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Design and Development of Solar Air Cooler with Cooling Cabinet

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ABSTRACT: In a country like ours where the temperature is high there is always a need to make the environment cooler and comfortable around us and there is need to store perishable goods for longer duration in hot temperature. Also, the need of the hour is to come up with a solution that is eco-friendly. So, keeping these above points in mind our thought is to design and fabricate a solar powered air cooler with cooling cabinet. This system uses an evaporative cooling system. As air passes through the wet cooling pad, the water evaporates, resulting in a drop in temperature, and the cooled air is circulated into the cabinet. Evaporative air coolers are devices that use cool air to cool. There are a lot of air coolers available. However, they are costly. They mainly run only on electricity. However, in case of power failure it stops running. Systems like refrigeration and air conditioning have been increased rapidly to attain comfort. Air conditioning plays a very important role in thermal comfort. Our model uses water as refrigerant since it is cheaper and non-toxic.

The different components used are MS square hollow pipe of 16 gauge, MS perforated sheet metal 16 gauge, battery 12v 10Ah, solar panel 15watts, 12v submersible pump, dc motor for fan 12v, 1800 rpm, Wires, switches, caster wheels and coir. Once the connections are made, the solar panel charges the battery. Once the battery is charged and the switch is on, it runs the fan. Another switch is used to run the submersible motor which pumps water into the cooling cabinet. This model is made using mild steel due to its cost effectiveness and ease of availability. We can further improve this model by making it fully automated and adding extra system like heater and making it capable to be used in larger rooms. The results demonstrate the feasibility and practicality of the proposed solar air cooler with a cooling cabinet. This project contributes to the development of sustainable cooling technologies that can mitigate the environmental impact of traditional cooling systems and provide an affordable solution for individuals and small businesses in regions with ample solar resources.

I. INTRODUCTION

Evaporative cooling is a process which reduces the temperature of a substance due to the cooling effect from the evaporation of water. The conversion of sensible heat to latent heat causes a decrease in temperature and evaporated water gives cooling effect. The cooling system is used in both small and large industry. Evaporative cooling can provide longer life to fruits and vegetables. Humidity and hot climate condition can reduce the life span of fruits and vegetables. Market value of fruits and vegetables depend on its freshness and quality. Deterioration of fruits and vegetables is mainly because of temperature fluctuation. At high temperature fruits and vegetables can deteriorate at higher rate. Too lower temperature can also damage some of agriculture produce. Fruits and vegetables are kept in



normal humidity condition to maintain quality. Damaged vegetables have shorter lifespan and these are kept at lowest safe temperature. Safe temperature can increase the storage life by reducing water loss and lowering respiration rate.

Refrigerated cold storage is the best method for storage but it is very expensive. During evaporative cooling, air is passed through wet pad towards preservation area therefore cooling takes place. The effective evaporative cold storage system can store fruits, vegetables, water bottles temporarily before consumption. Evaporative air coolers are used for humidification, where dry air is humidified during cool weather. Evaporative air coolers with cooling cabinet are environment friendly because they don't use any refrigerant gas.

II. LITERATURE REVIEW

Various journal papers were taken for the literature review. The following are the journal papers taken for this project:

Sl no.	Title	Author	Year
1	Fabrication of solar air cooler for remote areas	Kotresh, Chethan , Girish	2017
2	Design of solar powered mud pot air cooler	Omkar and Vijaykanth	2021
3	Solar air cooler with PIC micro controller	Gaurav , Amol	2017
4	Design of solar powered air cooler cum heater	Mr.Hamza , Huzaifa Rais	2022

This is the literature review we have got from various sources. The first title is an air cooler designed for remote areas. It was designed by Kotresh, Chethan and Girish. This air cooler is run using a battery only. The next title is an air cooler designed using a mud pot. Mud pot is made up of Slurry Soil made by Craftsman according to their requirements of size and shape. Mud pot is porous in nature so rate of cooling as compare to other medium is bit high, that's why it helps to reduce the room temperature. As result this pot gives a high rate of cooling effect. The title is an air cooler designed using a PIC micro controller. The PIC micro charge controller is employed in between solar panel and battery which prevents overcharging. And finally we have an air cooler which has a heater system also. All of the above mentioned air coolers only cool the outside air. They do not cool items. Therefore we are adding a cooling cabinet to the air cooler so that the cool air can be used to cool items like water bottles, fruits and vegetables.

From going through the journal papers we were able to summarize the following:

- **Solar air coolers with cabinet are perfect for village, schools and offices or any domestic purpose:** Since in villages there is less power source available this is very useful and applicable. Since it runs on solar energy, there is no power required and a lot of sunlight is abundant in villages. If there is a power shortage or power is not available then schools and offices can use this instead.
- **They provide an alternate method of power failure:** Since it runs on solar power, there is no need to connect it to a socket.

- **It is eco friendly and also saves electricity:** It is eco friendly since it uses eco friendly materials. It saves electricity because it runs on solar energy thereby reducing the electricity.
- **We can learn about the non-conventional energy source and utilization:** Just like other non-conventional energy sources we can learn about one such type of energy source and its uses.

Working Principle:

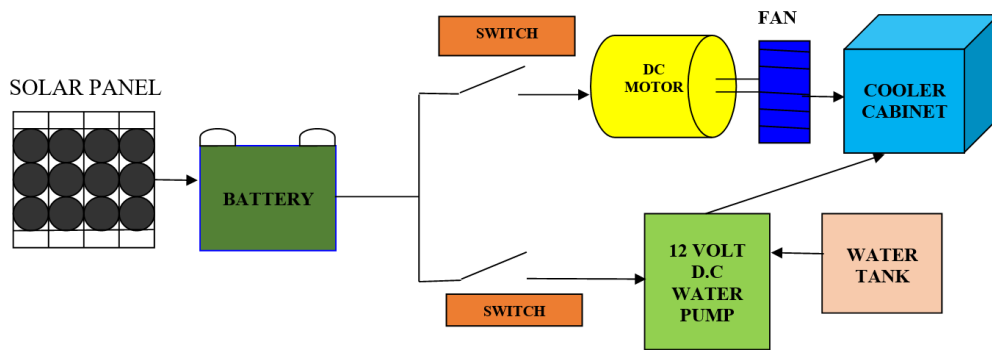


Figure 1: Block diagram of the solar air cooler with cooling cabinet

A solar air cooler with cabinet, also known as a solar evaporative cooler, operates on the principle of evaporative cooling using the energy from the sun. It combines the concepts of traditional evaporative cooling and solar power to provide a low-cost and environmentally friendly cooling solution.

The working principle of a solar-powered air cooler can be summarized in the following steps:

1. **Solar panels:** The system includes one solar panel that convert sunlight into electricity. This solar panel consist of photovoltaic cells that generate direct current (DC) electricity when exposed to sunlight. The DC electricity generated by the solar panels is connected to a solar charge controller. The charge controller regulates the flow of electricity from the solar panels to the battery and prevents overcharging.
2. **Battery storage:** The electricity produced by the solar panels is stored in a battery for later use. The battery acts as an energy reservoir, allowing the air cooler to operate even when sunlight is not available.
3. **Water supply:** The air cooler requires a water source, typically in the form of a water tank or reservoir. The water is supplied to the air cooler through a pump.
4. **Pump and distribution system:** Using a switch when it is switched on, the pump draws water from the water source and circulates it to a distribution system, which is usually a network of pipes or channels. The water is evenly distributed to wet a series of cooling pads.
5. **Evaporative cooling:** The cooling pads are typically made of a porous material that retains water. As the water flows through the pads, air is drawn into the air cooler through a fan or blower.
6. **Fan or blower:** Using another switch, the fan or blower pulls air from the surroundings and forces it through the wet cooling pads. The water on the pads evaporates, causing the air passing through them to cool down.
7. **Cooler air circulation:** The cooled air is then released into the desired space, providing a refreshing and cooler environment in the cabinet. The process of evaporative cooling helps reduce the temperature in the cabinet.
8. **Solar-powered operation:** The entire air cooler system, including the fan or blower and the water pump, is powered by the electricity generated from the solar panels. The solar charge controller ensures that the battery is charged during sunny periods, enabling the air cooler to operate even in low-light conditions or at night.

By harnessing solar power, a solar-powered air cooler offers an energy-efficient and sustainable alternative to conventional air conditioning systems, especially in regions with abundant sunlight and dry climates where evaporative cooling is most effective.

III. TESTING AND RESULTS

Following experiments were conducted with different water temperature conditions:

Experiment 1

Sr. no.	Conditions	Outside air temperature (Th) in °C	Inside air temperature (Tc) in °C	Difference in temperature in °C	COP
1	Water at 25 °C	32	28.1	3.9	16.25
2	Water at 15 °C	31.9	26	5.9	24.58

Table 1: Tabulated test values

COP calculation:

$COP = \text{Cooling effect} / \text{Power consumed}$

Where,

Cooling effect = Mass flow rate * Specific heat * Temperature drop,

Power consumed = Electrical power input

Since, air is the working fluid, we can estimate the specific heat of air at constant pressure to be around 1 kJ/(kg·K).

The mass flow rate of air is not given, but we can assume it to be constant for the sake of calculation. Let's say the mass flow rate is 0.1 kg/s and air cooler has a power input of 24W=0.024KW.

Trial 1: The temperature drop is 3.9 deg C

Cooling effect = $0.1 * 1 * 3.9 = 0.39 \text{ kW}$

Therefore, the COP would be:

$COP = 0.39/0.024 = 16.25$

Trial 2: The temperature drop is 5.9 deg C

Cooling effect = $0.1 * 1 * 5.9 = 0.59 \text{ kW}$

Therefore, the COP would be:

$COP = 0.59/0.024 = 24.58$

Inference: From these 2 trials we can observe that the cooling pads and the fan will keep the cooling cabinet stay cooler than the outside.

Experiment 2: In the Cabinet, we stored some fruits – 4 raw bananas for 3 days. And also kept some raw bananas outside. And monitored the progress of ripening of the fruits. The outside temperature ranged from 29 deg C to 34 deg C during day and the temperature in the cabinet was maintained at 25 deg C. During the day the cooling pads were made sure that it stays wet and fan was run intermittently to maintain the temperature.

Result: After 3 days, it was observed that the fruits in the cooling cabinet had ripened less than the fruit stored outside. From this experiment we can infer that the perishables can be stored longer in the cooling cabinet.



Figure 2: Initial state of fruits on Day1

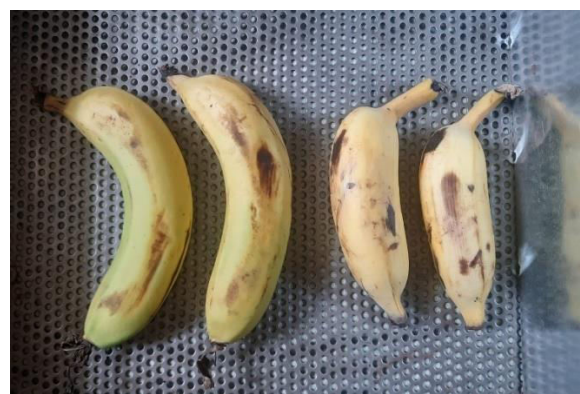


Figure 3: State of fruits in cabinet on Day3



Figure 4: State of fruits kept outside on Day3

IV. CONCLUSION

In conclusion, the Solar Air Cooler with cooling cabinet project has successfully demonstrated the feasibility and effectiveness of utilizing solar power for efficient and sustainable cooling. By harnessing the energy of the sun, this project has provided an alternative cooling solution that reduces reliance on conventional electricity sources and lowers greenhouse gas emissions. The results have shown that the solar air cooler with the cooling cabinet achieves effective cooling while operating with reduced energy consumption. This outcome validates the system's energy efficiency and cost-effectiveness, making it an attractive option for domestic and small-scale commercial applications.

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