



HEAT EXCHANGER SYSTEMS

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Notes to lecturer

- Simulated data was used to complete this assignment.
- For calculations, temperature difference has been considered to be negative for water and positive for air. This is opposite to how the data has been originally recorded in the provided experiment 1 simulated result tables.
- The energy balance coefficient has been converted to absolute value.
- All non-provided values are calculated using formulas and not entered manually (except the specific heat capacity of air which can be assumed to stay constant), thus, it is possible to view more accurate results by increasing the number of decimal places in Excel.

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1 Abstract

This report focuses on the analysis of a heat exchanger set up in a parallel flow configuration. The table below summarises all the main variables and constants in each of the experiments. The main focus of each experiment is highlighted in red.

Experiment 1

Component	Type	Value
Water flow rate	Variable	0.75, 1, 1.25, 1.5, 1.75 L/min (+/-0.01)
Heater tank temperature	Constant	60°C (+/-1 T _{W1})
Air pressure delta	Constant	250Pa (+/-5)

Experiment 2

Component	Type	Value
Water flow rate	Constant	0.25L/min (+/-0.01)
Heater tank temperature	Constant	60°C (+/-2.4 T _{W1})
Air pressure delta	Variable	25, 50, 100, 150, 200, 250 Pa (+/-5)

Experiment 3

Component	Type	Value
Water flow rate	Constant	0.25L/min (+/-0.01)
Heater tank temperature	Constant	45°C (+/-4.4 T _{W1})
Air pressure delta	Variable	25, 50, 100, 150, 200, 250 Pa (+/-5)

2 Notation

Table 1 (TecQuipment, 2014)

Symbol	Definition	Units
A	Heat Transfer Area	m^2
A_O	Orifice Area	m^2
C	Heat capacity	J.K^{-1}
C_d	Coefficient of discharge (orifice)	-
c_p and $c_{p,A}$ and $c_{p,W}$	Specific Heat Capacity, of air and water at Constant Pressure (atmospheric pressure for air)	$\text{J.kg}^{-1}\text{K}^{-1}$
$LMTD$	Logarithmic Mean Temperature Difference	K or °C where shown
ρ and ρ_A and ρ_W	Density, of air and water	kg.m^{-3}
η_o	Overall Efficiency	%
C_{EB}	Energy Balance Coefficient	-
$\bar{\eta}_A$ and $\bar{\eta}_W$	Mean Temperature Efficiencies	%
Δp	Orifice pressure drop	Pa
Q	Heat energy transferred for a unit mass	J.kg^{-1}
$\dot{Q}$	Heat energy transferred for a unit time (heat transfer rate - or power)	W
$\dot{Q}_A$ and $\dot{Q}_W$	Heat energy (power) absorbed by the air and emitted by the water in a unit time	W
R	Specific gas constant for dry air	287 J/kg.K
T, T_W, T_A	Temperature, of water and air	K or °C where shown
ΔT	Change in Temperature	K or °C where shown
$\bar{T}$	Mean Temperature	K or °C where shown
U	Heat Transfer Coefficient	$\text{W.m}^{-2}\text{K}^{-1}$
$\dot{m}_W$ and $\dot{m}_A$	Mass Flow Rate (hot water circuit and air circuit)	kg.s^{-1}

3 Equations and units used

Equations:	
$\rho_A (\text{kg/m}^3) = P(\text{Pa}) / (R(\text{J/kg.K}) * T(\text{K}))$	
$\rho_W (\text{kg/m}^3) = (999.839 + 16.952 * \text{Avg } T_W(c) - 7.99 * 10^{-3} * \text{Avg } T_W(c)^2 - 46.241 * 10^{-6} * \text{Avg } T_W(c)^3 + 105.846 * 10^{-9} * \text{Avg } T_W(c)^4 - 281.03 * 10^{-12} * \text{Avg } T_W(c)^5) / (1 + 16.887 * 10^{-3} * \text{Avg } T_W(c))$	
$\dot{m}_A (\text{kg/s}) = C_d * A_O(\text{m}^2) * \text{SQRT}(\Delta p(\text{Pa}) * 2 * \rho_A(\text{kg/m}^3))$	
$\dot{m}_W (\text{kg/s}) = \text{volume flow } (\text{m}^3/\text{s}) * \rho(\text{kg/m}^3) \text{ thus } \dot{m}_W = \text{volume flow } (\text{L/min}) / 60000 * \rho(\text{kg/m}^3)$	
$C_{p,W} (\text{J kg}^{-1} \text{K}^{-1}) = (0.996185 + 0.0002874 * ((\text{Avg } T_W(c) + 100) / 100)^{5.26 + 0.0116 * 10^{-4} * (-0.036 * \text{Avg } T_W(c))}) * C_{p,W} @ 15^\circ \text{C} (\text{J kg}^{-1} \text{K}^{-1})$	
$\dot{Q}_W (\text{W}) = \dot{m}_W (\text{kg/s}) * C_{p,W} (\text{J kg}^{-1} \text{K}^{-1}) * \Delta T_W(c)$ Temp difference must be negative	
$\dot{Q}_A (\text{W}) = \dot{m}_A (\text{kg/s}) * C_{p,A} (\text{J kg}^{-1} \text{K}^{-1}) * \Delta T_A(c)$ Temp difference must be positive	
$C_{EB} (\text{ratio}) = \dot{Q}_A (\text{W}) / \dot{Q}_W (\text{W})$ Converted to absolute value	
$\eta_W (\%) = ((T_{W1}(c) - T_{W2}(c)) / (T_{W1}(c) - T_{A1}(c))) * 100$	
$\eta_A (\%) = ((T_{A2}(c) - T_{A1}(c)) / (T_{W1}(c) - T_{A1}(c))) * 100$	
$\bar{\eta} (\%) = (\eta_W (\%) + \eta_A (\%)) / 2$	
$LMTD = ((T_{W2}(c) - T_{A1}(c)) - (T_{W1}(c) - T_{A2}(c))) / (\ln((T_{W2}(c) - T_{A2}(c)) / (T_{W1}(c) - T_{A1}(c))))$	
$U (\text{J kg}^{-1} \text{K}^{-1}) = (\dot{Q}_W (\text{W})) / (A(\text{m}^2) * LMTD)$	

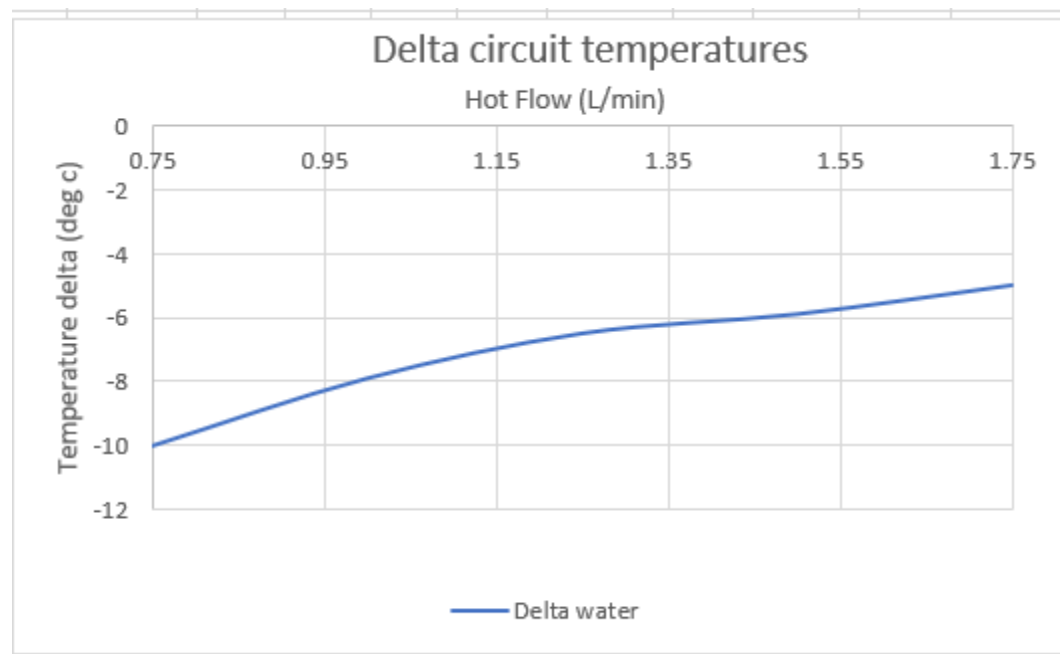
4 Experiment 1 – Effects of varying water flow rate

This experiment has been covered in more detail to explain the function of a heat exchanger. Those fundamentals/concepts also apply for the other experiments.

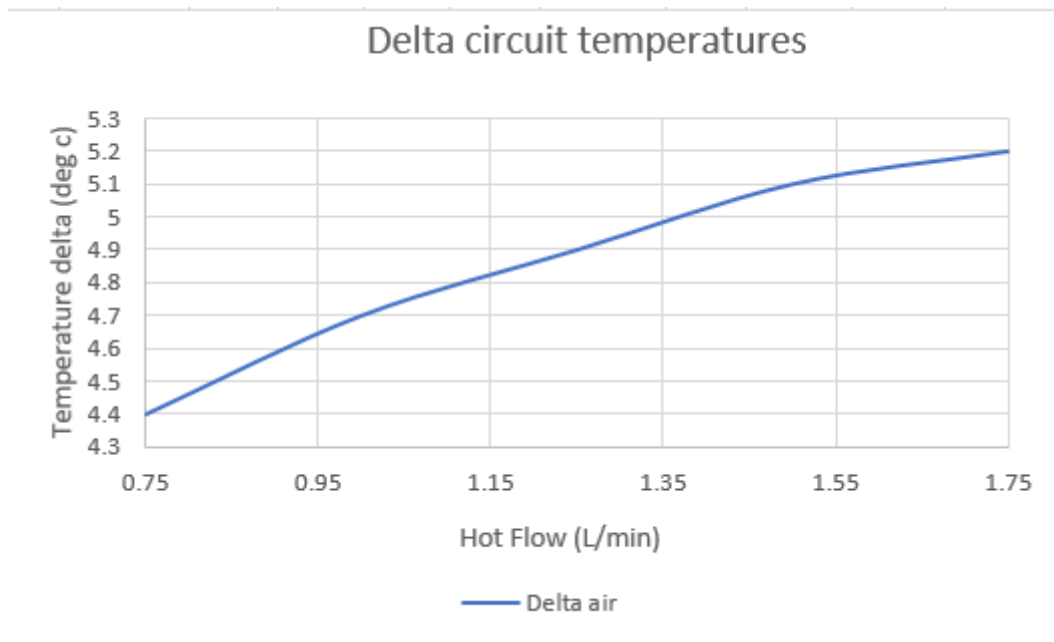
4.1 Results table

Experiment 1 - Effects of varying water flow rate																								
Volume flow (water)	Temperature (water)	Temperature (water)	Temperature difference (water)	Average temperature (water)	Temperature (air)	Temperature (air)	Temperature difference (air)	Average temperature (air)	Temperature (air)	Water efficiency	Air efficiency	Water density	Air density	Specific heat capacity (water)	Specific heat capacity (air)	Power (water)	Power (air)	Energy balance coefficient	Mean temperature efficiency	Heat driving force	Heat transfer coefficient	Mass flow (water)	Mass flow (air)	
Hot Flow (L/min)	T _{w1} (C)	T _{w2} (C)	ΔT _w (C)	Avg T _w (C)	T _{a1} (C)	T _{a2} (C)	ΔT _a (C)	Avg T _a (C)	T _{a3} (C)	η _w (%)	η _a (%)	ρ _w (kg/m³)	ρ _a (kg/m³)	c _{pw} (J kg⁻¹ K⁻¹)	c _{pa} (J kg⁻¹ K⁻¹)	Q _w (W)	Q _a (W)	ε	η (%)	LMTD	U (W/(m²K))	ṁ _w (kg/s)	ṁ _a (kg/s)	
1.75	61	56	-5	58.5	25.7	30.9	5.2	28.3	25.3	14.16	14.73	983.95	1.167	4183.48	1005.00	-600.30	596.15	0.99	14.45	29.91	-128.82	0.029	0.114	
1.5	61	55.1	-5.9	58.05	25.8	30.9	5.1	28.35	25.3	16.76	14.49	984.17	1.167	4183.29	1005.00	-607.27	584.64	0.96	15.63	29.36	-132.77	0.025	0.114	
1.25	60.5	54	-6.5	57.25	25.7	30.6	4.9	28.15	25.3	18.68	14.08	984.57	1.167	4182.96	1005.00	-557.71	561.90	1.01	16.38	28.72	-124.62	0.021	0.114	
1	60.3	52.4	-7.9	56.35	25.8	30.5	4.7	28.15	25.4	22.90	13.62	985.02	1.167	4182.61	1005.00	-542.46	538.96	0.99	18.26	27.72	-125.59	0.016	0.114	
0.75	60.1	50.1	-10	55.1	25.8	30.2	4.4	28	25.4	29.15	12.83	985.63	1.168	4182.14	1005.00	-515.26	504.69	0.98	20.99	26.45	-125.03	0.012	0.114	
Heat transfer area A	0.1558 m²																							
Cd	0.6																							
Heater temperature	333 K																							
Orifice Δp	250 Pa																							
Ambient Pressure	100900 Pa																							
Orifice diameter	0.10011 m																							
Orifice area	0.01 m²																							
Gas constant R	287.00 J kg⁻¹ K⁻¹																							
C _{pw} @ 15c	4185.50 J kg⁻¹ K⁻¹																							

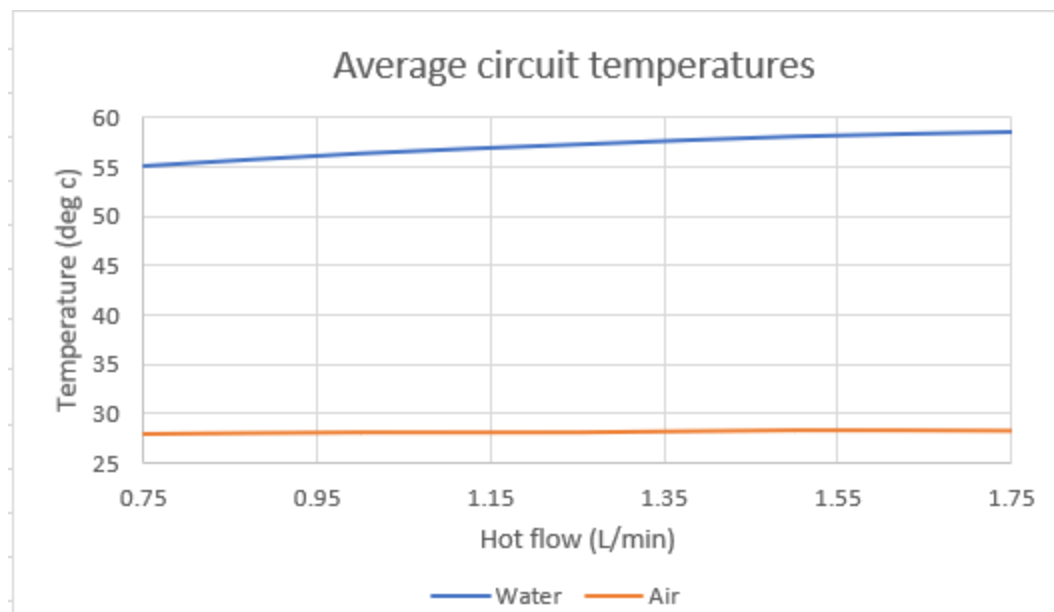
4.2 Average and delta circuit temperatures



The temperature difference of the water circuit decreases with higher water flow rates, due to less time available for heat transfer.

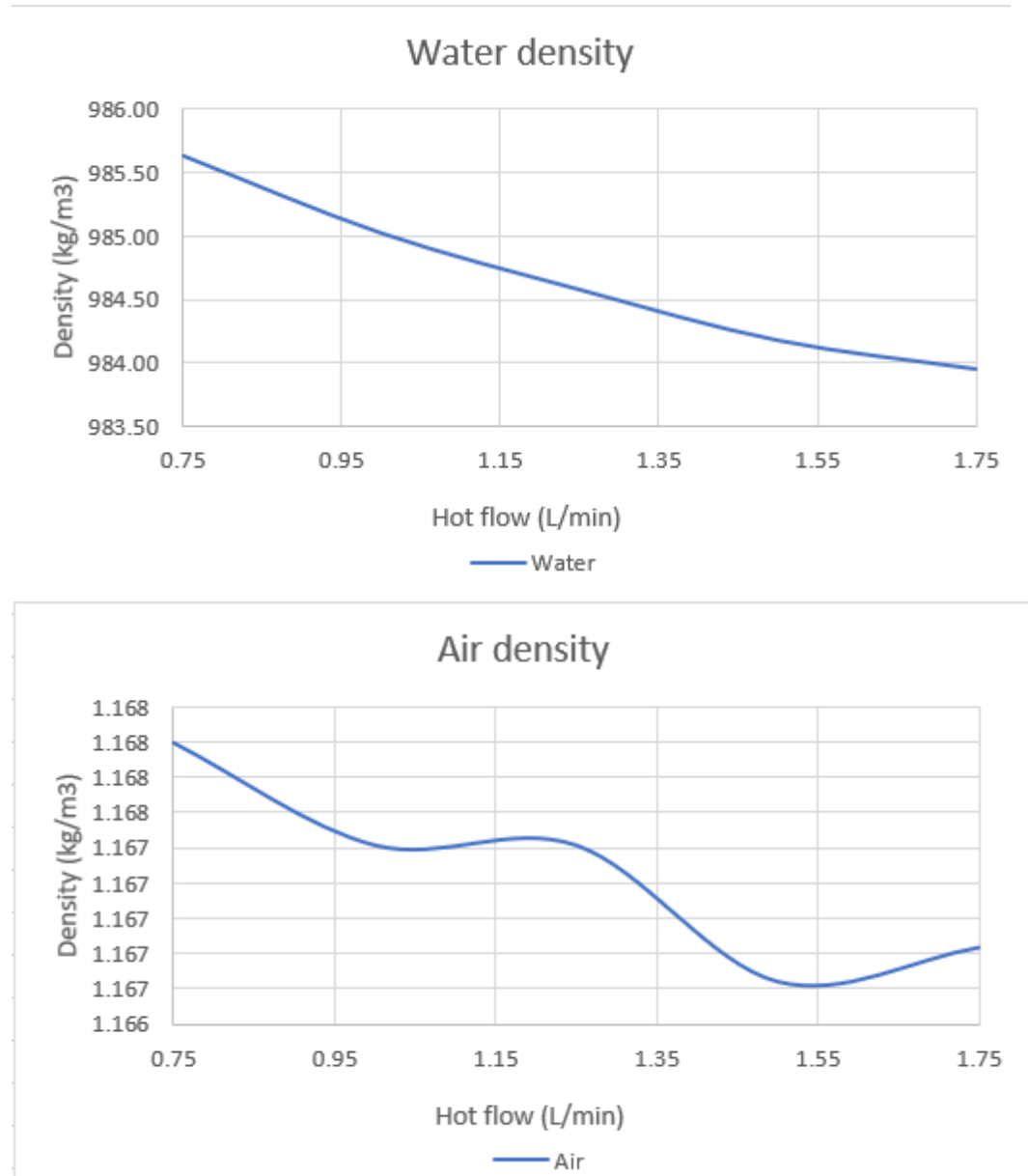


The air temperature difference increases with higher water flow rates as the average temperature of water increases, but the change in temperature is not as significant as in the water example.



Observing the change in average circuit temperature confirms that the higher the hot flow rate, the higher the average water temperature. The change in average air temperature is negligible.

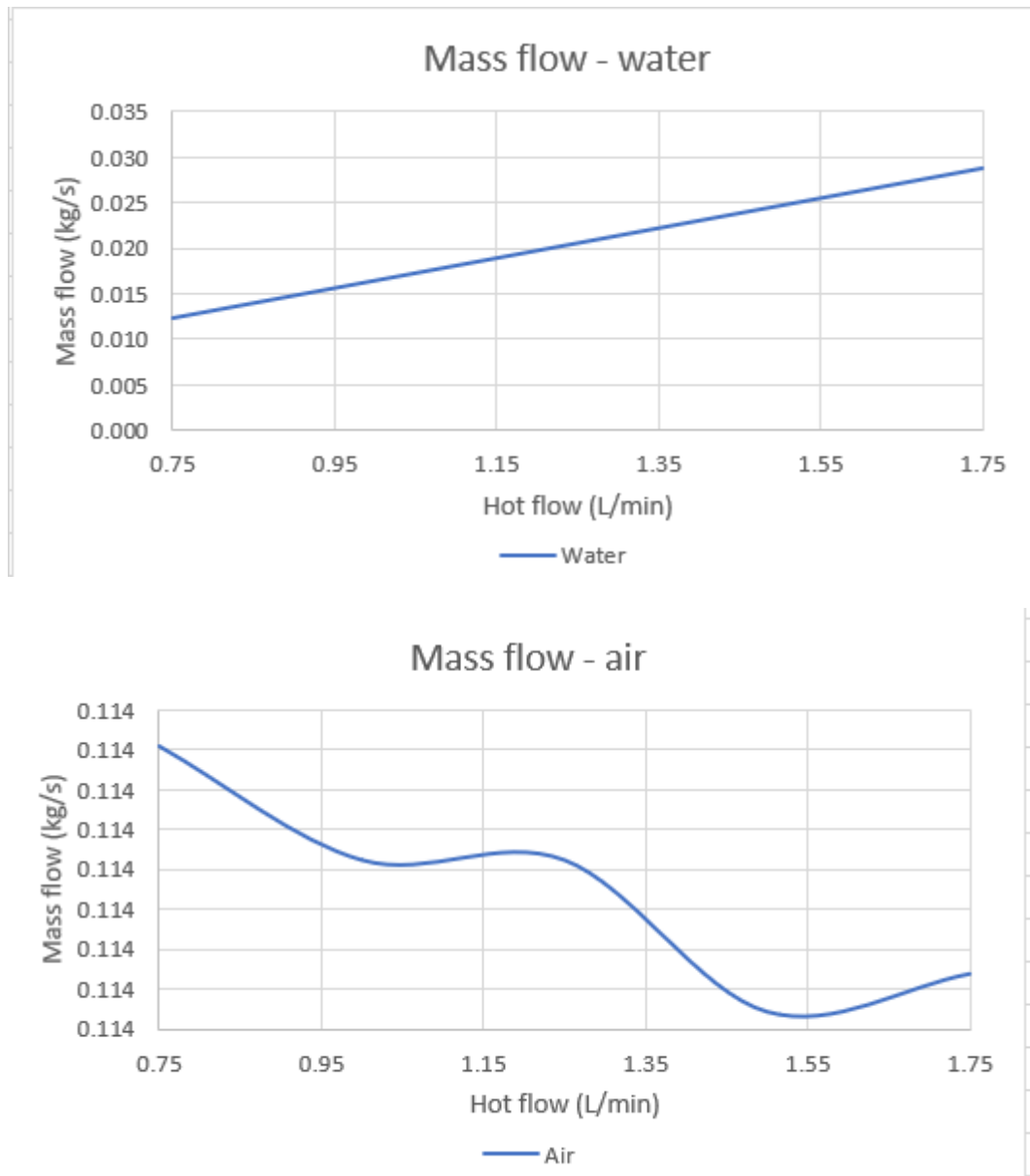
4.3 Water and air density



The general trend shows that the change in density for air and water at different hot flow rates is very small. This is mainly because the changes in average circuit temperature are relatively small. This is especially true for air density. The results show lower density with higher hot flow rates. The air density graph shows unsteady behaviour due to a relatively high margin of error when the scale is taken into consideration, thus the general trend has been used to make an observation.

It can be assumed that the rate of change of water and air density is digressive the higher the hot flow rate.

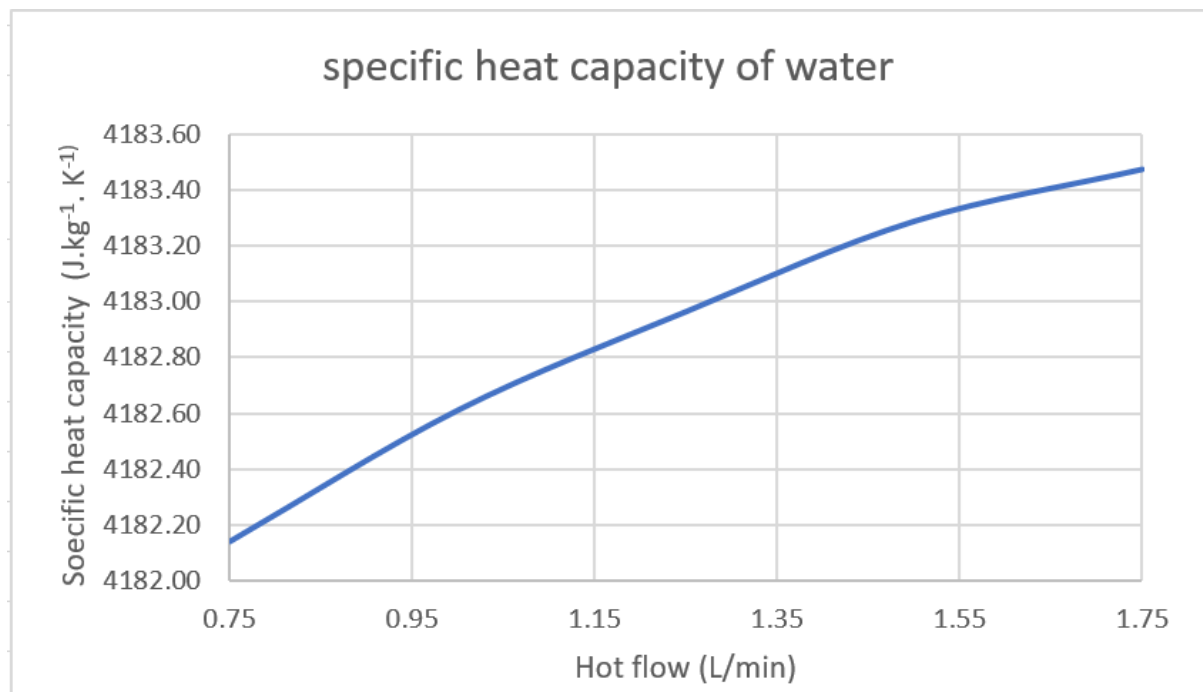
4.4 Air and water mass flow rate



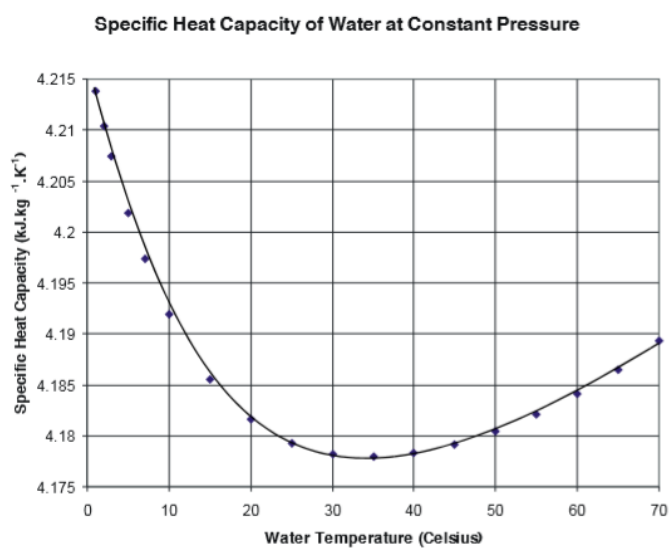
The mass flow of water increases linearly with hot flow rate.

While the second graph shows air mass flow rate fluctuate in a downward trend, its change in mass flow rate can be assumed to be negligible (the graph exaggerates the trend due to narrow range on the y-axis). It has to be taken into account that the air flow rate remains constant throughout this experiment.

4.5 Specific heat capacity of water



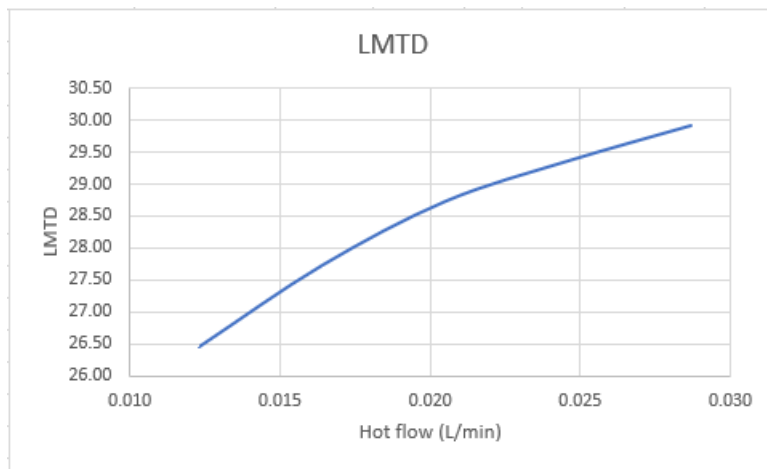
The specific heat capacity of water increases with increased hot flow rate with an exponential decay pattern. This also shows that in this very experiment, with higher average water temperatures (and thus higher hot flow rates), more energy is required to increase the water temperature by one kelvin. If the temperature range in this experiment was extended, the situation would be different as seen in the parabola type figure below.



(TecQuipment, 2014)

Air specific heat capacity can be assumed to be constant ($1005 \text{ J.kg}^{-1} \cdot \text{K}^{-1}$).

4.6 LMTD

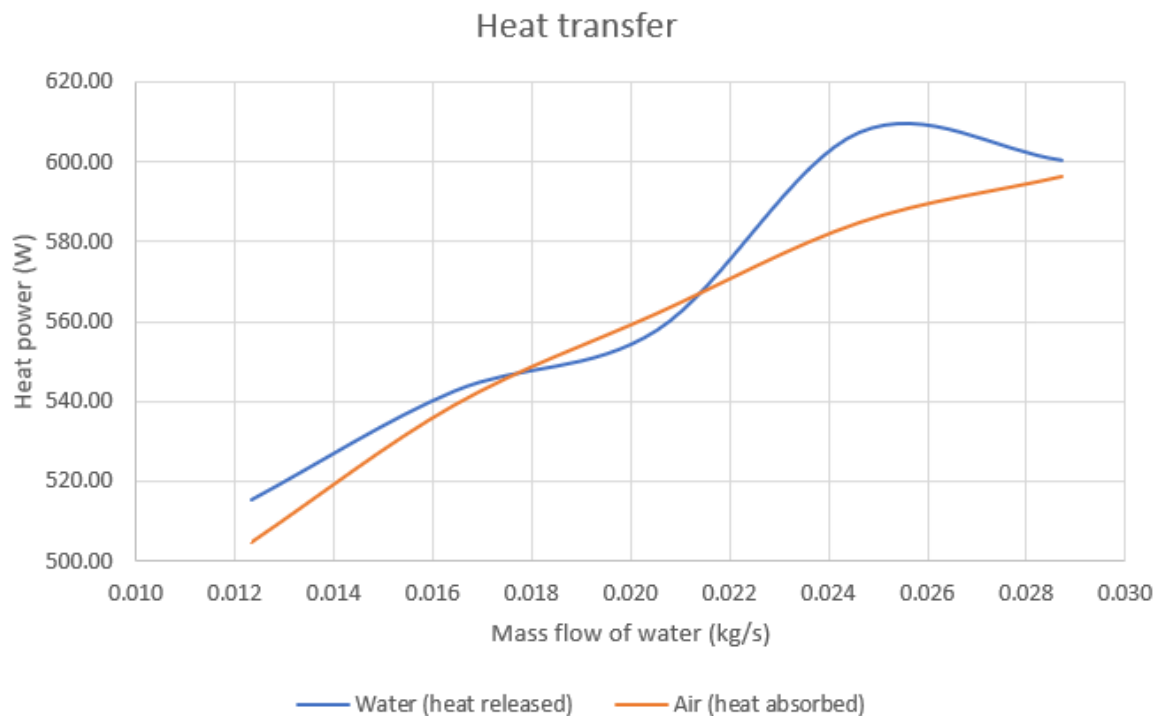


The LMTD is a value that can be used to represent the driving force of heat transfer. It rises with higher water hot flow rates, thus it can be assumed that the heat transfer power will also increase with higher hot flow rates.

4.7 Assignment specific plots

4.7.1 heat released and absorbed

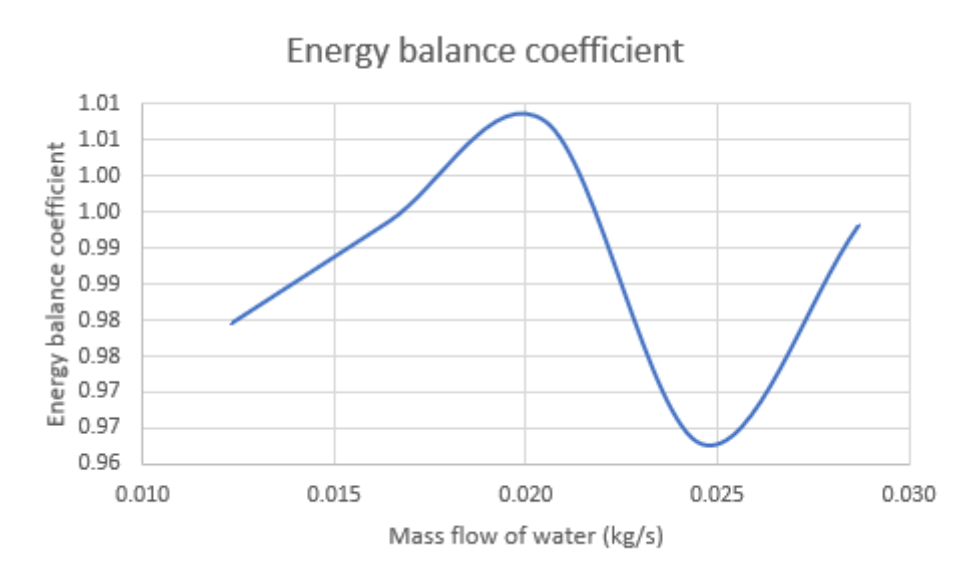
The water emits heat energy while the air absorbs it. Negative values (heat released by water) have been represented as absolute values on the graph.



The results show that with an increased mass flow of water, the heat released by water is increased. The heat power received by air also increases as heat energy transfers from one medium (water) to another medium (air), thus it can be concluded that the overall heat transfer power increases with higher mass flow rates of water. Energy can't be destroyed; it can only be transferred. The trend in the graph shows somewhat of an exponential decay pattern, indicating that the gains from increasing the mass flow rate of water get smaller the higher its value. It has to be considered that this experiment was carried out in real-life conditions and thus the heat exchanger can't be considered as ideal and fully isolated. Some energy can be released to surroundings (or vice versa if the ambient temperature was higher than the heat exchanger temperature). For this reason, and margin of error, the heat power dissipated by water

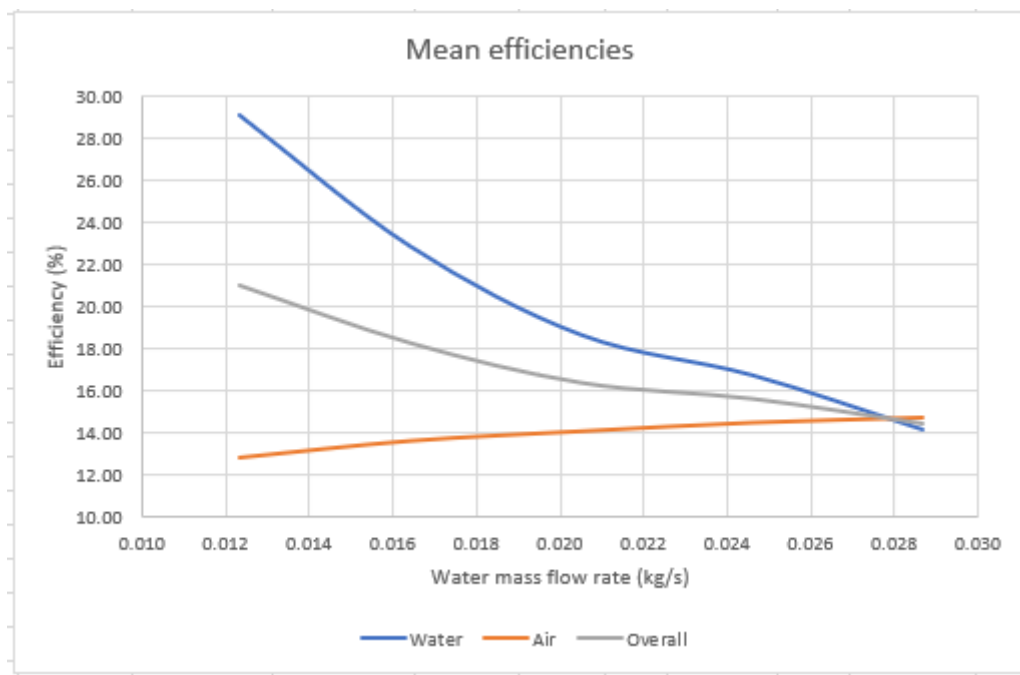
is not exactly equal to the heat power absorbed by the air. More heat is released by water than absorbed by air (one of the data points being an exception). The topic of energy balance coefficient explores this in further detail.

4.7.1.1 *Energy balance coefficient*



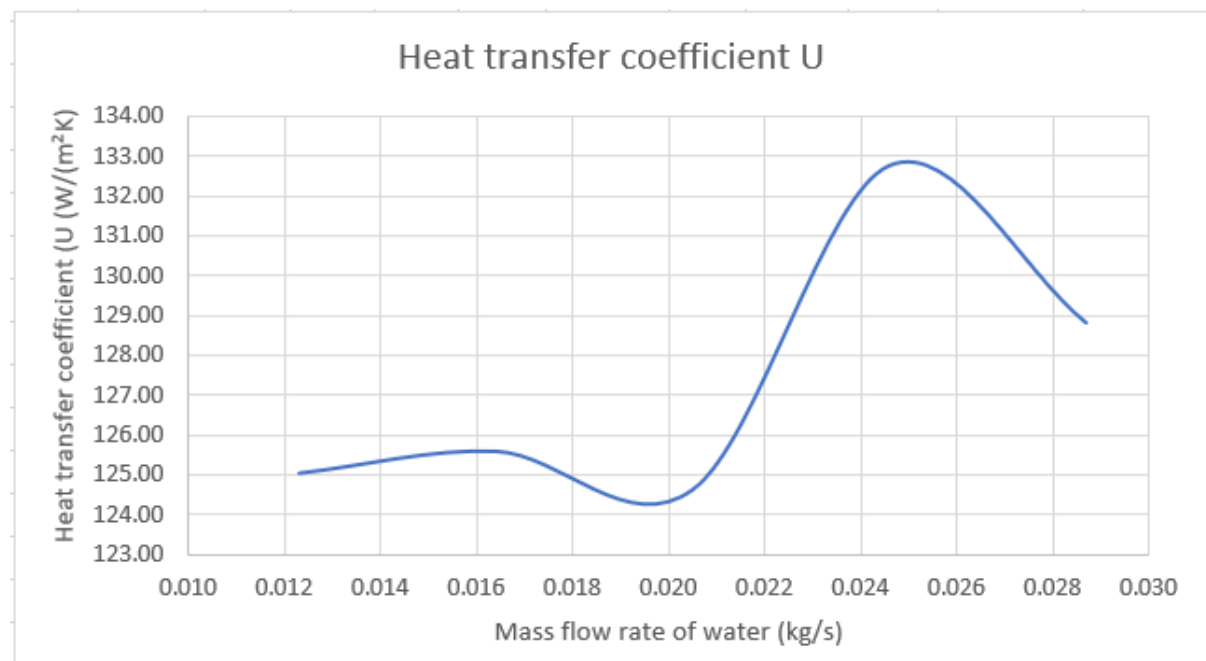
To back up the point made in the earlier section, the graph above shows the energy balance coefficient. Values below one indicate that the heat exchanger has absorbed heat energy from surroundings, whereas values below 1 indicate that heat energy has been transferred to the surroundings. The values are very close to 1, indicating that the heat exchanger is insulated well, but not fully.

4.7.2 Mean temperature efficiencies



The mean temperature efficiency shows the thermal efficiency of the system. In this particular heat exchanger, it is visible that the efficiency of heat dissipation by water significantly reduces with higher water mass flow rates. On the contrary, the efficiency of heat absorbed by the air increases with higher water mass flow rates by not by a significant amount, thus the overall efficiency of the system decreases with higher water mass flow rates. The change in water efficiency over a range of mass flow rates is larger than the change in air efficiency is due to a bigger change in delta temperature of the water relative to air. In an ideal heat exchanger, the temperature difference of the medium (air or water depending on what is being considered) would be the same as the difference between the hottest and coldest points of the heat exchanger, providing 100% efficiency. The efficiency of water is higher at lower mass flow rates due to higher drop in temperature of the system. The gradient of the efficiency line reflects the change in gradient of the heat power emitted/absorbed line.

4.7.3 Heat transfer coefficient



The trend seen in the heat transfer coefficient graph is rather erratic, however, it can be determined that the heat transfer coefficient rises with increased mass flow rates of water. The sudden jump in heat released by water (W) at 0.025 kg/s is the cause of the rather wobbly shape of the heat transfer coefficient line. It can be concluded that at higher mass flow rates, the materials can absorb more heat power per unit of area squared multiplied by temperature. The higher the U value, the easier the heat is transferred from water to air (TLV, n.d.).

4.8 Concluding the findings in experiment 1

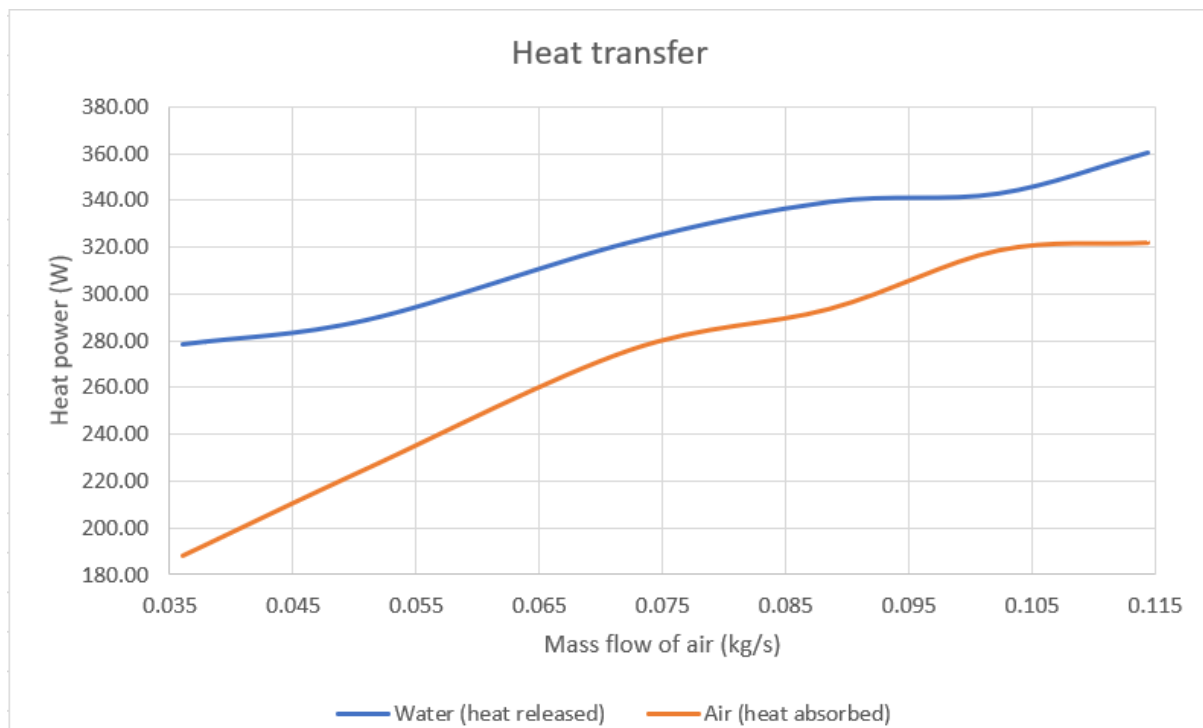
Increasing the mass flow rate of water enables more heat dissipation as the heat transfer graph shows, and the heat transfer coefficient does somewhat rise with higher flow rates. This, however, comes at the cost of lower mean efficiency of the system, not to mention increased running and development costs due to more hydraulic or electrical power needed to move water at a faster rate. The heat power dissipated by water at a flow rate of 0.029 kg/s is only 16.5% higher than at a base/starting water flow rate value of 0.012 kg/s .

5 Experiment 2 – Effects of varying air flow rate

5.1 Results table

Experiment 2 - The effect if varying air flow rate																								
Air pressure Δp	Volume flow (water)	Temperature (water)	Temperature (water)	Temperature difference (water)	Average temperature (water)	Temperature (air)	Temperature (air)	Temperature difference (air)	Average temperature (air)	Water efficiency	Air efficiency	Water density	Air density	Specific heat capacity (water)	Specific heat capacity (air)	Power (water)	Power (air)	Energy balance coefficient	Mean temperature efficiency	Heat driving force	Heat transfer coefficient	Mass flow (water)	Mass flow (air)	
Air pressure Δp (Pa)	Hot Flow (L/min)	$T_{w1}(^{\circ}\text{C})$	$T_{w2}(^{\circ}\text{C})$	$\Delta T_{w1}(^{\circ}\text{C})$	Avg $T_{w1}(^{\circ}\text{C})$	$T_{a1}(^{\circ}\text{C})$	$T_{a2}(^{\circ}\text{C})$	$\Delta T_{a1}(^{\circ}\text{C})$	Avg $T_{a1}(^{\circ}\text{C})$	$T_{a1}(^{\circ}\text{C})$	$\eta_w (\%)$	$\eta_a (\%)$	$\rho_w (\text{kg/m}^3)$	$\rho_a (\text{kg/m}^3)$	$c_{pw} (\text{J kg}^{-1} \text{K}^{-1})$	$c_{pa} (\text{J kg}^{-1} \text{K}^{-1})$	$\dot{Q}_w (\text{W})$	$\dot{Q}_a (\text{W})$	ϵ_{wb}	$\bar{\eta} (\%)$	UMTD	$U (\text{W/m}^2 \text{K})$	$\dot{m}_w (\text{kg/s})$	$\dot{m}_a (\text{kg/s})$
250	0.25	57.6	36.7	-20.9	47.15	25.3	28.1	2.8	26.7	24.9	64.71	8.67	989.28	1.173	4179.68	1005.00	360.08	321.86	0.89	36.69	17.91	-129.05	0.004122	0.114
200	0.25	58.3	38.4	-19.9	48.35	25.4	28.5	3.1	26.95	24.9	60.49	9.42	988.76	1.172	4179.99	1005.00	342.69	318.59	0.93	34.95	19.15	-114.85	0.004120	0.102
150	0.25	58.9	39.2	-19.7	49.05	25.5	28.8	3.3	27.15	24.9	58.98	9.88	988.45	1.171	4180.18	1005.00	339.16	293.61	0.87	34.43	19.71	-110.43	0.004119	0.089
100	0.25	59.2	40.5	-18.7	49.85	25.6	29.4	3.8	27.5	24.9	55.65	11.31	988.09	1.170	4180.41	1005.00	321.84	275.89	0.86	33.48	20.31	-101.69	0.004117	0.072
50	0.25	59.7	42.9	-16.8	51.3	26.3	30.7	4.4	28.5	25.2	50.30	13.17	987.43	1.166	4180.84	1005.00	288.98	225.52	0.78	31.74	21.05	-88.11	0.004114	0.051
25	0.25	60.3	44.1	-16.2	52.2	26.6	31.8	5.2	29.2	25	48.07	15.43	987.01	1.163	4181.13	1005.00	278.56	188.24	0.68	31.75	21.23	-84.21	0.004113	0.036
Heat transfer area	0.1558 m ²																							
Cd	0.6																							
Heater temperatur	333 K																							
Ambient Pressure	100900 Pa																							
Orifice diameter	0.10011 m																							
Orifice area	0.01 m ²																							
Gas constant R	287.00 J kg ⁻¹ K ⁻¹																							
$c_{pw} @ 15^{\circ}\text{C}$	4185.50 J kg ⁻¹ K ⁻¹																							

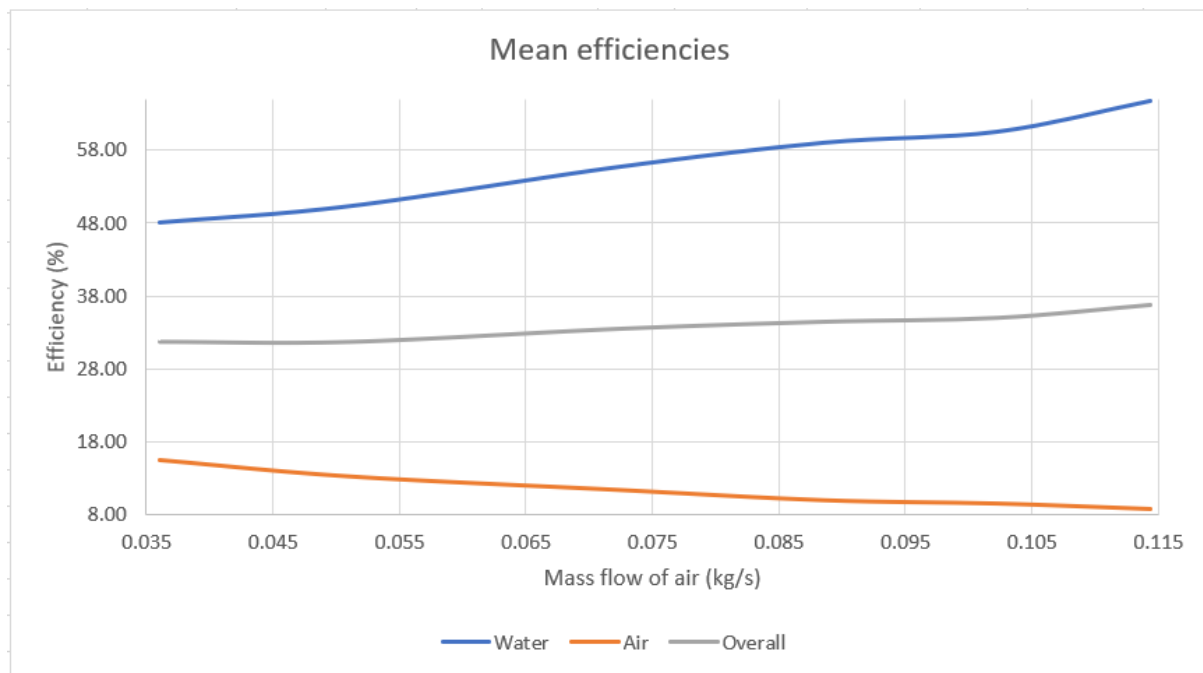
5.2 Heat released and absorbed



The heat power released by water increases with increased air flow rate due to heat being carried away at a faster rate. As expected, the power absorbed by the air also increases with higher air flow rates as heat energy is transferred from water to air. What is interesting to note, is that the difference between power emitted and power absorbed in this experiment is quite large when compared to experiment 1. This suggests that at a lower water mass flow rate of 0.25L/min, more heat power escapes to the surroundings than in experiment 1. The mass flow of air also seems to influence this, as the gap between air and water heat power somewhat decreases with higher mass flow rates of air. This is backed up by the fact that the energy balance coefficient reaches values as low as 0.68, much lower than the 0.96 seen in experiment 1. It has to be taken into consideration that this is not an ideal fully isolated heat exchanger.

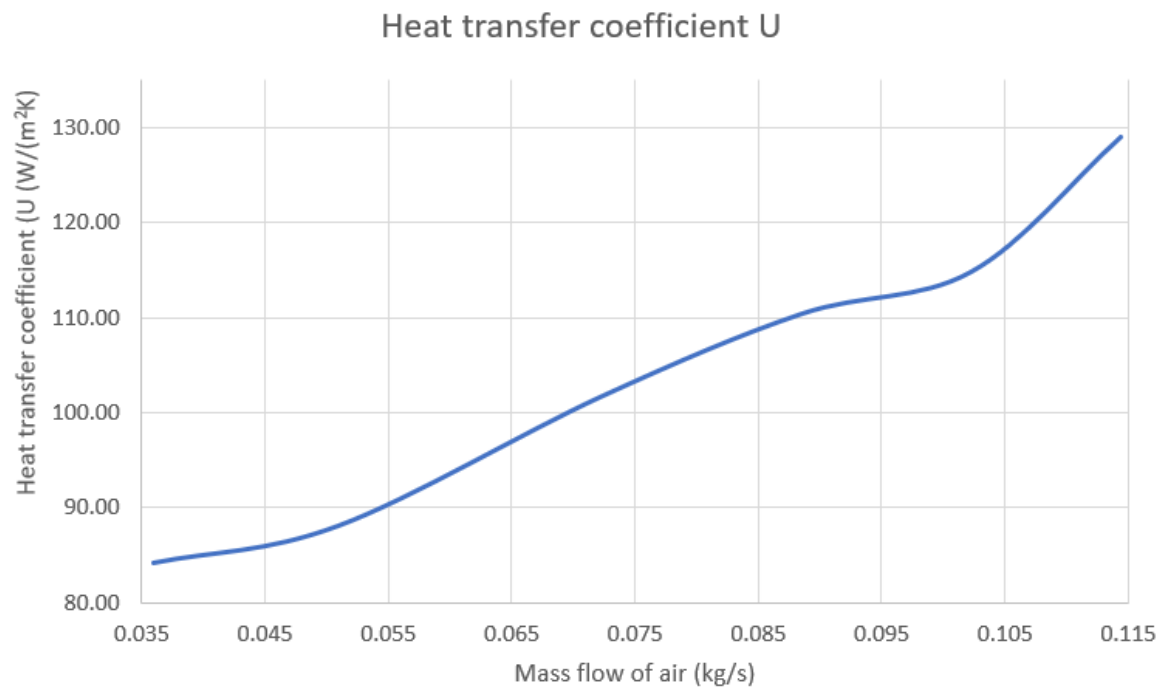
In this particular case, increasing the air flow rate has provided a similar increase in the amount of heat dissipated by water as increasing the water flow rate (85 Watts and 81.5 Watts respectively). Maximising both, the air flow rate and water flow rate would provide the best results.

5.3 Mean temperature efficiencies



The trends seen in the change of efficiency in experiment 2 are opposite to the change in efficiency found in experiment 1. The water efficiency increases, while air the air efficiency decreases. It can be concluded at this point that increasing the mass flow of either of the mediums will cause a reduction in the efficiency of the medium that is being varied. It interesting to note, that unlike in the first experiment, the overall efficiency increases with higher mass flow. It is also worth noting that the overall efficiency in this experiment is greater than in the first experiment.

5.4 Heat transfer coefficient



The heat transfer coefficient for experiment 2 contains a wider range of values when compared to experiment 1, however, both show a pattern of an increase the higher the mass flow. Although the highest value is similar, the lowest value (which occurs at the lowest mass flow) is 40 W/(m²K) lower in experiment 2. This can be attributed to heat driving force (LMTD) having an inverse pattern to experiment 1.

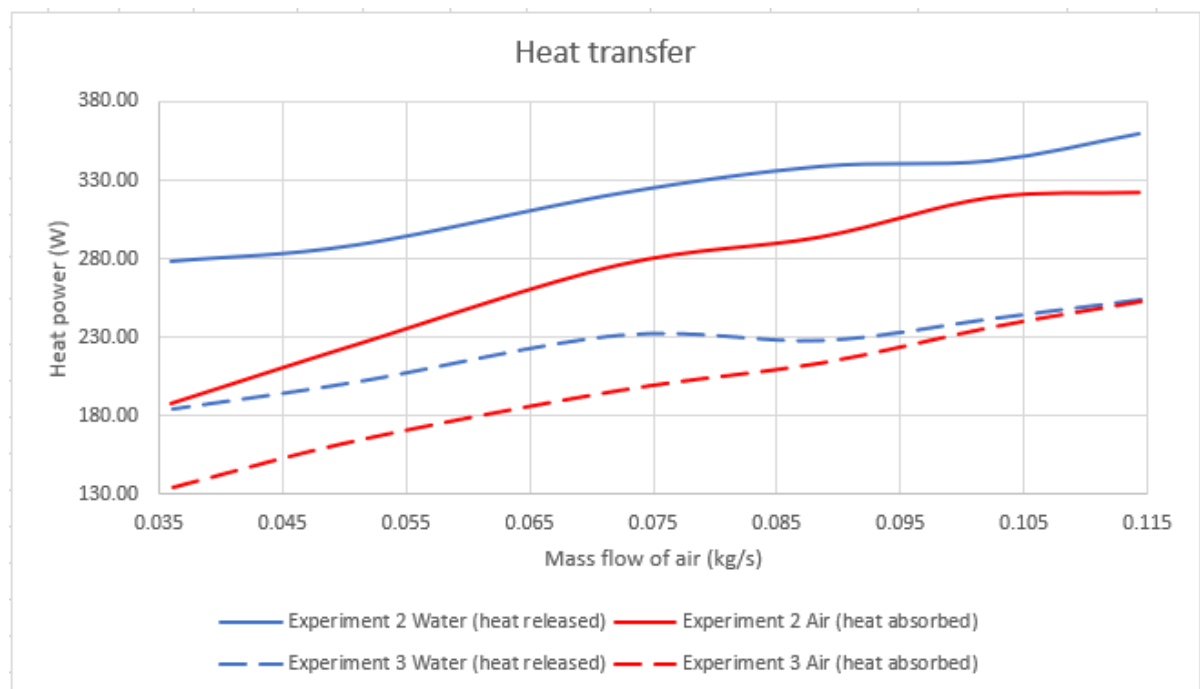
6 Experiment 3 – Effects of varying temperature

For direct comparison between experiment 2 and experiment 3, both experiments have been plotted on the same graph for this section.

6.1 Results table

Experiment 3 - The effect if varying temperature																								
Air pressure delta	Volume flow (water)	Temperature (water)	Temperature (water)	Temperature difference (water)	Average temperature (water)	Temperature (air)	Temperature (air)	Temperature difference (air)	Average temperature (air)	Water efficiency	Air efficiency	Water density	Air density	Specific heat capacity (water)	Specific heat capacity (air)	Power (water)	Power (air)	Energy balance coefficient	Mean temperature efficiency	Heat driving force	Heat transfer coefficient	Mass flow (water)	Mass flow (air)	
Air pressure Δp (Pa)	Hot Flow (L/min)	T _{w1} (C)	T _{w2} (C)	ΔT _w (C)	Avg T _w (C)	T _{a1} (C)	T _{a2} (C)	ΔT _a (C)	Avg T _a (C)	η _w (%)	η _a (%)	ρ _w (kg/m³)	ρ _a (kg/m³)	c _{pw} (J kg ⁻¹ K ⁻¹)	c _{pa} (J kg ⁻¹ K ⁻¹)	Q _w (W)	Q _a (W)	C _{eff}	η (%)	LMTD	U (W/(m²K))	m _w (kg/s)	m _a (kg/s)	
250	0.25	48.9	34.2	-14.7	41.55	25.1	27.3	2.2	26.2	61.76	9.24	991.60	1.18	4178.56	1005.00	-253.79	253.10	1.00	35.50	13.65	-119.34	0.004132	0.114	
200	0.25	48.6	34.6	-14	41.6	25.2	27.5	2.3	26.35	59.83	9.83	991.58	1.17	4178.57	1005.00	-241.70	236.61	0.98	34.83	13.67	-113.51	0.004132	0.102	
150	0.25	48.1	34.9	-13.2	41.5	25.3	27.7	2.4	26.5	57.89	10.53	991.62	1.17	4178.56	1005.00	-227.90	213.77	0.94	34.21	13.53	-108.08	0.004132	0.089	
100	0.25	49	35.6	-13.4	42.3	25.4	28.1	2.7	26.75	56.78	11.44	991.30	1.17	4178.68	1005.00	-231.28	196.28	0.85	34.11	14.04	-105.70	0.004130	0.072	
50	0.25	49.1	37.4	-11.7	43.25	25.8	29	3.2	27.4	50.21	13.73	990.92	1.17	4178.85	1005.00	-201.87	164.31	0.81	31.97	14.60	-88.72	0.004129	0.051	
25	0.25	49.4	38.7	-10.7	44.05	26.4	30.1	3.7	28.25	46.52	16.09	990.59	1.17	4179.00	1005.00	-184.56	134.15	0.73	31.30	14.64	-80.93	0.004127	0.036	
Heat transfer area A	0.1558 m²																							
Cd	0.6																							
Heater temperature	318 K																							
Ambient Pressure	100900 Pa																							
Orifice diameter	0.10011 m																							
Orifice area	0.01 m²																							
Gas constant R	287.00 J kg ⁻¹ K ⁻¹																							
c _{pw} @ 15c	4185.50 J kg ⁻¹ K ⁻¹																							

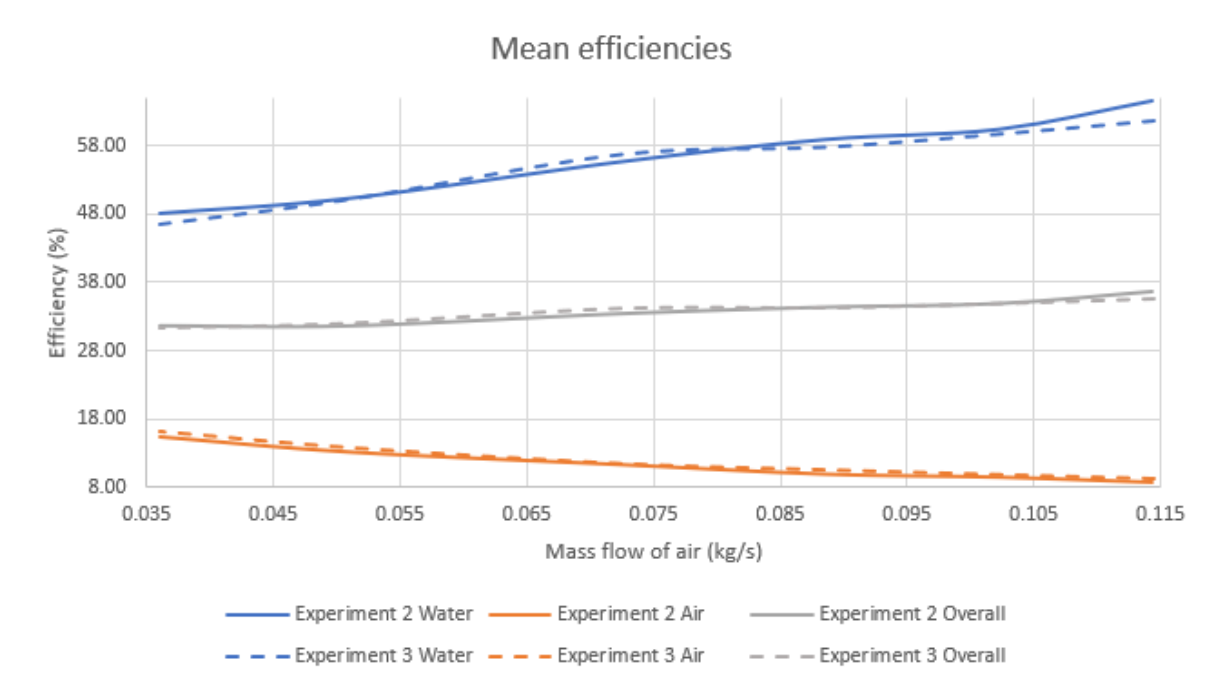
6.2 Heat released and absorbed



Decreasing the heater temperature by 15 degrees Celsius results in significantly lower heat power emitted by water and a lower amount of heat power absorbed by air. This is due to the difference in

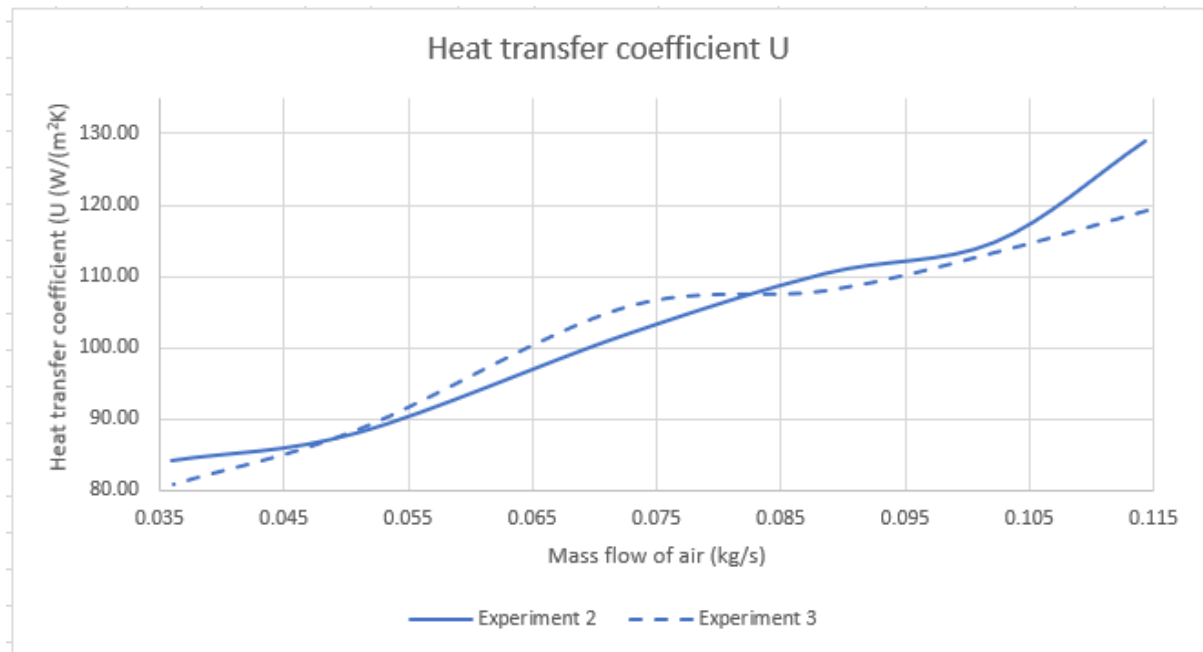
temperatures between air and water being smaller in experiment 3 (causing lower heat driving force). This can be verified by looking at the mean value of LMTD, which is 19.9 for experiment two and 14.02 for experiment three. For both experiments, the heat power increases with the increase of mass flow of air. Its worth to note that the graph also shows less heat losses to the surrounding environment in experiment 3, especially towards higher mass flow rates of air, which can also be seen by looking at the energy balance coefficient value (0.89 for experiment two and 1.00 for experiment three at 0.114kg/s (air))

6.3 Mean temperature efficiencies



The change in efficiency between experiment 2 and 3 is negligible. It can be concluded that the efficiency of the system does not change when the heater temperature is decreased by 15 degrees. The explanation provided for experiment 2 also applies for experiment 3.

6.4 Heat transfer coefficient



Like with experiment two, 'U' value increases the higher the mass flow of air. While the change in heat transfer coefficient between experiment two and three is not large, it is sufficient enough to conclude that at lower heater temperatures, the heat transfer coefficient is somewhat lower at the maximum mass flow of air when compared to experiment two. It is hard to precisely determine the exact impact of decreasing the heater temperature due to measurement margin of error when small ranges of values are involved. This can be seen by looking at the graph as the largest 'U' value varies between experiment two and three depending on the mass flow of air.

7 Conclusion

Increasing the temperature difference between one medium and another will create a bigger driving force, causing more heat power to be emitted by water and thus more heat power absorbed by the air. The heat power absorbed and heat power emitted values are not the same because of a margin of error but more notably because of heat being transferred to the surroundings as noted by the balance coefficient which can be regularly seen reaching values below 1. Reducing the air flow rate has a very significant impact on the increase of heat being transferred to surroundings, while other experiments proved that varying air flow rate has had close to no effect on this. While reducing the heater temperature in experiment 3 has somewhat helped to reduce this issue, it was not enough to stabilise the heat balance coefficient. Increasing the mass flow rate of water or mass flow rate of air will also cause an increase in heat power due to an increase in the rate of heat transfer. All experiments have shown that increasing water or air flow rate provides more heat transfer power however at an exponential decay (especially at lower heater temperatures). This means that at some point, increasing either of those would not provide a significant benefit as the gradient of the heat power line begins to level off.

It can also be seen that reducing or increasing the heater temperature does not affect the system efficiency, despite temperature difference being different between experiment two and three. Throughout the experiments, an increase in heat transfer coefficient can be observed when the air or water mass flow rate is increased. This means that the material is able to conduct heat at a faster rate when it is at higher temperatures. It is also worth to note that increasing the water flow rate causes a decrease in overall system efficiency while increasing air flow rate has the opposite effect.

8 References

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