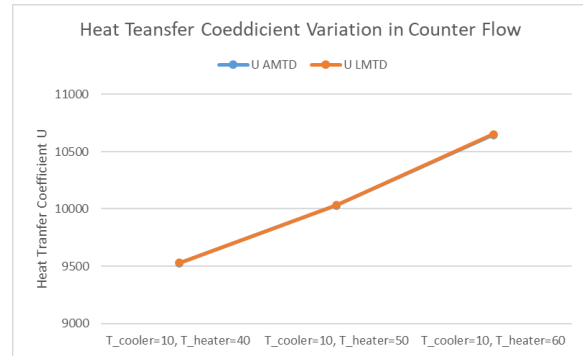
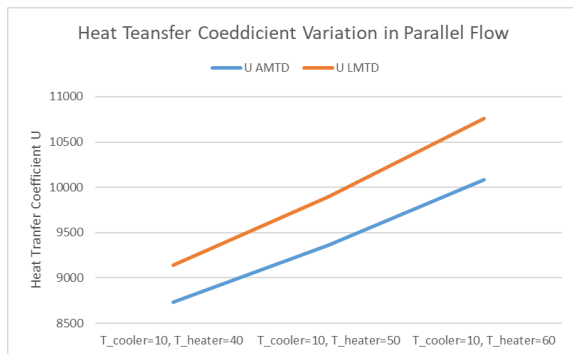
## 9. Precautions & maintenance instructions:

1. Ensure the hot water temperature is operated below 70°C.
2. Do not operate pump without water.
3. Ensure the water level in the hot water reservoir is maintained and the warning lamp is switched off.
4. Ensure that the chiller unit has sufficient water.
5. Avoid the use of water with a high-water hardness.

## 10. Conclusion

### Graphs





- With increase in inlet heater input the hot in, hot out and cold out temperature all 3 show an increase in temperature in both the cases.
  - Hot in temperature increases as with input temperature is increased.
  - Hot out temperature increases as the temperature increase in input is much more than the increase in temperature reduction by heat lost.
  - Cold in remains constant as the cooler input is constant.
  - Cold out increases as the heat gained is increased due to increases in hot in temperature.
- Heat transfer in case of counter flow is higher than parallel flow as the temperature differences between the 2 flows over the heat exchanger length will be higher in case of counter flow. This also results in higher heat transfer coefficient value in counter flow.
- We observe  $U_{AMTD}$  and  $U_{LMTD}$  to increase with heater input temperature as this causes the AMTD and LMTD to increase causing more heat transfer.
- AMTD is found to be higher than LMTD in parallel flow cases and almost equal for the counter flow case. LMTD gives more accurate values.