

University of Wales Trinity Saint David
School of Engineering

Cross-Flow Heat Exchanger Laboratory
Thermofluid Mechanics: M5X00406

Alexander Baldwin

1801714

26/04/2020

Contents

1 Introduction	1
2 Experimental Procedure	2
2.1 Equipment.....	2
2.2 Method	2
3 Results.....	3
3.1 First experiment.....	3
3.2 Second Experiment	4
3.3 Third Experiment.....	6
4 Analysis	8
5 Conclusion.....	9
6 Evaluation	10
7 Further Work.....	10
References	11
Appendices.....	12

1 Introduction

Experiment was done using a cross-flow heat exchanger. These heat exchangers are mostly used in cooling and ventilation systems that require heat to be transferred from one stream of liquid or gas to another stream. Some examples of a cross-flow heat exchanger are; an automobile radiator, air conditioners, refrigerators and fans. They work by cold water flowing into the inlet tube and running perpendicular to hot plates which therefore heat up the water to a temperature which is measured. Then air flows past the hot pipes and is then heated up. The temperature of the plates is controlled and the inlet and outlet temperatures of the feedwater and airflow are measured.

The aim of the experiment was to see how different flow rates for water or air affect the performance of a cross-flow heat exchanger for specific inlet waterflow temperatures.

2 Experimental Procedure

2.1 Equipment

- TD1007 water to air cross-flow heat exchanger
- Stopwatch

2.2 Method

The cross-flow heat exchanger was turned on and the temperature was set to 40°C. The air pressure flowing through the heat exchanger was set to 250Pa and lowered 5 times with a difference of 50Pa and a wait of 4 minutes until the next measurement to allow the heat exchanger to settle, therefore achieving better results.

Temperature was then increased to 60°C, the same tests were done and measurements taken at this higher temperature.

The temperature then remained the same and the air pressure was set to 250Pa throughout the next tests. The water flow rate was increased to a maximum amount of 2L/min and decreased by 0.25L/min each step, down to 1L/min. The original plan was to start at 2.25L/min and decrease by 0.5L/min until 0.25L/min but the filter in the cross-flow heat exchanger was dirty, therefore the flow could not go over 2L/min thus changes to the test had to be made.



Figure 1 - Picture showing the TD1007 water to air cross-flow heat exchanger used in the experiments.

3 Results

3.1 First experiment

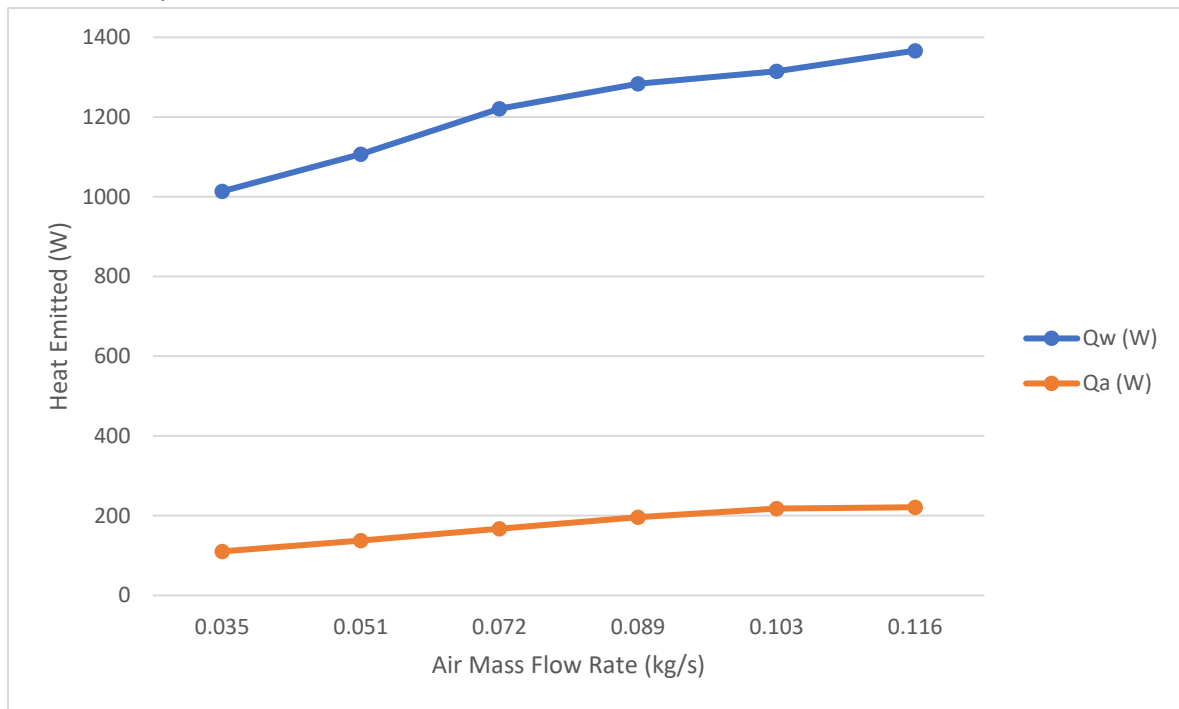


Figure 2 - Graph showing heat emitted for water and air against air mass flow rate.

The heat emitted for both water and air increased linearly. The heat emitted by the water increased faster per unit of air mass flow rate than the heat emitted to the air.

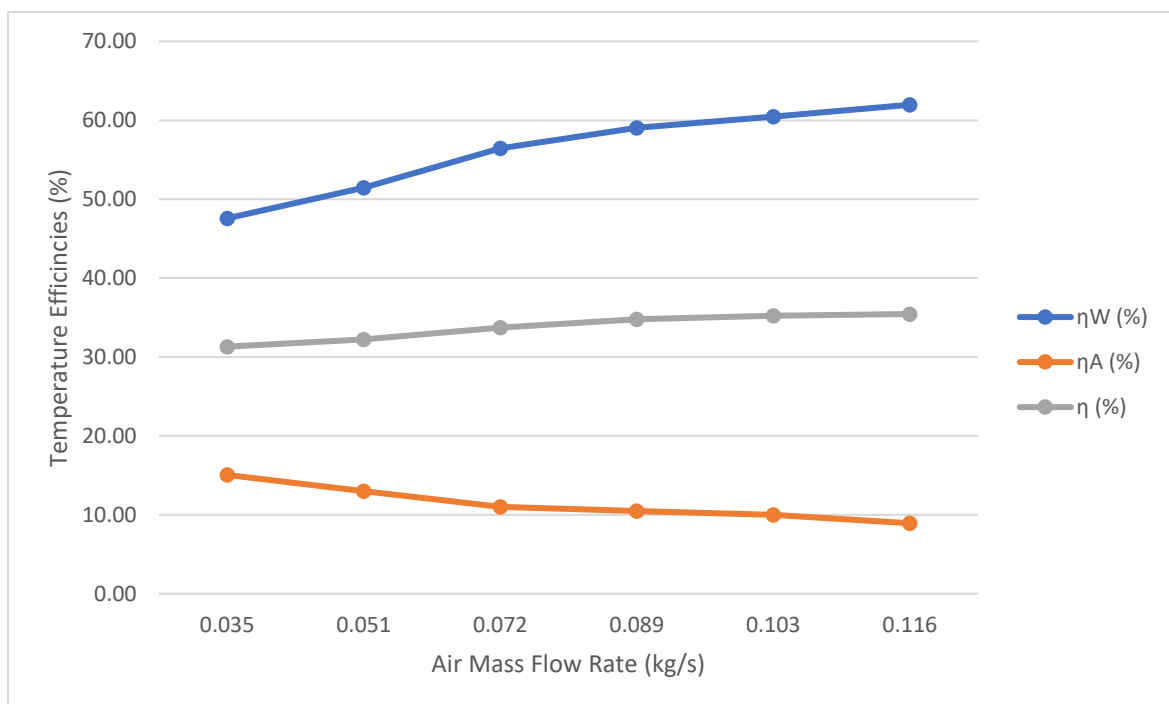


Figure 3 - Graph showing temperature efficiencies for water, air and average against air mass flow rate.

The efficiency of water increased linearly while the efficiency of air decreased linearly. The average efficiency increased linearly.

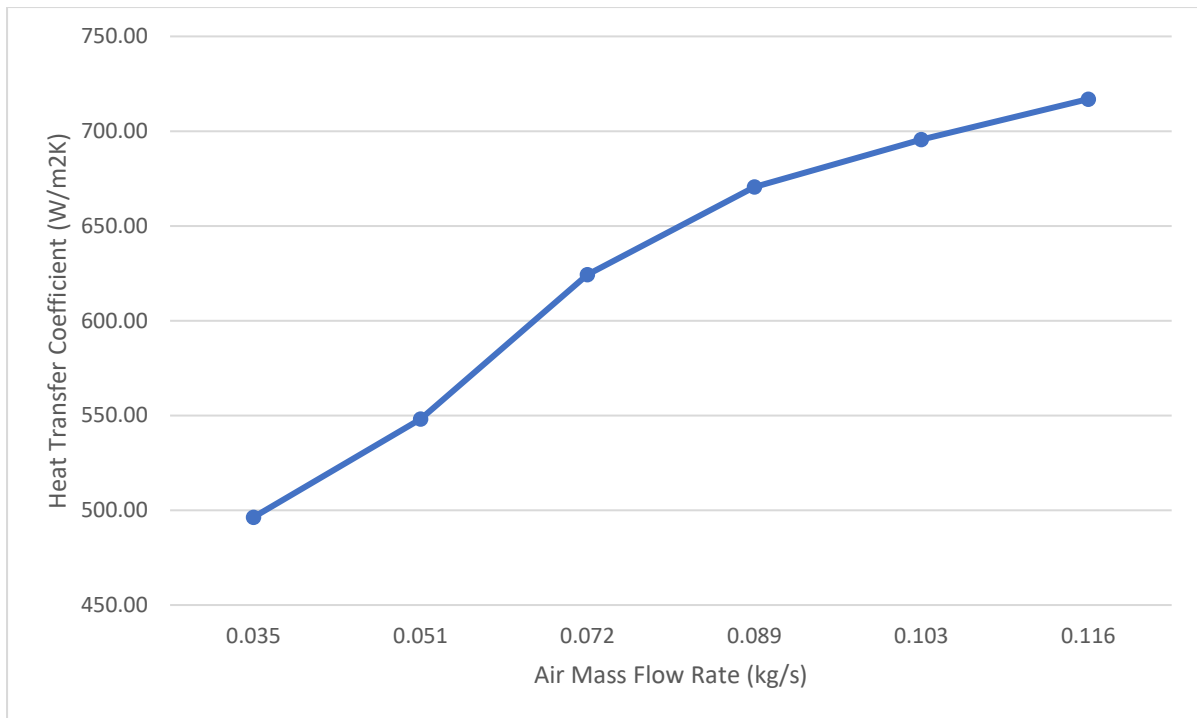


Figure 4 - Graph showing heat transfer coefficient against air mass flow rate.

The heat transfer coefficient increased linearly with a steep gradient then the gradient decreased at 0.089kg/s.

3.2 Second Experiment

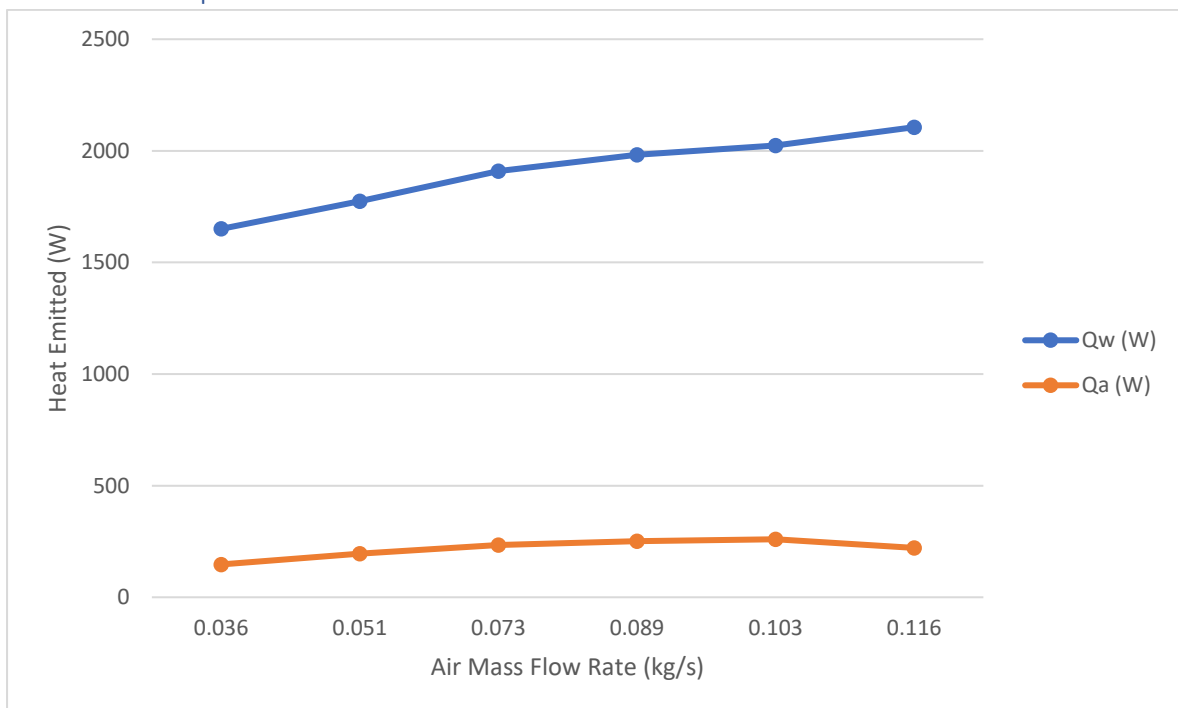


Figure 5 - Graph showing heat emitted for water and air against air mass flow rate.

The heat emitted for both water and air increased linearly. The heat emitted by the water increased faster per unit of air mass flow rate than the heat emitted to the air.

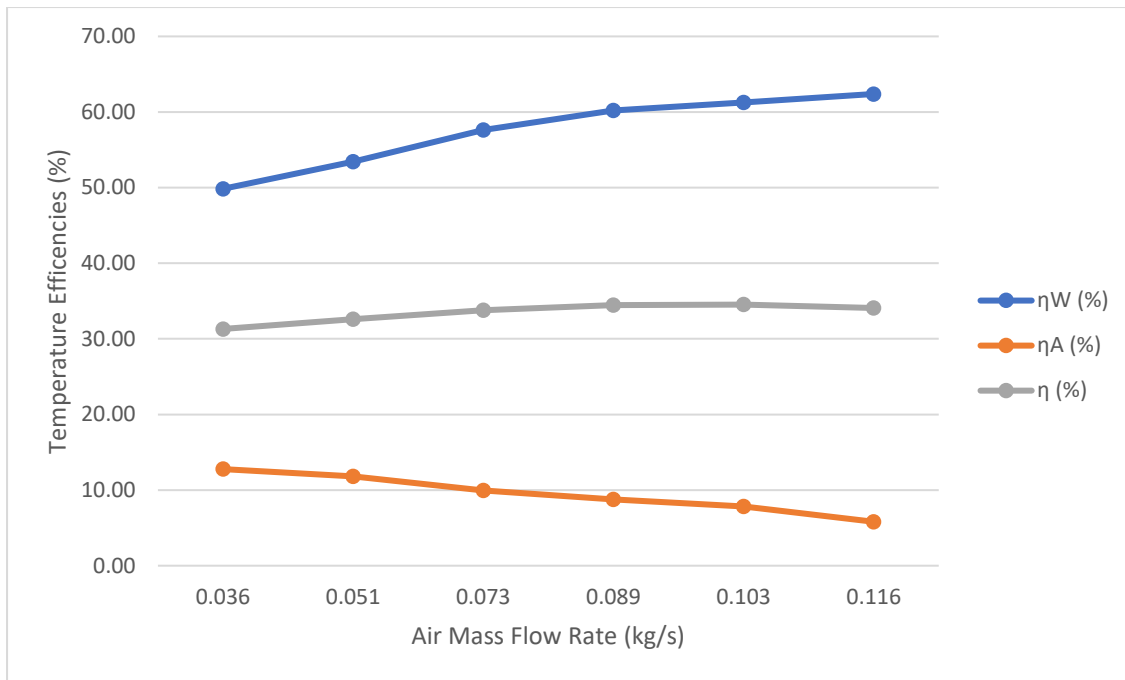


Figure 6 - Graph showing temperature efficiencies for water, air and average against air mass flow rate.

The temperature efficiency of water increased linearly while the temperature efficiency of air decreased linearly. The average temperature efficiency increased linearly until an air mass flow rate of 0.089m/s, then it decreased linearly.

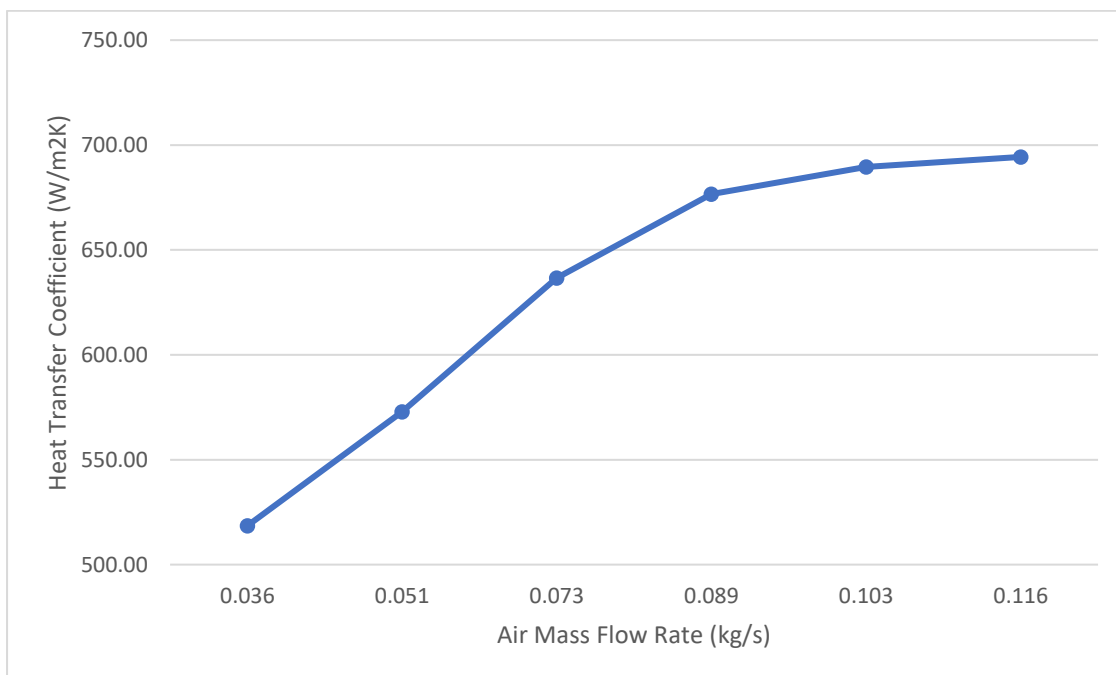


Figure 7 - Graph showing heat transfer coefficient against air mass flow rate.

The heat transfer coefficient increased linearly with a steep gradient then the gradient decreased at 0.089kg/s.

3.3 Third Experiment

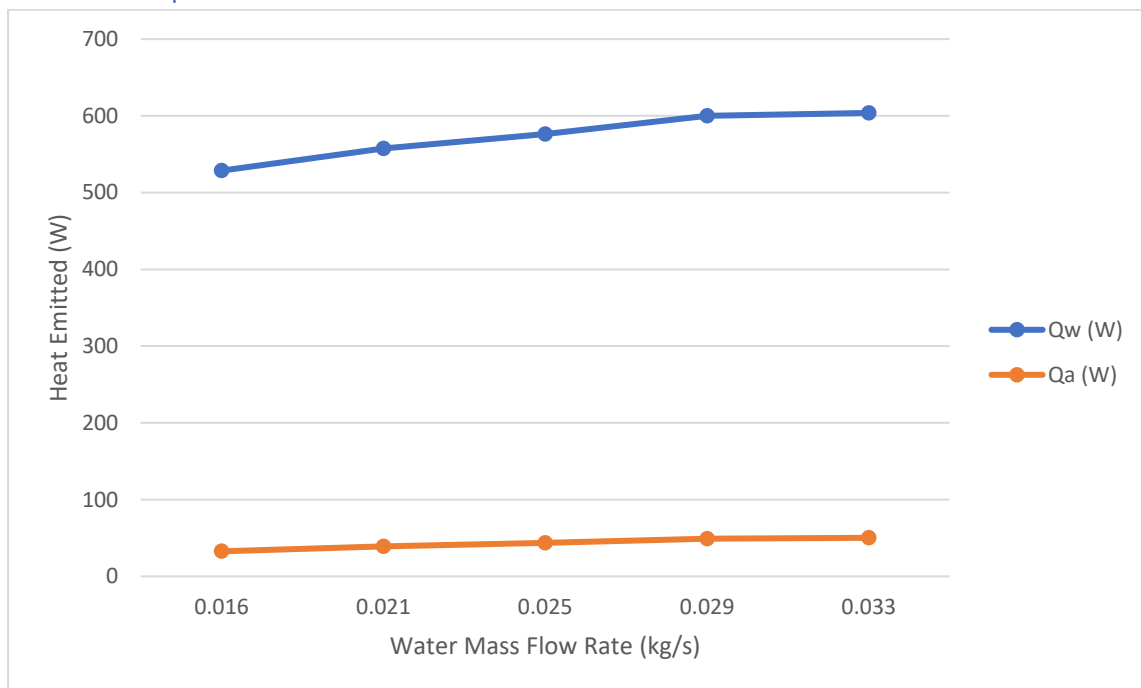


Figure 8 - Graph showing heat emitted for water and air against water mass flow rate.

The heat emitted from the water increased linearly but the heat emitted to the air remained fairly constant.

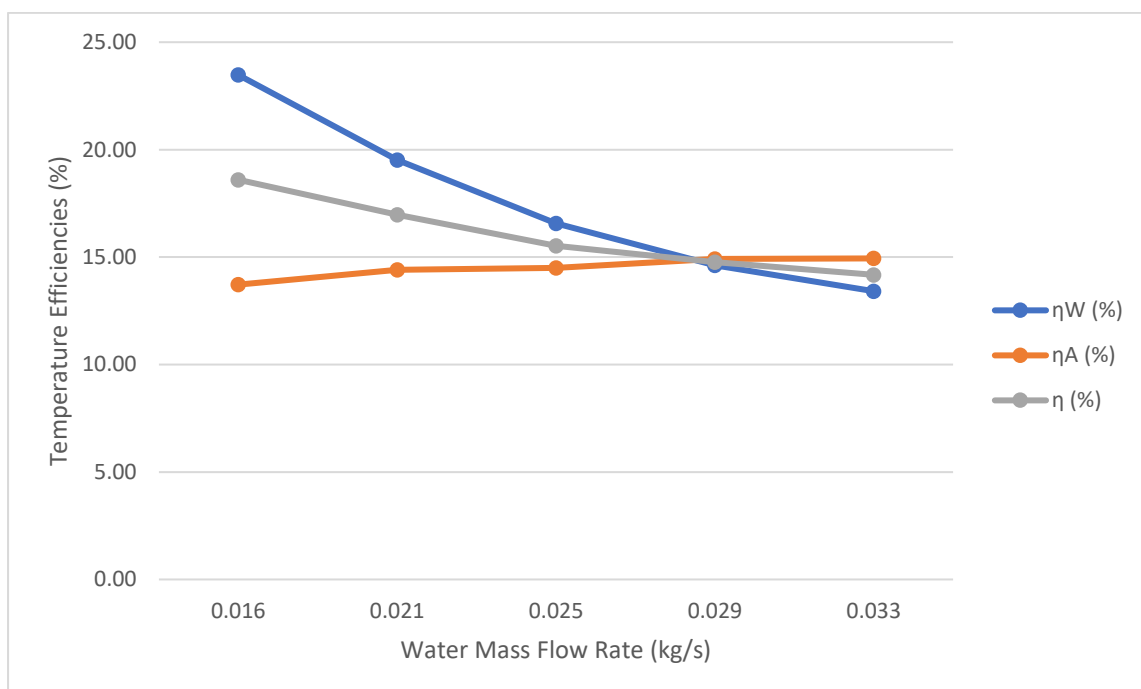


Figure 9 - Graph showing temperature efficiencies for water, air and average against water mass flow rate.

The temperature efficiency of the water decreased exponentially while the temperature efficiency of the air increased linearly and they cross over around 0.029kg/s water mass flow rate. The average of the temperature efficiency decreased exponentially.

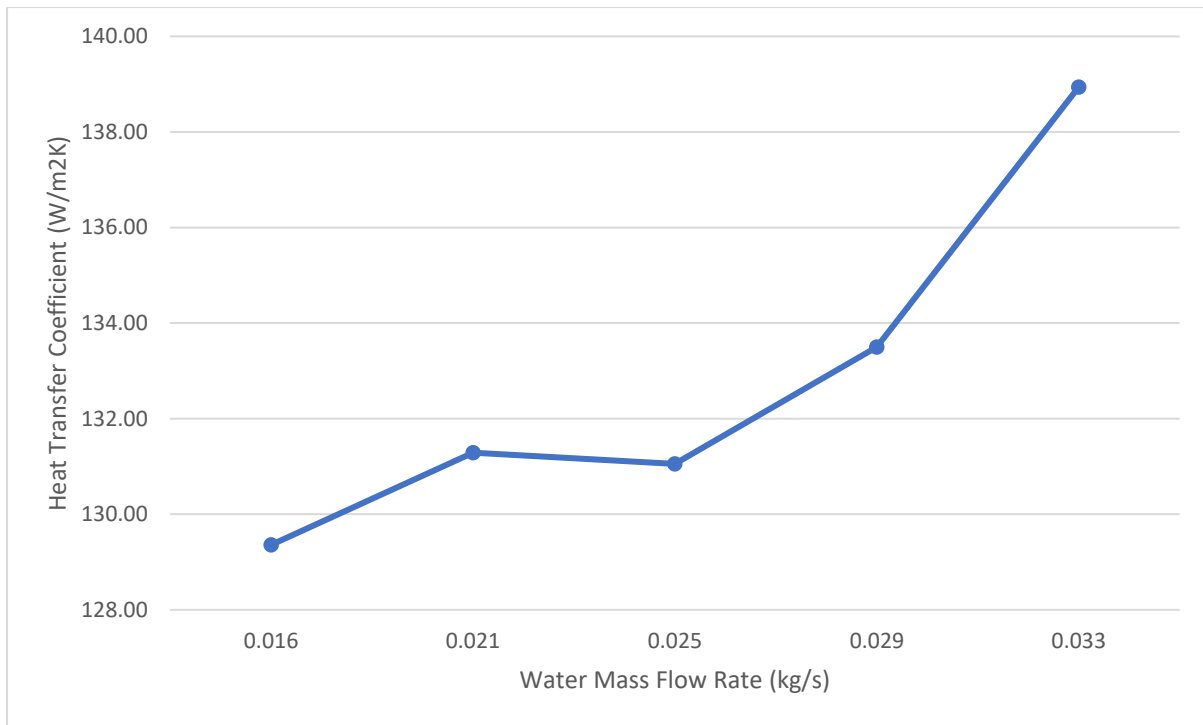


Figure 10 - Graph showing heat transfer coefficient against water mass flow rate.

The heat transfer coefficient increased then decreased at 0.021kg/s. Furthermore, it starts increasing exponentially from 0.025kg/s onwards.

4 Analysis

Figure 2 shows that as the air mass flow rate increased so did the heat emitted for both water and air. This indicates that more heat is emitted to surroundings and also a larger power is absorbed into the air. This is due to a larger mass of air flowing into the cross-flow heat exchanger which also adds more energy into the system. The gradient for the heat emitted by the water is greater than the air which shows that there are some energy losses to the surroundings. The heat emitted for water and air is calculated by using the equations $Q_W = m_W \times c_{pW} \times \Delta T_W$ and $Q_A = m_A \times c_{pA} \times \Delta T_A$ respectively where c_p is specific heat capacity and ΔT is change in temperature. Figure 3 shows that the efficiency for both water and air against the air mass flow rate increased linearly as the flow rate increased. This shows that the cross-flow heat exchanger is more efficient at a higher air flow rate at 40°C. The temperature efficiency for both water and air are calculated using equations $\eta_W = \frac{T_{W1} - T_{W2}}{T_{W1} - T_{A1}} \times 100$ and $\eta_A = \frac{T_{A2} - T_{A1}}{T_{W1} - T_{A1}} \times 100$ respectively where T is the temperatures in °C. Furthermore, Figure 4 shows that the heat transfer coefficient increased linearly as air mass flow rate increased. The heat transfer coefficient is a characteristic of convective heat transfer between a fluid and a solid and is calculated using the equation $U = \frac{Q_W}{A \times LMTD}$ where LMTD is the logarithmic mean temperature difference (Holman, 2010).

The second test at 60°C, as shown from Figure 5, has a similar correlation to Figure 2. However, the values for the heat emitted of the water in Figure 5 is larger than the values in Figure 2. This is due to the higher water temperature. As the temperature of the water increased so did the heat emitted because the specific heat capacity of the water is increased. The temperature efficiency in shown Figure 6 indicates that there is a slight difference between the first experiment which is shown in Figure 3. The average efficiency starts to decrease at an air mass flow rate of 0.103kg/s which means the cross-flow heat exchanger becomes less efficient after this point onwards. The Heat transfer coefficient shown in Figure 7 is very similar to the first test shown in Figure 4, which is a steep increase then starts to level out peaking at a smaller value.

The final test done, which was also at 60°C but with varying water mass flow rate showed different patterns in the results. As shown in Figure 8, the heat emitted by the water linearly increased but the heat absorbed into the air remained steady. Both of the values were a lot less than the last two tests. The temperature efficiency acted very differently compare to previous tests which is shown in Figure 9. Temperature effectiveness of water decreased exponentially and the temperature effectiveness of air increased linearly. They cross over one another around 0.0296kg/s water mass flow rate. The average temperature efficiency decreased exponentially also. Figure 10 which shows the heat transfer coefficient measurements had some errors as the graph rises, drops, then rises exponentially. This shows that the error occurred at 0.021kg/s water mass flow rate.

As the temperature of the feedwater increased, the average efficiency decreased but the heat transfer coefficient remains mostly the same with a change in temperature.

5 Conclusion

The tests done using the cross-flow heat exchanger returned good results which were predicted to occur. There was only one error in the data gathered but it did not cause any issues to the overall experiment. As the filter for the water was dirty, better tests could not have been done on the third experiment which could have potentially caused some errors. Cross-flow heat exchangers have a large impact on everyday society and designing them to be more efficient could decrease costs and provide a better functioning heat exchanger.

6 Evaluation

Tests were carried out in a controlled room with a measured ambient pressure of 1.010bar. Four minutes waited between tests to get better results but tests were not repeated. To get better results, measurements could have been taken 3 times with a four minute wait in between each test and an average taken to eliminate any errors. Filter should be replaced for future experiments to get better results.

7 Further Work

These experiments can help improve cross-flow heat exchangers used in many everyday life systems, as changes can be made to the heat exchangers in the lab and measurements can be taken with greater ease.

References

Holman J.P. (2010) 'Heat transfer 10th ed', International Boston [Mass.] ; London: McGraw-Hill.

Appendices

Table 1 – Table showing all data measured and calculated from the first experiment.

Air Pressure (Pa)	Tw1 (°C)	Tw2 (°C)	ΔTw (°C)	Average Tw (°C)	Tw3 (°C)	TA1 (°C)	TA2 (°C)	ΔTA (°C)	Average TA (°C)	TA3 (°C)	ηW (%)	ηA (%)	ρW (kg/m ³)	ρA (kg/m ³)	CpW (J/kgK)	CpA (J/kgK)	Qw (W)	Qa (W)	Ceb	η (%)	LMTD	U (W/m ² K)
250	49.6	36.4	13.2	43	35.7	28.3	30.2	1.9	29.25	27.7	61.97	8.92	991.02	1.203	4178.75	1005	1366.608	221.16	0.161834	35.45	12.24	716.92
200	49.5	36.8	12.7	43.15	35.8	28.5	30.6	2.1	29.55	27.7	60.48	10.00	990.96	1.191	4178.78	1005	1314.771	217.52	0.165447	35.24	12.13	695.62
150	49.7	37.3	12.4	43.5	35.9	28.7	30.9	2.2	29.8	28	59.05	10.48	990.82	1.181	4178.84	1005	1283.549	196.52	0.153109	34.76	12.29	670.49
100	49.8	38	11.8	43.9	35.9	28.9	31.2	2.3	30.05	27.8	56.46	11.00	990.66	1.171	4178.92	1005	1221.262	167.05	0.136789	33.73	12.56	624.22
50	50	39.3	10.7	44.65	36	29.2	31.9	2.7	30.55	27.8	51.44	12.98	990.35	1.152	4179.07	1005	1107.109	137.53	0.124224	32.21	12.97	548.05
25	50.3	40.5	9.8	45.4	36.1	29.7	32.8	3.1	31.25	28.1	47.57	15.05	990.03	1.126	4179.23	1005	1013.706	110.40	0.108905	31.31	13.11	496.34

Table 2 - Table showing all data measured and calculated from the second experiment.

Air Pressure (Pa)	Tw1 (°C)	Tw2 (°C)	ΔTw (°C)	Average Tw (°C)	Tw3 (°C)	TA1 (°C)	TA2 (°C)	ΔTA (°C)	Average TA (°C)	TA3 (°C)	ηW (%)	ηA (%)	ρW (kg/m ³)	ρA (kg/m ³)	CpW (J/kgK)	CpA (J/kgK)	Qw (W)	Qa (W)	Ceb	η (%)	LMTD	U (W/m ² K)
250	61	40.6	20.4	50.8	37.4	28.3	30.2	1.9	29.25	27.9	62.39	5.81	987.66	1.203	4180.66	1005	2105.823	221.16	0.105025	34.10	19.47	694.34
200	60.1	40.5	19.6	50.3	37.6	28.1	30.6	2.5	29.35	27.4	61.25	7.81	987.89	1.199	4180.51	1005	2023.635	259.84	0.128402	34.53	18.84	689.52
150	60	40.8	19.2	50.4	37.8	28.1	30.9	2.8	29.5	27.4	60.19	8.78	987.84	1.193	4180.54	1005	1982.259	251.39	0.126819	34.48	18.80	676.68
100	60.1	41.6	18.5	50.85	37.8	28	31.2	3.2	29.6	27.2	57.63	9.97	987.63	1.189	4180.68	1005	1909.655	234.18	0.122632	33.80	19.25	636.61
50	60.3	43.1	17.2	51.7	37.9	28.1	31.9	3.8	30	26.9	53.42	11.80	987.24	1.173	4180.95	1005	1774.872	195.33	0.110051	32.61	19.89	572.88
25	60.8	44.8	16	52.8	37.9	28.7	32.8	4.1	30.75	27.1	49.84	12.77	986.73	1.144	4181.31	1005	1650.327	147.19	0.08919	31.31	20.43	518.54

Table 3 - Table showing all data measured and calculated from the third experiment.

Hot Flow (L/min)	Tw1 (°C)	Tw2 (°C)	ΔTw (°C)	Average Tw (°C)	Tw3 (°C)	TA1 (°C)	TA2 (°C)	ΔTA (°C)	Average TA (°C)	TA3 (°C)	ηW (%)	ηA (%)	ρW (kg/m ³)	ρA (kg/m ³)	CpW (J/kgK)	CpA (J/kgK)	Qw (W)	Qa (W)	Ceb	η (%)	LMTD	U (W/m ² K)
2	60.5	56.1	4.4	58.3	38	27.7	32.6	4.9	30.15	27.1	13.41	14.94	984.05	1.167	4183.38	1005	603.7743	50.25	0.083223	14.18	27.89	138.94
1.75	61.4	56.4	5	58.9	38.3	27.2	32.3	5.1	29.75	27	14.62	14.91	983.74	1.183	4183.63	1005	600.1947	49.25	0.082055	14.77	28.86	133.50
1.5	61.2	55.6	5.6	58.4	38.5	27.4	32.3	4.9	29.85	27.2	16.57	14.50	984.00	1.179	4183.42	1005	576.3062	43.73	0.075887	15.53	28.23	131.05
1.25	60.9	54.4	6.5	57.65	38.7	27.6	32.4	4.8	30	27.3	19.52	14.41	984.37	1.173	4183.11	1005	557.6114	39.01	0.069961	16.97	27.26	131.29
1	60.7	53	7.7	56.85	38.7	27.9	32.4	4.5	30.15	27.5	23.48	13.72	984.77	1.167	4182.79	1005	528.6174	32.63	0.061728	18.60	26.23	129.36