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Alternative Air Cooler Technology That is Suitable for Residential Use in the Philippines

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Abstract— *The summer season in the Philippines is the most enjoyable and brings people (local and international) to different destinations. Evaporative coolers and air conditioning units are in great demand during this time. Electricity bills go up the most compared to other seasons. Evaporative coolers consume less electricity than air conditioners, but the evaporative cooling process is insignificant in the Philippines' climatic conditions due to high humidity. High humidity can complicate the maintenance and operation of the unit. Although there was plenty of water in the Philippines, evaporative coolers were less prepared than air conditioners because high humidity would render the system inefficient. The development of technology enhancements that use box-type fans with misting and maintenance procedures could mitigate operating problems in the Philippines, which can address the issues.*

Keywords— *Evaporative Coolers, Misting, Tropical Climates, Residential Coolers.*

I. INTRODUCTION

1.1. Rationale

The summer months are the height of our season in the tropical nation of the Philippines [1]. The researcher is trying to find a solution to the issue during the summer or on any given day of the year. The researcher already has air conditioners on hand, but they are extremely expensive, and energy usage becomes a concern. Therefore, it makes sense to find a solution to this issue to improve the cooling of our surroundings and, as a result, reduce the amount of electricity we use. In contrast to conventional air conditioning systems, which use vapor-compression or absorption refrigeration cycles, an evaporative cooler uses evaporation to chill the air. Water that can absorb a significant quantity of heat is used in evaporative cooling to cause the water to evaporate [2]. In populated places, the dry air's temperature might drop dramatically [2]. It takes less energy than refrigeration to easily cool this air [2].

Evaporative coolers lower the indoor air's temperature by operating on the evaporative cooling theory [3]. Utilizing air's thermal energy to transform liquid water into vapor and reduce air temperature makes this method more efficient. As a result, evaporative cooling lowers air temperature proportionally to the sensible heat loss while also increasing humidity proportionally to the latent heat gain. By enhancing the existing designs, the user may employ a more effective technology to help us handle the resident's issues, lowering their electricity bills in the process.

1.2. Theoretical Background

An evaporative cooler is a technology that cools air through water's evaporation. It differs from typical conditioning systems, which use vapor-compression or absorption refrigeration cycles [4]. Water's ability to absorb a significant quantity of heat is used by evaporative cooling to cause it to evaporate (that is, it has a large enthalpy of vaporization). As seen in figure 1, the phase shift of liquid water to water vapor (evaporation) can cause the temperature of dry air to drop dramatically. Compared to refrigeration, this uses a lot less energy to chill the air.

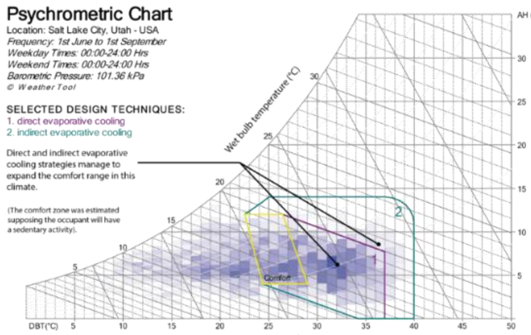

Fig. 1. Psychrometric Chart of Evaporative Cooling [5].

In contrast to conventional air conditioning systems, which employ vapor-compression refrigeration or absorption refrigeration, evaporative coolers use the evaporative cooling principle to reduce the air's temperature. By harnessing the thermal energy in the air to turn liquid water into vapor, evaporative cooling lowers the air's temperature. The energy required to evaporate the water is extracted from the air as sensible heat, which changes the air's temperature, and transformed into latent heat, which is the energy contained in the water vapor component of the air, while the air's enthalpy value remains constant. Due to the fact that this sensible heat to latent heat conversion takes place at a constant enthalpy value, it is referred to as an isenthalpic process. As a result, evaporative cooling results in a decrease in air temperature proportionate to a sensible heat loss and a rise in humidity corresponding to a latent heat gain. [6].

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Fig. 2. Air cooler [7]

1.2.1. Design

Most designs make use of the fact that water has one of the highest known enthalpies (latent heat of vaporization) values of any common material. Evaporative coolers are more energy-efficient than vapor-compression or absorption air cooling systems because they use less energy. Except in extremely dry places, the single-stage (direct) cooler can, however, increase relative humidity (RH) to a level that is uncomfortable for occupants. Through the use of indirect and two-stage evaporative coolers, the RH is reduced[6].

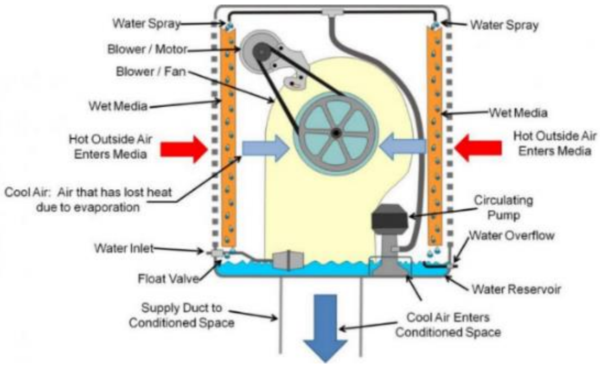

Fig. 3. Evaporative cooler diagram [8]

Direct Evaporative Cooling Design

Using the latent heat of evaporation and cooling the environment by converting liquid water to water vapor, direct evaporative cooling (open circuit) raises the air's humidity. The energy in the air remains constant throughout this operation. Cool, humid air replaces warm, dry air. Water evaporates using the heat of the ambient air. As the RH rises to 70 to 90%, the cooling effect of human perspiration is diminished. To prevent the air from becoming saturated and evaporation from ceasing, the moist air must be continuously evacuated outside [9].

A wetted membrane, which has a wide surface area for the evaporation of water into the air, is used in mechanical direct evaporative cooler units to pass air through. Figure 3 illustrates how water is sprayed at the top of the pad so that it can drip through the membrane and continuously maintain it wet. Any extra water that leaks from the membrane's bottom is gathered in a pan and cycled to the top. Since the membrane, water pump, and centrifugal fan are the sole components in single-stage direct evaporative coolers, they are frequently compact. The municipal water supply's mineral content will scale the membrane, which throughout the membrane's lifetime will create a blockage. Regular cleaning and maintenance are necessary to ensure optimal performance depending on this mineral content and the rate of evaporation. The high humidity of the supply air from the single-stage evaporative cooler typically necessitates direct exhaust (one-through flow). There are a few design ideas that have been developed to make use of the energy in the air, such as channeling exhaust air through two sheets of double-glazed windows to reduce solar energy absorption via the glazing. Single-stage evaporative coolers use less energy compared to the energy needed to use a compressor to produce the same cooling load.

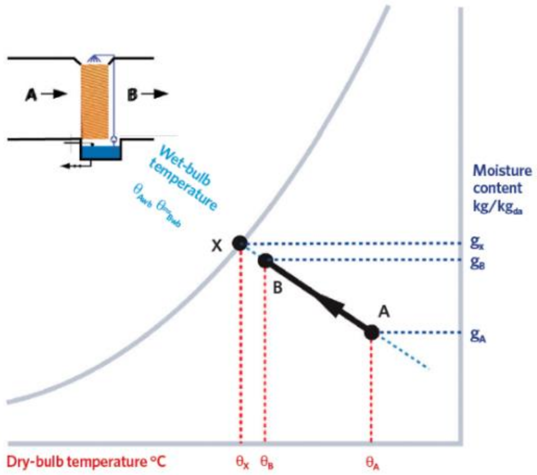

Fig. 4. Direct evaporative cooling [10]

Passive Direct Evaporative Cooling Design

Passive direct evaporative cooling can occur anywhere that the evaporative cooled water can cool a space without the assistance of a fan [11]. Fountains or more complex architectural forms, such as the evaporative downdraft-cooling tower, sometimes known as a "passive cooling tower," can be used to accomplish this. The top of a tower built inside or next to the building can be opened to let outside air in according to the passive cooling tower design. Through a wet membrane or a mister, the outside air comes into touch with the water inside the tower. The air in the outer atmosphere cools down and gets less buoyant as it evaporates, which causes a downward flow inside the tower. The colder air enters the interior of the tower through an exit at the base. Towers, which are similar to mechanical evaporative coolers in that they just need a water pump to raise water to the top of the tower, can be an appealing low-energy solution for hot and dry climates [12]. Depending on the environment and heat load, utilizing a passive direct evaporating cooling approach can save energy. Cooling towers can offer enough cooling during summer design conditions for arid climates with significant wet-bulb depression to be net zero. For instance, two passive cooling towers in Tucson, Arizona, each producing 11890 m^3/h (7,000 cm) of airflow, can completely cool a 371 m^2 (4,000 ft^2) retail store with a sensible heat gain of 29.3 kJ/h (100,000 Btu/h) [13].

Design considerations

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The following criteria must be taken into account: water use, shading, mechanical systems, and exhaust [6].

Misting fan

A humidifier and a misting fan are comparable. A water mist is released into the air by a fan. The water evaporates, collecting heat from the air and enabling the misting fan to also function as an air cooler if the air is not too humid [6].

1.2.2. Performance

The efficacy of evaporative cooling might vary depending on the humidity and temperature outside. The air should be cooled down by a residential cooler to within 3 to 4 °C (5 to 7 °F) of the wet bulb temperature. [14].

The direct saturation efficiency of a direct evaporative cooler determines how closely the temperature of the air exiting the cooler matches the wet-bulb temperature of the air coming in. As can be seen below, direct saturation efficiency may be calculated.[15] [16]:

$$\epsilon = \frac{T_{e,db} - T_{l,db}}{T_{e,db} - T_{e,wb}}$$

Where:

$\epsilon = direct\ evaporative\ cooling\ saturation\ efficiency$ (%)

$T_{e,db} = entering\ air\ dry-bulb\ temperature\ (°C)$

$T_{l,db} = leaving\ air\ dry-bulb\ temperature$

$T_{e,wb} = entering\ air\ wet\ bulb\ temperature$

The efficiency of evaporative media typically ranges from 80% to 90%. Most efficient systems can lower the dry air temperature to 95% of the wet-bulb temperature; the least efficient systems only achieve 50% [16]. The evaporation efficiency drops very little over time.

Around 85% efficiency is provided by typical aspen pads u sed in domestic evaporative coolers [17].

According to this calculation, the wet bulb temperature is roughly equal to the ambient temperature, less a third of the difference between the ambient temperature and the dew point. As before, increase by 5-7 °F as mentioned above [18].

This connection is best illustrated by the following examples: At 32 °C (90 °F) and 15% relative humidity, air may be cooled to almost 16 °C (61 °F). In these circumstances, the dew point is 2 °C (36 °F). Air may be chilled to roughly 24 °C (75 °F) at 32 °C and 50% relative humidity. In these circumstances, the dew point is 20 °C (68 °F).[14] .

1.3. Statement of the Problem

The purpose of this project was to improvise an evaporative air cooler technology for residential usage by upgrading a box-type electric fan as misting fan.

This study wants to address the following:

1. The materials used to upgrade a box-type electric fan into a misting fan:
   1.1 electrical
   1.2 mechanical parts.
2. The design of the Exhaust duct system allows air to continually escaped the air-conditioned area.
3. The suitable and efficient evaporative cooling system and installation to be utilized in the Philippines.
4. The maintenance procedures for the technology implemented are efficient and not prone to faults.

1.4. Significance of the Study

1.4.1. Residents

The locals' monthly electricity costs will be reduced as a result. Others who are unable to purchase vapor compression air conditioning units or commercial "Cool Breeze" air conditioners may be able to feel the cooling impact of the evaporative air cooler.

1.4.2. Students

The environment becomes colder, as a result, improving the learning environment.

1.4.3. Future Researchers

This project has a lot to upgrade, the designs are limited to the Philippines' climatic conditions and the available technology today. Shortly, the researchers may use the new technology to enhance this study that can be utilized to cope with both the Philippine's and other countries climatic conditions.

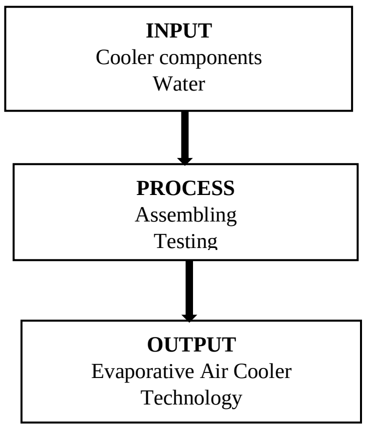
1.5. Scope and Limitations

The study focuses on how well the makeshift "Cool Breeze" evaporative air cooler performs in terms of cooling and cost-effectiveness.

Evaporative cooling, on the other hand, adds moisture to the chilled environment. The air may be a little humid if sufficient ventilation isn't present. However, it will provide a better experience when used with open windows.

Due to a lack of accurate measuring instruments such as a hygrometer, the researcher only focused on the temperature. Also, to the comfort that the cooler gives during the tests.

II. Research Methodology



1.6. Research Environment

The researcher conducted the assembly and testing of the project at the University of Cebu – Main Machine Shop.

1.6.1. Assembly

This design resembles the evaporative cooler patent in some way. The distinction is that this evaporative cooler functions as a single unit by combining various parts, some of which are recycled.

The electric fan is assembled by mounting it in front of the cooling pad, as seen in figure 5. The pump circulates the water through the PVC line to the cooling pad.

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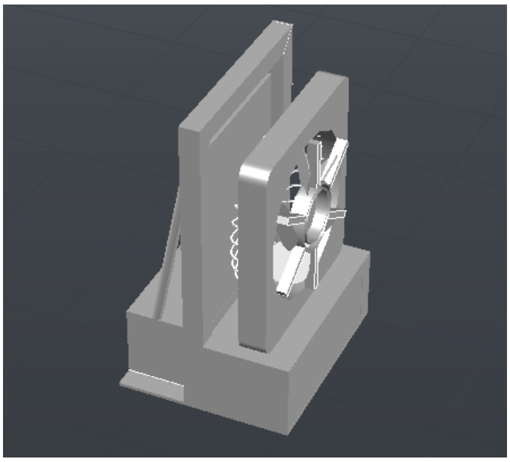
Fig. 5. 3D design

In this configuration, ambient air travels past the cooling pad, which subsequently evaporatively cools the air. As a result, both the air and the water that is moving through the system cool, providing cold air that the fan may disperse in a particular area.

Typical Installations of Misting Systems

Residential evaporative coolers are typically enclosed metal or plastic boxes with vented sides that use direct evaporation to chill air. The evaporative cooling pads are wetted by a water pump, and the air is propelled by a centrifugal fan or blower (often powered by an electric motor with pulleys known as "sheaves" in HVAC language) [19].

Water is forced through a pump in misting systems, and because the water droplets that make up the mist are so minute, they rapidly flash and evaporate. In just a few seconds, flash evaporation can cool the air around it by up to 35 °F (20 °C) [20].

1.7. Project Design

1.7.1. Components

- Box-type electric fan
- Submersible pump - 18W
- PVC pipe - ¾” dia.
- Wood - 1.5” x 1.5” x 1’
- Plywood - 24” x 24”
- PVC 90 deg. elbow
- Honeycomb cooling pad -15” x 30”
- Water storage box -12L
- Filter

1.8. Definition of Terms

AC, A/C -- Air Conditioning
ACU -- Air Conditioning Unit

“Cool Breeze” -- refers to the evaporative air cooler that the researcher has proposed.

Vapor compression ACU--a device that uses refrigerants such as freon R-22, R11, R12, R134a, etc. to achieve cooling

Vapor compression AC--the air conditioning cycle or system that utilizes the refrigerant to cool a certain space by superheating the refrigerant then condensing it and then expanding it to lower the temperature and lastly exchanging heat to the cooled space.

III. Presentation, Interpretation, and Analysis of the Study

Materials

In the past, cooler-pad media consisted of an evaporative Elbow Honeycomb cooling pad 15" x 30" inside a containment net, but more recent materials like Plywood PVC 90 deg. and Water storage box 12L Filter is now being used. Modern rigid media, which is often 8" or 12" thick, absorbs more moisture and cools air more effectively than aspen media, which is typically much thinner. Other components include a Box-style electric fan, an 18-watt submersible pump, and a 3-inch-diameter PVC pipe.

Design considerations

Shading

The rate of evaporation is accelerated by exposing the media pads directly to the sun. In addition to heating other components of the evaporative cooling design, sunlight may also destroy some media. Therefore, in the majority of situations, shading is advised [6].

Mechanical and electrical systems

The evaporation rate is increased by exposing the media pads to direct sunlight. Along with heating other components of the evaporative cooling design, sunlight may also destroy some media. So, in the majority of cases, shade is recommended [6].

Exhaust

Exhaust ducts and/or open windows were used at all times to allow air to continually escape the air-conditioned area. Otherwise, pressure builds up, making it difficult for the system's fan or blower to effectively move air through the media and into the air-conditioned space. The continuous flow of air from the air-conditioned space must be vented to the outside for the evaporative system to work [21]. By optimizing the placement of the cooled-air inlet, along with the layout of the house passages, related doors, and room windows, the system can be used effectively to direct the cooled air to the required areas. Without the aid of an above-ceiling ducted venting system, a well-planned structure may efficiently scavenge and evacuate the hot air from targeted places [22]. Continuous airflow is essential, so the exhaust windows or vents must not restrict the volume and passage of air introduced by the evaporative cooling machine.

Misting fans

A misting fan is similar to a humidifier. A water mist is blown into the air by a fan [23]. The water evaporates, removing heat from the air, and enabling the misting fan to also function as an air cooler if the air is not very humid [24]. You may use a misting fan outside, especially in a dry region. It can also be applied inside. There are hand-operated water spray pumps and small, portable battery-powered misting fans available for purchase.

Performance

Based on the tests, the alternative air cooler does give a cooling effect, which lowers the air temperature to about 24 degrees Celsius. The water in the tank when full takes about 7-8 hours to evaporate. As a rule of thumb, it estimates that the wet bulb temperature is approximately equal to the ambient temperature, minus one-third of the difference between the ambient temperature and the dew point. As before, add 5–7°F as described above. At 32 °C (90 °F) and 15% relative humidity.

In terms of cooling effect in comparison with the commercial air cooler, the alternative evaporative cooler can have the same temperature drop they only differ with the air power because the fan of the commercial evaporative cooler is much bigger.

In terms of power consumption, the alternative air cooler. It ranges from about 65-80 watts depending on the size of the fan and pump. The researcher used a 50w fan and an 18w motor so the power consumption in 1 hour is just .068kwh.

IV. Summary, Findings, Conclusions, and Recommendations Summary

The Materials use were an evaporative Elbow Honeycomb cooling pad - 15" x 30" inside a containment net, Plywood PVC 90 deg., and Water storage box-12L Filter, which are entering use as cooler-pad media. Other materials such as a Box type electric fan, a Submersible pump 18W, and a PVC pipe with a - ¾" diameter.

In the Design considerations, the water used in arid and semi-arid climates, and the scarcity of water make water consumption a concern in cooling system design. Based on the experiment, 3 liters per day may be needed.

Shading is allowing direct solar exposure to the media pads to increase the evaporation rate. Sunlight may degrade some media, in addition to heating other elements of the evaporative cooling design. Therefore, shading is advisable in most applications.

The mechanical and electrical systems are from fans used in mechanical evaporative cooling, pumps are the only other piece of mechanical equipment required for the evaporative cooling process in both mechanical and passive applications.

At all times, exhaust ducts and/or open windows were employed to let air continuously leave the air-conditioned room. A humidifier and a misting fan are comparable. A water mist is released into the air by a fan. It's possible to utilize a misting fan outside, especially in a dry region. It can also be applied inside. There are hand-operated water spray pumps and small, portable battery-powered misting fans available for purchase.

Findings

Based on the tests, the alternative air cooler does give a cooling effect which lowers the air temperature to about 24 degrees Celsius. The water in the tank when full takes about 7-8 hours to evaporate. As a rule of thumb, it estimates that the wet bulb temperature is approximately equal to the ambient temperature, minus one-third of the difference between the ambient temperature and the dew point. As before, add 5–7 °F as described above. At 32 °C (90 °F) and 15% relative humidity.

In terms of power consumption, the alternative air cooler ranges from about 65-80 watts depending on the size of the fan and pump. The researcher used a 50w fan and an 18w motor so the power consumption in 1 hour is just .068kwh.

V. Conclusion

The alternative evaporative cooler may achieve the same temperature drop as the commercial air cooler in terms of cooling impact; the only difference is in air power because the commercial air cooler's fan is much larger.

According to the study, switching from a box-style electric fan to an evaporative air cooler can be the best alternative, depending on the individual and what they find most comfortable. Although the alternative air cooler uses less energy than other cooling devices, it is undeniable that it cannot match the level of comfort provided by an air conditioner.

Recommendations

The researchers suggest that future researchers that are interested in air cooling combine vapor compression and evaporative air conditioning. By doing so, it might also be considerably more effective in terms of cooling impact cost-efficiencies.

The researchers also suggest, that future researchers can integrate additional dehumidifiers (e.g. Thermoelectric Dehumidifiers) into the system to cope up the humidity problems in the Philippines.

VI. Output of the Study

The researchers adopt some of the available manuals for safety, operations, maintenance, and etc. because of advantages that it brings to the study.

USER GUIDE

Just follow the following steps

Operation:

1. Add water to the reservoir until it's full.
2. Plug the power cord.
3. Turn on the electric fan
4. Turn on the switch of the pump.
5. Relax and wait for the air to cool down.
6. Keep an eye on the water level.
7. When full, it takes 7-8 hours before you need to add water again.

Maintenance:

1. Turn off the pump when the water runs out.
2. Do not turn on the pump until the reservoir is filled with water.
3. Remove and clean the filter once a month.
4. Place the equipment on a flat surface.

Safety Read and Save These Instructions:

The following fundamental safety considerations should always be observed while utilizing electrical appliances:
120 volts AC at 60 hertz is used to power your cooler.

Make sure the household voltage is the same as the appliance's rate by checking [25]:

1. specification. Take the item out of the packing before using it, and make sure it's in excellent shape.
2. Always unplug the product before refilling the water tank.
3. Always unplug the appliance from the power source before cleaning, servicing, or relocating the unit.
4. Remove the power cord from the electrical receptacle by grasping and pulling on the power cord plug-end only, never pull the cord.
5. AVOID using the product in locations where paint, gasoline, or other combustible materials are kept. Make sure the water tank is full before utilizing the "COOL" setting.
6. A cooler's electrical or mechanical components should not be repaired or adjusted since doing so could jeopardize the cooler's warranty.
7. DO NOT cover the air inlet or outlet on the appliance as this may cause motor damage.
8. DO NOT insert or allow objects to enter any ventilation or exhaust opening as this may damage the product and could cause an electrical shock or fire.
9. DO NOT operate with the Honeycomb Media removed as this will overload and damage the motor.
10. Allowing kids to play with this appliance, the packaging, or the plastic bags is not recommended. Do not continue using the device if it has been damaged or is acting improperly. To troubleshoot, refer to the section on troubleshooting, and consult a specialist.
11. AVOID using in restrooms. Never place the item where it might accidentally fall into a bathtub or another body of water.
12. Store in a dry area when not in use.
13. This device is not meant to be used by people (including kids or the elderly) who have diminished physical, sensory, or mental capabilities, or who lack experience and knowledge, unless those people have received supervision or training from a person who is accountable for their safety.

Caution:

1. Filling with water: Unplug from power when refilling; Unplug the air cooler from the power supply
2. The water tank of this cooler holds up to 1.8 gallons of water. Make sure the tank's water level is consistently higher than the minimum water level. Open the Water Fill Door on the rear side panel of the tank and fill it with water to the Max Level, as shown on the Water Level Indicator, to replenish it. Keep water levels below the Max water level threshold. Close the water fill door after filling the water tank, then switch on the power supply and attach the power cord.

Cleaning and Maintenance

1. Draining and Cleaning the Water Tank: Turn the power “off” and disconnect the air cooler from the power supply.
2. Place the appliance wherever it can be drained. The water drain plug's cap should be removed, and the tank should be let empty.
3. Fill the water tank with fresh water to the top and then totally empty it.
4. Fill the water tank and rinse at least 2-3 times before use.
5. Connect the device to the power source and turn it on.

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