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Enhancing the performance of a desert cooler using an evaporative split cooling system

Akash Kanwar | Chakradhar Patel | Dhanika Sahu | Dushyant Kumar | Ajay Tripathi | Govind Sahu

Department of Mechanical Engineering, Government Engineering College Raipur Chhattisgarh, 492015

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ABSTRACT

To address the demand for energy-efficient cooling solutions, we propose the development of a split cooling unit designed to operate efficiently without significantly increasing humidity levels. Unlike conventional air conditioners that rely on energy-intensive vapor compression refrigeration systems, this unit will utilize evaporative cooling technology, renowned for its cost-effectiveness and energy efficiency. By passing air through the split unit, we can achieve optimal cooling while minimizing humidity. This is crucial for ensuring comfort, especially in regions like India where high humidity levels can be uncomfortable. Additionally, this technology can help mitigate energy waste in governmental buildings, where poor construction techniques contribute to significant electricity losses. Traditional HVAC systems exacerbate energy inefficiency by consuming a large portion of a building's energy, primarily derived from fossil fuels. Our split cooling unit offers an environmentally friendly alternative, aiming to reduce reliance on fossil fuels and promote long-term sustainability. Through this innovation, we strive to address both the energy and comfort needs of buildings, offering a solution that is both economical and eco-friendly.

KEYWORDS: Heat Exchanger, Evaporation, Humidity.

1. INTRODUCTION

The demand for energy-efficient ventilation, heating, and cooling (HVAC) systems, as well as equipment, has been on the rise due to the significant energy consumption of buildings. One common method of cooling, particularly in the 20th century, is the evaporative cooler. These systems often utilize wooden wool pads to facilitate evaporation by exposing a large volume of water to circulating air. A typical evaporative cooler features a water tank, a pump to circulate water over the pads, and a fan that draws air through the moistened pads, thus reducing the air temperature.

Despite its simplicity, this design has persisted in some regions, especially where increasing humidity is desired. However, studies conducted by India's Union Ministry of Power reveal that government buildings waste a considerable amount of electricity approximately 20-25% because of nonoptimal design, leading to an annual financial loss of approximately Rs.1.5 billion.Moreover, traditional HVAC systems, including conventional vapor compression air conditioners, contribute significantly to overall building energy consumption.[5] These units consume a significant amount of electrical power, much of it obtained from fossil fuels, making them harmful for the environment and insupportable in the long term.[1,2]

1.1 DESIGN OF SPLIT COOLING UNIT

The primary split cooling unit consists of two evenly spaced heat exchangers. Cool water is senr from the evaporative cooler through a high-power sub pump with consumption of 40W. Placed between the two heat exchangers is a 105 W fan, as illustrated in the diagram. A common intake rail connects to the split unit to ensure that all heat exchangers receive a consistent water supply at similar pressure. In addition to this, an additional shared outlet rail is connected with the outlets of both heat exchangers, obtaining water from these units and channeling it back towards the evaporative cooler's water tank.[1]

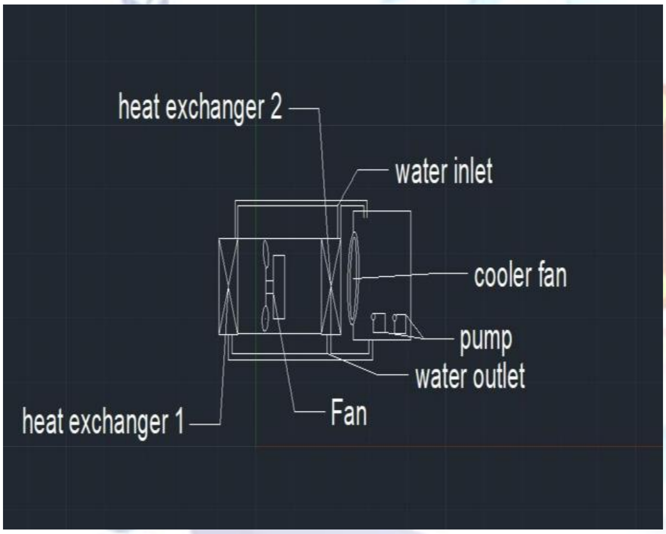

Figure 1.Block diagram split cooling unit

OBJECTIVES

The objective of an evaporative split cooling system is to provide efficient cooling by utilizing the principle of evaporative cooling. It typically consists of two main components: a unit installed evaporative cooler and another unit installed duct. The system works by evaporating water to cool the air, making it an energy-efficient alternative to traditional air conditioning systems, especially in dry climates.

1.2 EXPERIMENTAL SETUP

The revised design, illustrated in the diagram, incorporates several key elements:

1. Standard Evaporative Cooler: This forms the core of the cooling system, responsible for the evaporative cooling process.

2. Duct with Heat Exchangers and Fan: The duct is outfitted with two heat exchangers and a fan for air circulation. These components facilitate the transfer of heat from the air to the water within the system.

3. Submersible pumps: Two submersible pumps are employed in the system to circulate water. One pump, rated at 40W, delivers cold water to the heat exchangers through flexible tubing. The other pump is responsible for recirculating water within the system.

The operation of the system is as follows:

- The 40W high-pressure submersible pump pushes cold water through flexible tubing to the heat exchangers in the duct.
- Within the heat exchangers, heat from the surrounding air is transferred to the circulating water.
- The now-warmed water is collected and directed back to a common reservoir or rail.
- From there, the water is transferred towards the water tank of the evaporative cooler.
- Inside the evaporative cooler, the water undergoes evaporative cooling, extracting heat from the surrounding air and lowering its temperature.
- The cooled air is then circulated by the fan through the duct, providing a cooling effect in the intended space.The Figure 2 shows heat exchanger of split coolind unit.

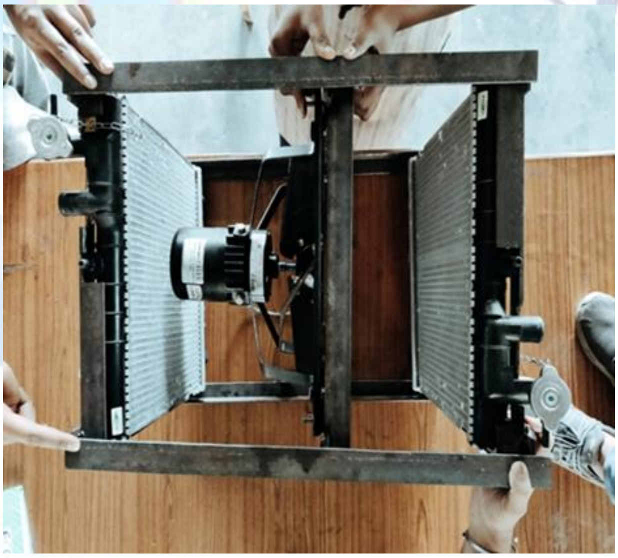

Figure 2. HEAT EXCHENGER

This design optimizes the cooling process by combining evaporative cooling with heat exchange mechanisms, enhancing efficiency and effectiveness in temperature regulation.

Table 1 Experimental Investigation

Sr.No	Time	Air Tempteratureat Various Points Of The Split Unit				Troom	Tamb
		1	2	3	4		
1	11:00	35	35	35	35	35	35
2	12:00	31.5	31.5	29	31.5	31	35
3	1:00	28.5	28.5	28.5	29	28	36
4	2:00	28	28	28	28	27.5	38
5	3:00	27	27	27	27.5	27	40
6	4:00	26	26	26	27	27	41

2. PROPOSED PROCEDURE

1. The evaporative coolers water tank provide water to the heat exchangers through a common tube.

2. The intake water temperature remains steady at 24°C for all Heat Exchangers.

3. As the air is transferred through the Heat Exchangers, it loses heat.

4. The chilled air is transferred into the space without increasing humidity levels.

5. The water from these heat exchangers is stored in the water reservoir of the cooler. At the outlet, the water temperatures measure 29°C at the second heat exchange unit and 28°C at the first heat exchanger.

This cooling system continues to enhance the cooling effect within the space and can effectively maintain ambient temperatures of up to 27°C. Remarkably, the device operates with a remarkably low total energy consumption of only 290W.

3. CALCULATION

To calculate the heat rejected at a specific time in both heat exchangers, we can apply the given information:

For the first heat exchanger:

Air Temperature at Heat Exchanger Inlet (T1) = 28°C

Air Temperature at Heat Exchanger Outlet (T2) = 28°C

Enthalpy of air at Heat Exchanger inlet (H1) = 51.5 kJ/kg for dry air.

Enthalpy of air at Heat Exchanger exit (H2) is 50 kJ/kg dry air.

We can calculate the heat rejection (Q) using the formula:

$Q = H1 - H2 = 51.5 - 50 = 1.5$ kJ/kg dry

2nd Heat Exchanger:

T1 = 29°C

T2 = 29.6°C

H1 = 50.2 kJ/kg

H2 = 50 kJ/kg

Again, we calculate the heat rejection (Q) using the same formula:

$Q = H1 - H2 = 50.2 - 50 = 0.2$ kJ/kg dry air

Therefore, in the first heat exchanger, the heat rejected is 1.5kJ/kg of dry air, and in the second heat exchanger, it is 0.2kJ/kg of dry air.

This system employs two fans: one for the cooler that evaporates water and one placed inside the split unit. The fan includes the following specifications:

Diameter: 150.00 mm (approx)
Operating speed: 1440 rpm
Phase: Single phase
Number of poles:04
Frequency: 50Hz
AC power consumption: 105 Watt

Below the figure 3 shows cooler fan.

Figure 3.FAN

Submersible pumps: The two sub pumps are used by the system, each for a different function. The second pump moves water into the cooler's reservoir to the split unit, while the first pump supports the evaporative cooler. The specifications of both pumps are the same:[3] belows the figure 4 shows submersible pump.

- Power Consumption: 20 watts each
- Voltage: 220 volts AC
- Outlet Nozzle Size: 1/2" maximum

Figure 4.pump

Cooler Tank: In order for the pump to deliver the necessary cooling water, the tank is essential for storing enough water. Its volume is usually between 80 and 120 liters, which guarantees a plentiful supply of water to power the cooling system to operate. To keep the flow continuous, the water is brought back to the tank after each cycle of circulation. But with time, because of slow evaporation, the quantity of water drops and, depending on how often the cooler is used, it needs to be periodically refilled. An increase in utilization quickens the water tank's water depletion rate. While cement tanks are a feasible alternative, galvanized metal sheeting is a common choice in construction. A drain valve is necessary for cleaning and maintenance, irrespective of the material used, guaranteeing the durability and effectiveness of cooling system.[4]

The tank typically measures around 60x60x16 cm^3, providing a holding capacity of around 80 liters, ensuring compatibility with the cooler's design and operation. Figure 5 depicts the outward ascepts of the cooler's tank., emphasizing its significance in the overall functionality of the system.[1] Fifure 5 shows the cooler surge water tank.

Figure 5.Water Tank

Pad: A cooling evaporative pad, also known as a swamp cooler pad or cooling pad, is a device used in evaporative air coolers. It's typically made of a special cellulose material that absorbs water. When air passes through the pad, the water evaporates, cooling the air in the process. This cooled air is then blown into the room, providing a refreshing cooling effect. It's an energy-efficient way to cool spaces, especially in dry climates.[5]

Figure 6 is shows the evaporative pad.

Figure 6.evaporative pad

3.1 CALCULATION FOR COP OF THE SYSTEM

Table2. Enthalpy and humidity values were derived from the psychometric chart

Sr.no.	Dry bulb tem.	Wet bulb temp.	Enthalpy	Relative humidity
1	41	35	128.68	67%
2	35	27	84.68	54%

The values are shown in Table No.2 to calculate the Coefficient of Performance (COP). The COP is determined using the formula:

$$COP=\frac{Energy\ supplied}{Energy\ used}$$

$$COP = m\times(H_1-H_2)$$

Where:

mm = mass flow rate in kg/sec

H1 = Initial enthalpy of dry air = 105 kJ/kg

H2 = Enthalpy of the air at the outlet of the split unit (final enthalpy) in dry air terms. = 50 kJ/kg

Substituting the given values, we get:

COP=5.6

Therefore, the Coefficient of Performance (COP) is 5.6

4. RESULTS AND DISCUSSION:

1. The split unit effectively manages the room temperature, maintaining it at a comfortable level of up to 35°C, resulting in a temperature reduction of 27°C. This is achieved by drawing air into the room, circulating it, and extracting a minimal amount of new air. The unit's capability to maintain a room temperature around 27°C is comparable to that of an air conditioner.
2. The system's Coefficient of Performance (COP) is determined to be 5.6 through equation (2).
3. The unit's total power consumption stands at 130 W, significantly lower than that of a traditional air conditioner. This consumption includes the power usage of both fans (each consuming 105 W) and two submerged pumps (each consuming 20 W), totaling 290 Watt.
4. The unit doesn't elevate air humidity; rather, it efficiently cools the air. Since the supply air isn't directly exposed to water and is delivered through the split unit, the air's humidity remains consistent. If an evaporative cooler were situated outside the room, it would not be able to add moisture to the air inside.The Figure 7 shows duct of split cooling systems.

Figure 7.duct

5. CONCLUSION

According to the experimental analysis provided, split units demonstrate considerable potential as moist mediums in cooling systems. This opens up opportunities for new and advance devices that require cooling. The split unit, with its ability to maintain a constant temperature of 27°C and its cost-efficient compared to usual air conditioning units, provides a solid alternative to air conditioning.

In future work, reducing the size of these split cooling units could potentially lead to even higher performance levels than those currently achieved. Additionally, enhancing performance could involve increasing the thickness of the pad.

Conflict of interest statement

Authors declare that they do not have any conflict of interest.

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