Designing and Prototyping for Conservation and Effective Utilization of Waste Heat from Air Conditioner

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Abstract. Nowadays Energy is becoming a crucial part of human needs and it’s essential for the day to day activities. We use an enormous amount of energy either from fossil fuels, electricity, or solar to heat the water to fulfil the need of residential or industrial sectors, and unfortunately, we consciously lose out a significant amount of energy in the form of heat from the condensers of air conditioning. Hence conservation of energy and its effective utilization has become imperative. The main objective of this research paper is to demonstrate how the waste heat which is dissipated from the condenser coil of a 1-ton Air conditioner is being utilized for heating the water and used to increase the Coefficient of Performance (COP) of the system. Therefore, by redesigning the condenser part of AC we would be able to appease the necessity of the heated water for bathing, cleaning, space heating, etc. in hostels, restaurants, for domestic and industrial use as a primary unit or with a hybrid water heater system.

1. Introduction

The use of air conditioners has increased significantly in the past few years including commercial as well as residential areas. Its effect is directly on the consumption of electricity and other resources. From an advancement perspective, especially the HVAC industry has grown incredibly well in terms of energy consumption, compact-ness, reduction in carbon footprints, use of environment-friendly refrigerants with a reliable and sustainable product. [1] Even though we are approaching to reach the peak in the advancement but unfortunately every year a huge amount of energy in the form of heat from the condenser of air conditioners is consciously released into the atmosphere in the form of waste which is pathetic. This research paper is about the methods or techniques by which a large portion of waste heat of air conditioner can be recovered and utilized for our day to day applications. In this research paper, two experiments are conducted to demonstrate how the modification in some portion of the air conditioner results in the recovery of a huge amount of heat which is otherwise gets wasted. The cost and efficiency are the two-parameter that governs the designing of any new system or doing some modification in the existing one by giving utmost importance to the primary function and quality. Therefore, considering all these parameters a system is designed and prototyped. From a future perspective, this experiment may help the researcher to rethink and design a system by which, such a great amount of energy can be utilized for human needs.
2. **Constructional Details:**

Annotations used in schematic representation as figure 1 are as follows,

- a. Window Air Conditioner
- b. Condenser coil
- c. High density poly Ethylene (HDPE) Tank
- d. Water Sprinkler
- e. Supporting frame
- f. Water tap
- g. Temperature sensor
- h. External pump

![Figure 1. Schematic representation](image1)

**Figure 1.** Schematic representation

**Figure 2.** Constructional setup

### 2.1. Window Air Conditioner & it’s Condenser Coil

In this experimental setup an old window air conditioning of 1 TR capacity is used which is as shown in figure 3. [2] In this A.C, the condenser portion is reconstructed by adding a copper coil to it which is then placed inside the tank as shown in figure 4 to carry out the experiment.

![Figure 3. Window Air Conditioner](image3)

**Figure 3.** Window Air Conditioner

![Figure 4. Condenser coil immersed in tank](image4)

**Figure 4.** Condenser coil immersed in tank

### 2.2. Water tank and Shower head

![Figure 5. HDPE water tank](image5)

**Figure 5.** HDPE water tank

![Figure 6. Shower head to sprinkling water](image6)

**Figure 6.** Shower head to sprinkling water
The high-density polyethylene tank is shown in figure 5. It is used because of the cost involved in using a metallic tank of the same size. It can withstand a temperature of 85°C without any significant change in physical properties as its melting point is 111.90°C which is obtained from the manufacturer’s manual. To carry out experiment a water sprinkler which is a showerhead used and connected with the tank as shown in figure 6.

2.3. Supporting Table and Water tap: -

As the window air conditioners are bulky and 150 liters of the tank with 100 liters of water, is used for the experiment, so to support these a robust base frame is designed and fabricated which is as shown in figure 7. Its dimensions are 50 cm×25 cm to hold the Air conditioner and 45 cm × 20 cm to hold the water tank & made up of mild steel. A water tap is also installed with the tank to drain out the water from the tank which is shown in figure 8.

3. Working:
As shown in figure 2, the entire assembly is placed over the frame. For analysis purposes after the theoretical conceptualization, it becomes imperative to validate it by using different experiments hence we conducted two experiments. In 1st experiment, as the Air conditioning is turned on the refrigeration cycle starts. [3] When the liquid refrigerant reaches at evaporator inlet after the expansion coil it absorbs the heat of the system and gets converted into vapor which then passed through the compressor where it pressurizes, and high-pressure high-temperature vapor enters into the condenser. Since the coil placed inside the water there is a significant amount of heat released to the water and as a result, this waste heat gets utilized for heating the water. In 2nd experiment, an external motor is used to force the water over the coil, and with the help of a water sprinkler, it gets converted into small droplets. [4] Here convection is taking place with air as well as the water droplets as a result more amount of heat gets released and sub-cooling takes place. Whereas in conventional A.C there is forced convection takes place over the coils by blowing air over it with the help of a fan.

4. Experimental Result

4.1. Sample Calculation: -

Following are the specification of the experimental setup: -
The Window A.C is 3-star rating, so the energy efficiency ratio (EER) is 2.7 [6]
Capacity of A.C = 1 TON
Usage of Water = 100 Liters
Running hours = 1 Hour
Rated Power Input = 1407 Watt
Rated Cooling Capacity = 3517 Watt
Type of Refrigerant = R-22
All the heat will be absorbed by the water inside the tank. The total amount of heat absorbed by the water is given by the equation,

\[ Q = m \cdot C_p \cdot (T_1 - T_2) \]

Where,

\( T_1 \) and \( T_2 \) are Inlet and outlet temperature of the water.

In an ideal condition, the entire rejected heat will be absorbed by the water and is equal to the sum of the power input and amount of heat absorbed from the room which is equal to cooling capacity. So, we can write,

\[ 1407 + 3517 = 100 \cdot 4187 \cdot (T_1 - T_2) \]

\[ (T_1 - T_2) = \frac{0.01176^\circ C}{\text{Sec}} \text{ equivalent to increase in temp. of 7}^\circ C \text{ in 10 minutes}. \]

4.2. Observation table

| Sr. No. | Time (In minutes) | Expected Temp. increment (\(^\circ C\)) | Observed Temp. increment (\(^\circ C\)) |
|---------|------------------|--------------------------------------|--------------------------------------|
|         | 0                | 28                                   | 28                                   |
|         | 10               | 35                                   | 33.5                                 |
|         | 20               | 42                                   | 37.4                                 |
|         | 30               | 49                                   | 41                                   |
|         | 40               | 56                                   | 43                                   |
|         | 50               | 63                                   | 45.7                                 |
|         | 60               | 70                                   | 47.8                                 |

*Expected time is calculated in topic 4.1

Table 1 shows the result obtained from the 1\(^{st}\) experiment. In this experiment, the condenser coil is immersed inside the water. The amount of water used in this experiment is 100 liters in a tank having a capacity of 150 liters. On the day of the experiment, the atmospheric temperature is 28\(^\circ\)C and the tank is open to the atmosphere. [5] When the air-conditioner is turned on the temperature of the water goes on increasing and it is recorded with the help of a digital thermometer in 10 minutes intervals. The ideal consideration was our temperature will increase linearly as time goes on as per the calculation in topic 4.1 but when we analyzed the result, we found that as the temperature goes on increasing, for the same period, the temperature gradient is decreasing which is as shown in figure 9.

![Figure 9. Comparison of expected temperature increment with experimental data](image_url)

In figure 9, the blue line indicates the increment in temperature of the water, and the red line shows the increment in temperature result obtained from 1\(^{st}\) experiment.

In the 2\(^{nd}\) experiment, we use a pump and a shower head to spray the water over the coil in fine droplets which is installed just above the condenser coil inside the tank. In this case, the water is stored in a
separate tank and then at different volume flow rates, it is sprayed over the coil. The pump discharge is 2.5 lpm and the outlet temperature of the water observed is 42.8°C which is optimum. Even though the outlet temperature of the water is lower than experiment 1 but it is the best method to recover the waste heat from the air conditioner effectively and efficiently. A sample calculation for each experiment is given in the below section. The amount of power consumed for running the pump is negligible in comparison to recovering the amount of heat, so its calculation is not included.

5. Sample Calculation: -

5.1. Experimental results obtained for calculation:

![Figure 10. Temperature (T) – Entropy (s) diagram](image1)

![Figure 11. Pressure (P) - Enthalpy (h) diagram](image2)

### Table 2. Enthalpy and entropy at different points as per figure 10 and figure 11

| Properties | 1   | 2   | 3   | 4   | 3'  | 4'  |
|------------|-----|-----|-----|-----|-----|-----|
| h (Enthalpy) | 397.9 | 426.3 | 302.5 | 302.5 | 318.3 | 318.3 |
| s (Entropy)  | 1.779 | 1.788 | 1.187 | 1.311 | 1.191 | 1.323 |

Here,  

$h_1$, $h_2$, $h_3$, and $h_4$ = Enthalpy of refrigerant at entry of compressor, condenser, expansion device and evaporator respectively with dismantling the coil of condenser and immersing inside the water as shown in figure 4.  

$h_3'$ and $h_4'$ = Enthalpy of refrigerant at exit of condenser and expansion device respectively without dismantling the coil of condenser.

COP of Conventional Air conditioning  

$$COP_{Conventional} = \frac{(h_1 - h_4')}{(h_2 - h_1)} = \frac{(397.90 - 318.3)}{(426.30 - 397.90)} = 2.8028$$

From figure 11,  

$$h_1' = h_4 + (h_4' - h_4)$$

COP of Modified Air conditioning system  

$$COP_{Modified} = \frac{(h_1 - h_4)}{(h_2 - h_1)} = \frac{(397.90 - 302.5)}{(426.30 - 397.60)} = 3.324$$

The above sample result is as per experiment 2nd Experiment which shows that there is a significant rise in COP of the system from 2.80 to 3.2 which could only be possible after modifying the condenser assembly.
5.2. Amount of waste heat recovered:

5.2.1 In 1st experiment: -
As the result obtained from the experiment, we can say that only a certain amount of the heat rejected from the condenser coil can be reutilized for the purpose of any specific application i.e. for heating of residential water storage system for day to day use, for industrial purpose, etc. As a result, the water temperature increases from 28°C to 47.8°C in a period of 1 hr. So, the total amount of waste heat recovered in 1 hr. is,

\[ Q_W = m \times C_p \times \Delta t \]

\[ Q_W = 100 \times 4.187 \times (47.80 - 28) = 8290.26 \, KJ \]

5.2.2 In 2nd experiment: -
Total amount of heat recovered (\(Q_W\)) in the period of 1 hr. is, (Outlet temp. is 42.8°C)

\[ (Q_W) = m \times C_p \times \Delta t \]

\[ Q_W = 2.50\times60\times4.187\times(42.8-28) = 9295.14 \, KJ \]

6. Conclusion: -
In summary, by doing modification in the existing system by keeping in mind the future obligations and waste energy in the form of heat which is dissipated in the atmosphere from air conditioners periodically, must be adequately utilized. Modification in condenser design not only makes it possible to use the waste heat appropriately but also unquestionably there is a marginal increment (from 2.80 to 3.32) in the coefficient of performance of the entire system. By this experiment, we could also be able to extract a considerably larger amount of heat (i.e. ~ 9300 KJ) which can be utilized for the sterilization in hospitals and medicals, for bathing purpose in hotels, hostels and may also be used for various domestic applications, in the restaurants, in various chemical industries for preheating the salts, ashes and different chemical solutions as a primary or secondary heating source. In the future, it may be one of the best source of energy at the economical rate, which must be utilized effectively for fulfilling the need of the human being, especially when the modern conventional air conditioners will be a part of solar modules and will use it as a primary source of power supply.

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