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Harvesting Rejected Heat by the Split A/C Condenser for Producing Warm Water

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Condenser; Conentric Tube Heat Exchanger;Heat Harvesting; Split A/C

Abstract

This study investigates the potential use of rejected heat by outdoor A/C units. Rather than being lost to the environment, the heat will be utilized to make warm water. An experimental setup was designed and constructed that cooled down the refrigerant heat of a condenser by tap water. R22 and tap water were used as hot and cold fluid, respectively. The inlet and outlet temperature of the shell side fluid i.e., water was measured by thermocouple. The mass flow rate of the inlet water was controlled by a valve and measured using a rotameter. The influence of inlet water temperature was also investigated in this study. It is found that recovered thermal energy decreased from 3.72 kW to 2.84 kW as mass flow rate of water decreased from 0.1 kg/s to 0.07 kg/s. When water flow rate decreased to 0.05 kg/s, thermal energy of 4.28 kW was recovered due to the rapid increase of water outlet temperature. Furthermore, this heat exchanger is utilized to determine the heat released by the condenser and the temperature of the condenser-generated hot water.

1. Introduction

Waste heat is generated throughout the bulk of a system's operations and subsequently released into the environment, despite the fact that it might be utilized for other beneficial and profitable purposes (Afifi, 2016; Deymi-Dashtebayaz & Valipour-Namanlo, 2019). It is associated with air or water waste streams that are discharged into the environment. The scientists are working on the recovery of waste heat. An air-conditioner consumes electric power and rejects heat to the environment. According to the International Energy Agency (IEA), air conditioning devices consume about 10% of the world's power. It is estimated that by 2050, approximately two-thirds of the world's homes will have air conditioning systems, with half of this growth coming from India, China, and Indonesia.In South Asia, Pakistan alone sees an annual addition of about 6 to 6.5 million air conditioners (Ramzan *et al.*, 2021). After anthropogenic warming of 1.5°C (2.0°C), the demand for residential air

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conditioning across the United States could increase by up to 8 percent, with a range of 5 percent to 8.5 percent (13 percent, with a range of 11 percent to 15 percent), or globally by 13 percent, with a range of 11 percent to 15 percent (Obringer *et al.*, 2021). In a recent study, the rise in land surface temperature of Bangladesh is 31.1℃ during 2013 to 2020 and half of the population of the country will reside in cities by 2025 (Roy *et al.*, 2021) which made people adopting more air conditioning systems. These vast use of air conditioners connects with more power usage which links to production of green-house gases, so the climate is also affected (Chowdhury *et al.*, 2020). Thus, the heat rejected from the air conditioners would be the root cause for global warming. On other hand, a reliable supply of hot water is a need in industrialized nations and is becoming increasingly popular in developing countries. Most residential structures in industrialized nations have a central air- conditioning system and a single central domestic hot water delivery system. A room air conditioner and an electrical, gas-fired or oil-fired water heater are also required in developing nations to provide space cooling and household hot water supply, respectively. Condensers of air conditioning system can be water or air cooled. Usually, the condensing fluid is routed (i) inside the tubes with air cooling or (ii) inside the tubes with a water-cooled arrangement (Thulukkanam, 2017). Again, Condensers are heat exchangers which are of different kinds, among them double pipe heat exchangers are the elementary types which have two concentric pipes of non-identical diameters.

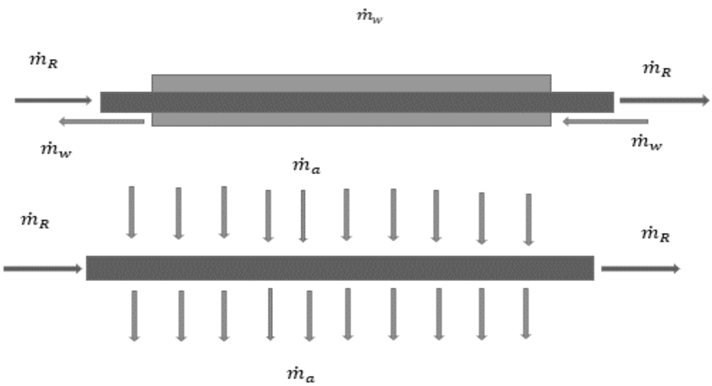

Figure 1: Double pipe counter flow water-cooled condenser and air-cooled cross flow condenser.

In double pipe heat exchangers, flow configurations can be either parallel or counter flow arrangements. In compact heat exchangers, where hot and cold fluids typically move perpendicular to each other, the flow configuration is referred to as cross-flow. Heat rejected at the air-cooled condenser can be calculated from,

$$\dot{q}_a = \dot{m}_a(h_{out} - h_{in}) \tag{1}$$

The heat rejected at water-cooled condenser is,

$$\dot{q}_w = \dot{m}_w(h_{out} - h_{in}) \tag{2}$$

Generally, heat from air-cooled condensers must be evacuated directly to the outdoors. This not only wastes energy but also causes thermal pollution in the surrounding environment. At the same time, most water heaters consume a significant amount of raw energy. Several studies have investigated the heat recovery potential of air conditioning condensers for various applications. Lokapure and Joshi (2012) conducted an experiment utilizing heat from a window air conditioner condenser by attaching a helical coil tube heat exchanger to improve system efficiency and provide hot water. The water temperature increased by 10°C at a flow rate of 1 lpm, reaching a maximum of 43°C from an initial temperature of 33°C. Sivaram *et al.* (2015) used a 1.5 Ton split air conditioning system condenser submerged in a water tank to produce hot water at 55°C. They observed that up to a hot water temperature of 37°C, the COP of the waste heat recovery system was higher than that of a conventional air conditioner. Beyond 37°C, as the hot water temperature increased, the COP of the waste heat recovery system decreased and became lower than that of a conventional air conditioner.

Fei Liu *et al.* (2008) experimented with an air conditioning water heater system in various modes for different seasons, achieving an inlet temperature of 15°C and an outlet temperature of 55°C in the space cooling and water heating mode. Napitupulu *et al*. (2018) used a modified condenser, a double pipe heat exchanger with a total length of 16.128 m, and achieved a maximum hot water temperature of 56.3°C when the cooling water entered the condenser at 36°C with a mass flow rate of 0.6 lpm. Aziz and Satria (2014) tested an air conditioning water heater with a trombone coil type dummy condenser at different cooling loads. The dummy condenser, placed in a 50 L water tank between the compressor and the actual air-cooled condenser, heated the water to a maximum temperature range of 61.54°C to 64.33°C after 30 minutes of testing at cooling loads of 3000 W.

Sonawan *et al*. (2018) conducted an experimental investigation using a copper coil submerged in a 40 L water tank as an additional condenser alongside an air-cooled condenser. The system raised the water temperature to a maximum of 69°C. Ong (2012) compared the performance of air conditioning systems with and without heat recovery systems, finding little difference in energy savings and cooling capacity. However, the internal coil method was more efficient, heating water up to 75°C after 8 hours of operation, compared to an exterior coil looped around the tank. Jiang *et al*. (2006) employed a 130 L cylindrical water tank and achieved a maximum static water temperature of 115°C. Rahman and Ng (2006) designed a heating tank with a copper tube conveying refrigerant coiled around the inner chamber filled with water. This system raised the water temperature by 46.5°C (from 28.5°C to 75°C) within five hours of operation. Wang (2005) studied a split air conditioner with a hybrid energy storage and water heater system, heating 90 kg of water from 18.2°C using refrigerant heat, which improved system performance. Abu (2006) designed and tested a thermosiphon heat recovery system with two heat exchangers installed between the compressor and condenser. They observed a 10°C temperature difference at the top and bottom of the tank after 4 hours with a coiled heat exchanger and 8 hours with a concentric heat exchanger.

As previously mentioned, many researchers have studied the utilization of condenser heat for various applications where water flow was either small or static. This study aims to investigate the temperature difference at higher water flow rates by replacing the air-cooled condenser with a Double Pipe Heat Exchanger (DPHE). The DPHE is designed to effectively capture waste heat into water at higher flow rates while maintaining a simple, compact, and cost-effective construction. This modified condenser provides a higher flow rate of warm water for various household tasks while also delivering air conditioning for room comfort.Section 2, 3 and 4 explain the objectives, experimental setup and design of DPHE, respectively. Results and discussion have been elaborated in section 5.

Nomenclature

A	Area, m^2	$\dot{m}$	Mass flow rate, kg/s
A_f	Area of flow, m^2	Pr	Prandtl number
C_p	Specific heat, kJ/kg.K	Q	Specific heat capacity, kW
D	Diameter, m	Re	Reynolds number
h	Heat transfer coefficient, kW/m^2K	T	Temperature, °C
h_{fg}	Heat of vaporization, kJ/kg	ΔT	Temperature Difference, °C
K	Thermal conductivity, kW/m.K	ΔT_{lm}	Log mean temperature, °C
L	Length, m	U	Overall heat transfer coefficient, kW/m^2K
$LMTD$	Log mean temperature difference, °C	x	Vapor quality

The aim of this study is to design and construct a counterflow heat exchanger to utilize the rejected heat from a split A/C condenser for heating water. This involves observing the heat transfer from the modified double-pipe counterflow water-cooled condenser and measuring the temperature change between the inlet and outlet water. By capturing condenser heat, this system can provide hot water for various household and apartment applications.

2. Calculation Procedure for Water-cooled DPHE Condenser

Pipe length and diameter are important parameters in designing a heat exchanger. The inner diameter of the pipe was selected based on availability. The calculation procedure for determining the heat exchanger length is shown in Figure 2.

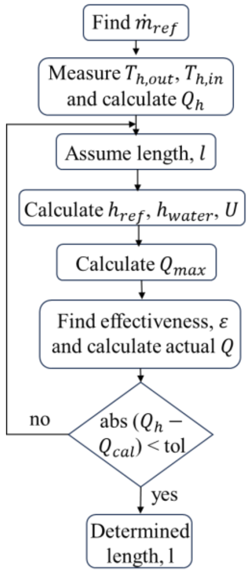

Figure 2: Calculation procedure flow chart.

The mass flow rate of the refrigerant ($\dot{m}_{ref}$) is found in the compressor catalog. The heat rejection rate of the air-cooled condenser is computed from the refrigerant's inlet and outlet temperatures. The overall heat transfer coefficient is determined by assuming the length of the condenser tube and calculating the heat transfer coefficients for both the refrigerant and the water. The maximum heat transfer rate and effectiveness are then calculated using the effectiveness-NTU method. The calculated and measured heat transfer rates are compared. If the deviation between these two rates is not within the tolerance limit, the length of the condenser tube is reassumed. This iterative process continues until the deviation is less than the tolerance.

2.1 Heat rejection calculation of condenser

The heat rejections of refrigerant vapor phase, two phase and liquid phase are calculated with the following equations

$$\dot{Q}_{single\ phase} = \dot{m}c_p\Delta T. \tag{1a}$$

$$\dot{Q}_{two\ phase} = \dot{m}h_{fg}. \tag{1b}$$

2.2 Heat Transfer Co-efficient of Refrigerant

2.2.1 Single phase heat transfer coefficient

The Reynolds number, the Prandtl number, and the heat transfer coefficient equations for single phase refrigerant are as follows:

$$Re = \frac{\rho V D_{inner}}{\mu}. \tag{2a}$$

The above equation can be re-written as:

$$Re = \frac{4\dot{m}}{\pi D_{inner}\mu}. \tag{2b}$$

$$Pr = \frac{\mu c_p}{k}. \tag{2c}$$

$$h = \frac{k}{D} f(Re, Pr). \tag{2d}$$

2.2.2 Two-phase heat transfer co-efficient

Two phase heat transfer coefficient is calculated by using the modified equation of viscosity. The two phase viscosity of refrigerant is calculated as:

$$\mu_{tp} = x\mu_{vapor} + (1-x)\mu_{liquid}. \tag{3}$$

Refrigerant flow area can be calculated by $\left(\pi D_i^2/4\right)$. The total heat transfer co-efficient of inner tube refrigerant calculated 2.515 KW.

2.3 Heat Transfer Co-efficient of Water

Water flows at the shell side of the heat exchanger. Hence, water flow area can be calculated using the following equation:

$$A_f = \frac{\pi}{4}\left(D_{outer}^2 - D_{inner}^2\right). \tag{4}$$

Equation 4 helps to calculate mass flow rate of water. In Equation 2a, D_{inner} needs to be replaced by $(D_{outer} - D_{inner})$ to calculate Reynolds number for water flow.

2.4 Overall Heat Transfer Co-efficient

The equation for overall heat transfer coefficient is,

$$\frac{1}{UA_o} = \frac{1}{h_i A_i} + \frac{ln(D_o/D_i)}{2\pi kL} + \frac{1}{h_o A_o}. \tag{5}$$

The length of the heat exchanger is calculated by,

$$L = \frac{Q_h}{\pi DU(T_{h,in} - T_{h,out})}. \tag{6}$$

As the diameter of the UPVC pipe varies, so does the length of the heat exchanger shown in Figure 3. We have chosen the double-pipe heat exchanger as a condenser with an outer UPVC tube diameter of 25.4 mm. This diameter of the UPVC pipe was chosen because it is easily accessible, and high water pressure in the annulus has minimal impact on the pipe surface. As the diameter decreases, the annular gap shrinks, resulting in increased water pressure close to the pipe surface.

As indicated in Figure 4, a copper pipe with a diameter of 0.000952 m was placed as an inner tube within the UPVC pipe. The total lengths of the UPVC and copper pipes are 12.6 m and 15.24 m, respectively, and the heat exchanger has 12 passes. Twelve UPVC pipes, each approximately 1 meter in length, were used. This 12-pass double-pipe heat exchanger (condenser) measures 130 cm in length, 44.5 cm in width, and 29.8 cm in height. UPVC T-joints were applied at both ends of the UPVC pipes to transmit water from one pipe to another. A 0.6096 m long UPVC pipe was used to connect the T-joints of two UPVC pipes, allowing water to flow from one pipe to another.

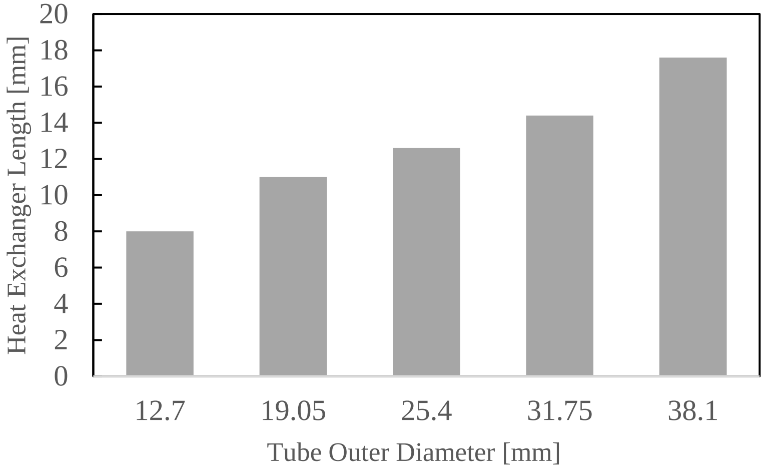

Figure 3: Effect of outer pipe diameter on pipe length.

Figure 4: Modified double pipe heat exchanger (Condenser).

3. Experiment with a Water Cooled Condenser

3.1 Test Setup

The experimental setup is designed to produce warm water by utilizing the heat generated by the A/C condenser. Figure 5, a simple block diagram, facilitates comprehension of the entire experiment and the operation of this air conditioning system. A water-cooled condenser was installed in place of an air-cooled condenser.The compressor was then activated to start the system. By compressing the R22 gas, the compressor increased the pressure and temperature. Cold water was distributed from a water tank in the opposite direction. A flow control valve was used to adjust and control the flow of water to examine the temperature variation at different flow rates. As shown in Figure 6, the setup consists of the following components: a compressor with a 1 kW electric capacity, an indoor A/C unit measuring 120 cm in length and 92 cm in width, a modified water-cooled condenser, and a capillary tube with a length of 81.28 cm. A digital thermometer was used to measure the temperature of the condenser water at both the inlet and outlet. The flow of water was measured using a rotameter.

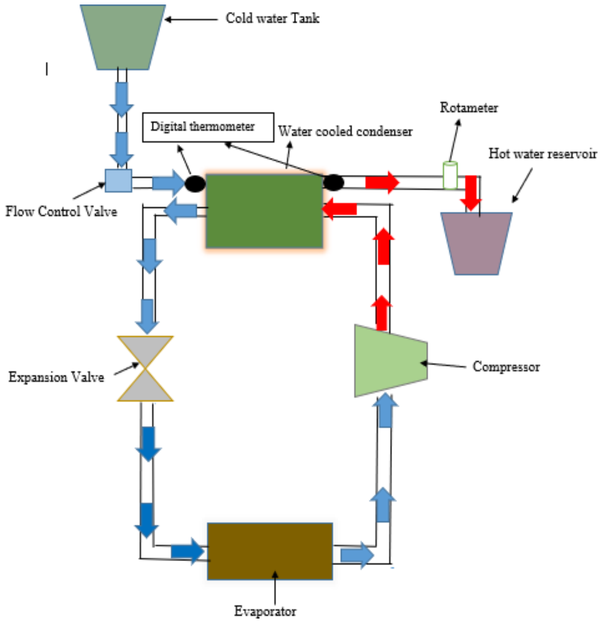

Figure 5: A block diagram of the test setup.

Figure 6: Fabricated experimental setup.

In the experiment, water flow rates of 3 lpm (0.05 kg/s), 4 lpm (0.07 kg/s), 5 lpm (0.08 kg/s), and 6 lpm (0.1 kg/s) were utilized. A rotameter was employed at the output point of the water flow section to measure the flow. When the system is turned on, the compressed high-temperature R22 gas and cold water pass through the condenser. The R22 gas releases heat into the water, increasing the water's temperature. The temperature difference between the inlet and outlet water was measured using a digital thermometer mounted in the inlet and outlet sections. In the experiment, three different input temperatures were used. Each experiment was conducted twice for each temperature and flow rate to facilitate comparison. Every experiment was conducted for at least 30 minutes, as the rise in water temperature was always halted after 30 minutes. The temperature difference of water was finally tested for a variety of flow rates and water temperatures at the inlet.

3.2 Validation of Digital Thermometer

To determine the accuracy of temperature measurements, digital thermometers were compared to analog thermometers.

Table 3.1: Comparison between inlet Digital Thermometer and Analog Thermometer

Temperature °C		%
Digital Thermometer (1)	Analog Thermometer	Deviation
26.7	26.6	0.38
29.4	29.3	0.34
53.1	53	0.19
42.1	42	0.24
		Average = 0.3 %

Table 3.2: Comparison between outlet Digital Thermometer & Analog Thermometer

Temperature °C		%
Digital Thermometer (2)	Analog Thermometer	Deviation
25.5	25.6	0.39

41.9	42	0.24
49.9	50	0.2
27.3	27.4	0.36
		Average = 0.3 %

4. Results and Discussion

4.1 Temperature Changes with Time for Different Flow Rates

We recorded temperature changes over time for various flow rates. We conducted the experiment two times for 30 minutes at each flow rate.

4.1.1 Experimental test when the watertemperature is 28°C

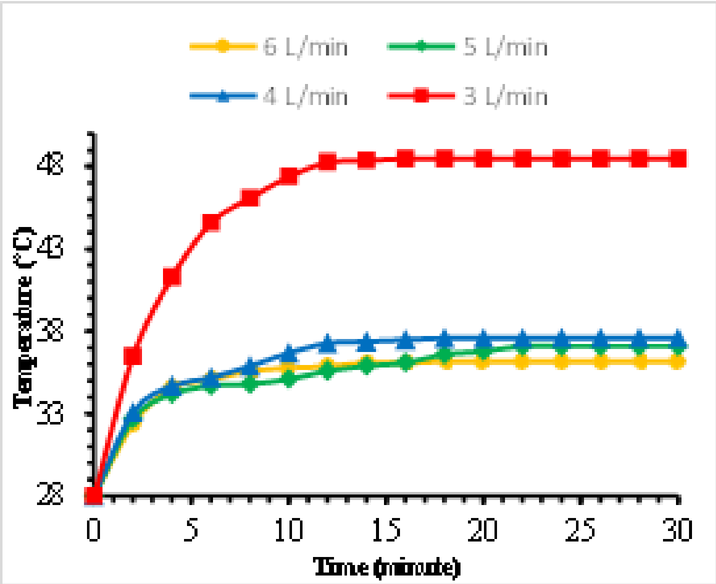

Figure 7: Time vs temperature graph when water temperature is 28°C (1st exp).

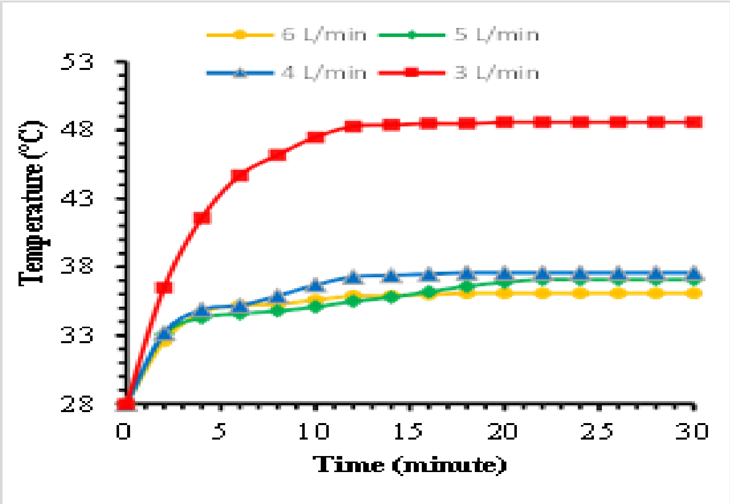

Figure 8: Time vs temperature graph when water temperature is 28°C (2nd exp).

In the first experimental test with an input temperature of 28°C, we observed the maximum temperature at a flow rate of 3 lpm and the minimum temperature at a flow rate of 6 lpm. The second experimental test, also with an input temperature of 28°C, yielded the same results: the maximum temperature at a flow rate of 3 lpm and the minimum temperature at a flow rate of 6 lpm.

4.1.2 Experimental test when the water temperature is 29°C

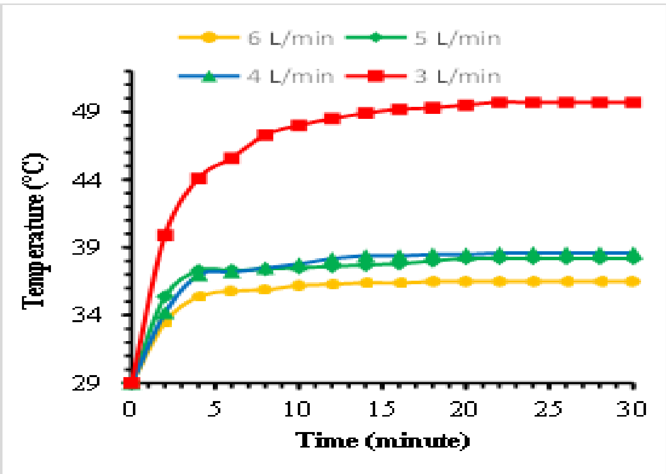

Figure 9: Time vs temperature graph when water temperature is 29°C (1st exp).

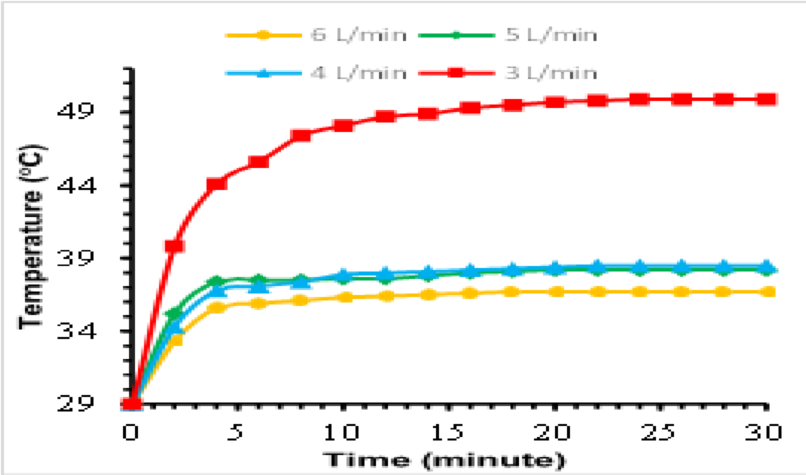

Figure 10: Time vs temperature graph when water temperature is 29°C (2nd exp).

In the first experimental test with an input temperature of 29°C, we observed the maximum temperature at a flow rate of 3 lpm and the minimum temperature at a flow rate of 6 lpm. The second experimental test, also with an input temperature of 29°C, yielded the same results: the maximum temperature at a flow rate of 3 lpm and the minimum temperature at a flow rate of 6 lpm.

4.1.3 Experimental test when the water temperature is 30°C

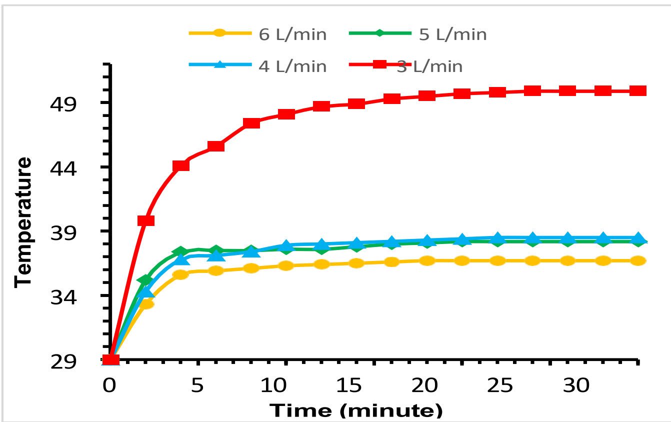

Figure 11: Time vs temperature graph when water temperature is 30°C (1st exp).

In the first attempt with an input temperature of 30°C, we observed the maximum temperature at a flow rate of 3 lpm and the minimum temperature at a flow rate of 6 lpm. The second attempt, also with an input temperature of 30°C, yielded the same results: the maximum temperature at a flow rate of 3 lpm and the minimum temperature at a flow rate of 6 lpm.

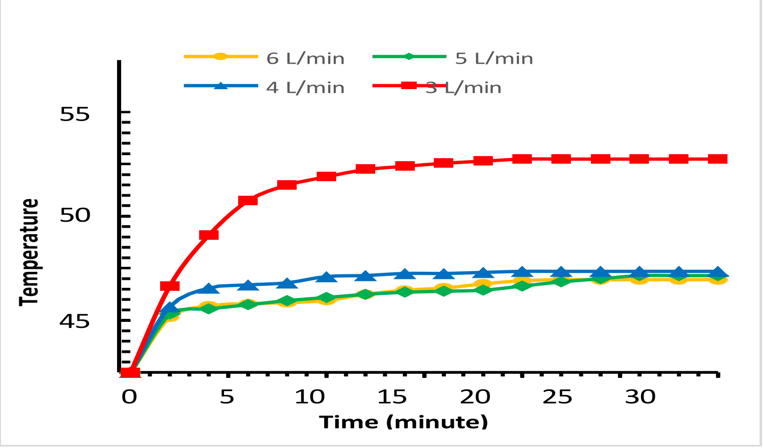

Figure 12: Time vs temperature graph when water temperature is 30°C (2nd exp).

When the mass flow rate is 6 lpm, the lowest outlet temperature is shown on the graph. The output temperature rises as the mass flow rate decreases. When the mass flow rate of water is 3 lpm, the outlet temperature of water rises considerably to 50.5°CFigure 12 which is maximum outlet temperature, as seen in the graph. The heat produced in the condenser may theoretically provide a water output temperature of up to 53°C. This increase is due to the less mass flow rate because when the mass flow rate is low, mass of waterflowing through the pipe section per second is less hence the water will get heated up faster. Another reason of this increase in the temperature can be when the mass flow rate is 3 lpm the Reynolds number is 2188. When the Reynolds number is less than 2300 it is considered as laminar flow. On other hand theoretical velocity of water are 0.0987 m/s, 0.1381 m/s, 0.1579 m/s and 1.974 m/s accordingly on flow rate of 3 lpm, 4 lpm, 5 lpm and 6 lpm. The velocity of the water in a laminar flow is lower, more the velocity of water decreases the temperature increases [19] and the water stays in the condenser for a longer period of time, allowing for a quicker increase in temperature in the water in this case. We also did the experiment at 2 lpm with a 30°C inlet and got 52.4°C outlet temperature for confirmation Figure 13. Howeverour setup was not intended to conduct the experiment at a mass flow rate of 2 lpm. We repeated the experiment multiple times to ensure consistency, and the results were nearly same each time.

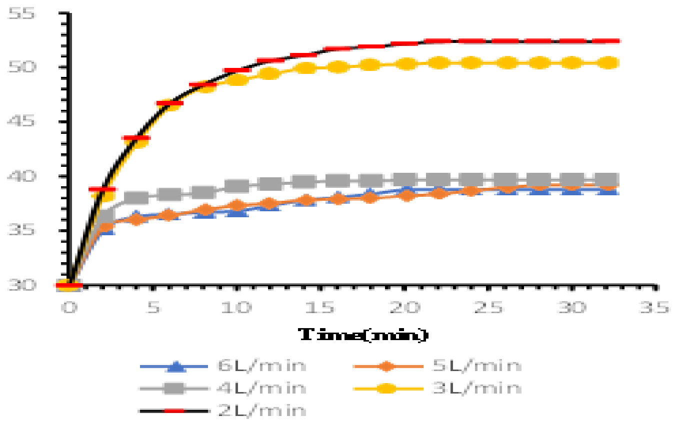

Figure 13: Time vs temperature graph.

4.2 Effect of Mass Flow Rate and Temperature Difference

4.2.1 For inlet temperature of water is 28°C

Table 7 shows that, when the mass flow rate of water is 0.05 Kg/s and the temperature difference is 20.5°C the heat energy gain by water is maximum Again when the mass flow rate of water is 0.07 Kg/s and the temperature difference is 9.6°C the heat energy gain by water is minimum.

Table 8 shows that, when the mass flow rate of water is 0.05 Kg/s and the temperature difference is 20.9°C the heat energy gain by water is maximum Again when the mass flow rate of water is 0.07 Kg/s and the temperature difference is 9.5°C the heat energy gain by water is minimum.

Table 7: Heat energy on Flow rate and Temperature difference at 28°C (1st exp)

Ma ss Flow rate (ṁ) kg/s	Heat Energy (Q) KW	Inlet Temperature (Tinlet) (°C)	Outlet Temperature (Toutlet) (°C)	Temperature Difference(ΔT)
0.10	3.43	28°C	36.2	8.2
0.08	3.04	28°C	37.1	9.1

0.07	2.81	28°C	37.6	9.6
0.05	4.28	28°C	48.5	20.5

Table 8: Heat energy on Flow rate and Temperature difference at 28°C (2nd exp)

Ma ss Flo w rate (ṁ) kg/s	Heat Energy (Q) KW	Inlet Tempera ture (Tinlet) (°C)	Outlet Temperature (Toutlet) (°C)	Temperature difference(ΔT)
0.10	3.39	28°C	36.1	8.1
0.08	3.04	28°C	37.1	9.1
0.07	2.81	28°C	37.6	9.6
0.05	4.31	28°C	48.6	20.6

4.2.2 For inlet temperature of water is 29°C

Table 9 shows that, when the mass flow rate of water is 0.05 Kg/s and the temperature difference is 20.7°C the heat energy gain by water is maximum Again when the mass flow rate of water is 0.07 Kg/s and the temperature difference is 9.6°C the heat energy gain by water is minimum.

Table 10 shows that, when the mass flow rate of water is 0.05 Kg/s and the temperature difference is 20.9°C the heat energy gain by water is maximum Again when the mass flow rate of water is 0.07 Kg/s and the temperature difference is 9.5°C the heat energy gain by water is minimum.

Table 9: Heat energy on Flow rate and Temperature difference at 29°C (1st exp)

Mass Flow rate (ṁ) kg/ s	Heat Energy (Q) KW	Inlet Temperature (Tinlet) (°C)	Outlet Temperature (Toutlet) (°C)	Temperature Difference(ΔT)
0.10	3.14	29°C	36.5	7.5
0.08	3.08	29°C	38.2	9.2
0.07	2.81	29°C	38.6	9.6
0.05	4.33	29°C	49.7	20.7

Table 10: Heat energy on Flow rate and Temperature difference at 29°C (2nd exp)

Mass Flow rate (ṁ)kg/ s	Heat Energy (Q) KW	Inlet Tempera ture (Tinlet) (°C)	Outlet Temperature (Toutlet) (°C)	TemperatureDiffer ence(ΔT)
0.10	3.21	29°C	36.7	7.7
0.08	3.07	29°C	38.2	9.2
0.07	2.78	29°C	38.5	9.5
0.05	4.37	29°C	49.9	20.9

4.2.3 For inlet temperature of water is 30°C

Table 11 shows that, when the mass flow rate of water is 0.05 Kg/s and the temperature difference is 20.4°C the heat energy gain by water is maximum Againwhen the mass flow rate of water is 0.07 Kg/s and the temperature difference is 9.7°C the heat energy gain by water is minimum.

Table 11: Heat energy on Flow rate and Temperature difference at 30°C (1st exp)

Mass Flowrate (ṁ) kg/s	Heat Energy (Q) KW	Inlet Temperature (Tinlet) (°C)	Outlet Temperature (Toutlet) (°C)	Temperature difference(ΔT)
0.10	3.7	30°C	38.8	8.8
0.08	3.08	30°C	39.2	9.2
0.07	2.83	30°C	39.7	9.7
0.05	4.3	30°C	50.4	20.4

Table 12: Heat energy on Flow rate and Temperature difference at 30°C (2nd exp)

Mass Flow rate (ṁ) kg/ s	Heat Energy (Q) KW	Inlet Tempera ture(T_{inlet}) (°C)	Outlet Temperature(T_{outlet})(°C)	Temperature difference(ΔT)
0.1	3.72	30°C	38.9	8.9
0.08	3.11	30°C	39.3	9.3
0.07	2.84	30°C	39.7	9.7
0.05	4.28	30°C	50.5	20.5

The table shows that, when the mass flow rate of water is 0.05 Kg/s and the temperature difference is 20.5°C the heat energy gain by water is maximum Again when the mass flow rate of water is 0.07 Kg/s and the temperature difference is 9.7°C the heat energy gain by water is minimum.

The green line depicts temperature difference, whereas the red line represents heat energy in the graph (Q). Heat energy is related to both mass flow rate and temperature difference and the temperature difference is inversely proportional to the mass flow rate. The graph demonstrates that when the mass flow rate is reduced from 0.1k g/s to 0.08 kg/s and 0.07 kg/s, the output temperature increases marginally compared to the reduction of the mass flow rate. As a result, the amount of heat energy transferred is reduced slightly. The temperature difference is greatest when the mass flow rate of water is 0.05 kg/s, which is why the heat transfer rate is higher.

5. Conclusion

In brief, the experiment was carried out in order to build a water-cooled condenser that would produce warm water by using the condenser's rejected heat. The condenser had more than enough capacity to generate hot water with a flow of 6 lpm, 5 lpm, 4 lpm and 3 lpm accordingly. This double pipe heat exchanger (condenser) has 12 passes, measuring 130 cm in length, 44.5 cm in width and 29.8 cm in height. The inner pipe uses a 3/8-inch copper pipe with a total length of copper 15.24. While the UPVC pipe is 1 inch in size. The total length of the annulus pipe is 12.6 m.

When the mass flow rate of water is 3 lpm, the condenser releases the most heat to the water 4.37 KW.The maximum hot water temperature obtained from the research results is when the flow rate o water is 3 lpm that is equal to 50.5° C where the inlet temperature of water was 30° C. These tasks completed as part of the thesis study that will help in the construction of a water-cooled condenser for split air conditioning. During the heat transfer between water and the refrigerant, some heat is lost. This may be overcome by utilizing fin to increase the area.

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Conflict of interest

There is no conflict of interest.

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