“SOLAR POWERED EVAPORATIVE AIR-CONDITIONING SYSTEM”

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Introduction:

Air conditioning market is currently dominated by the mechanical vapour compression air conditioning system which, formed as a loop (Fig. 1) comprising an evaporator, a condenser, a compressor and an expansion valve, allows a refrigerant (e.g., R-22, R-134a, R410A) to circulate around.Within the evaporator, the refrigerant absorbs heat from the surrounding causing change of its phase from liquid to vapour and subsequently the cooling of the surrounding medium (e.g., water, air). Afterwards, the refrigerant is fed into the compressor which, delivering a significant electrical power, enables generation of a high pressure, super-saturated refrigerant vapour. This form of vapour then enters into the condenser; where it loses heat to surrounding medium, leading to condensation of the high pressure refrigerant vapour. Leaving off the condenser, the refrigerant comes across an expansion valve which, through the throttle effect, causes reduction of the refrigerant’s pressure. This low pressure refrigerant is then back to the evaporator to recollect the heat.

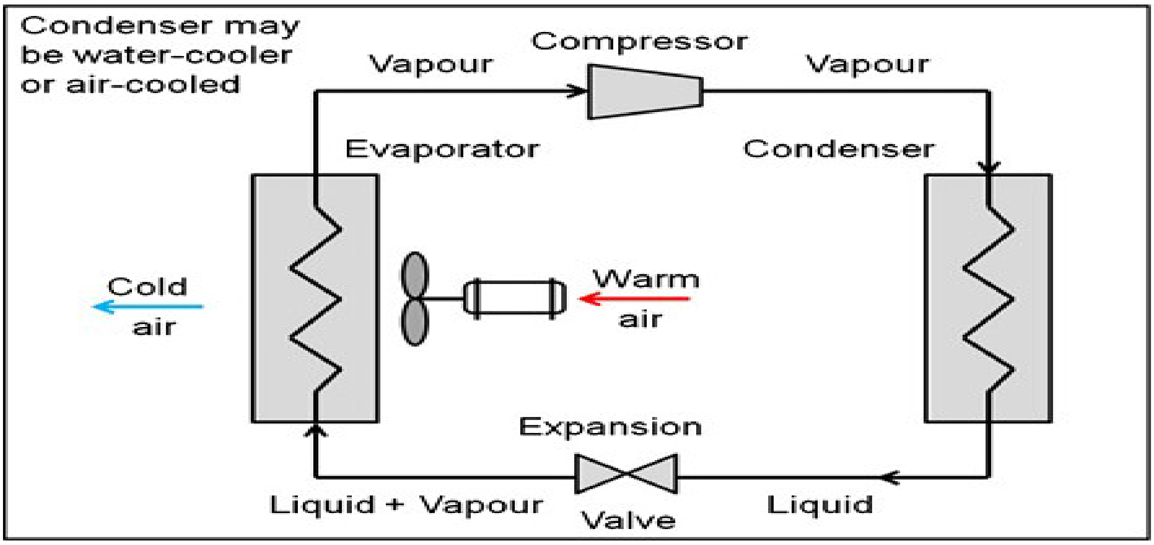


Fig.1 Block diagram of conventional

This kind of cycle was fully established and has been in practical use for over 100 years. Owing to its relatively long history and massive scale production, the technology presents many advantages e.g., good stability in performance, low cost, long life cycle time and reasonable good energy performance. However, this type of system has a major disadvantage that lies in high demand to electricity for operation of the compressor, owing to the high dependency of fossil fuel burning in current electrical industry. The most common refrigerant used in air conditioner are R-410A,R-134A,are strong contributors to global warming. Hence this technology is regarded as neither sustainable nor environmentally friendly.

Evaporative air conditioning system used in our project:

Evaporative air coolers have been popular for years because they offer an economical alternative to conventional air conditioning systems in a hot and dry climate. Compared to conventional air conditioning units, evaporative air coolers operate without ozone harming chlorodifluromethane (HCFCs) used by refrigeration based systems. An evaporative air cooler is a device that cools air through the simple evaporation of water. It is especially well suited for climates where the air is hot and humidity is low.

Objective:

Cost of energy, impact on the environment due to the release of ozone depleting substances and greenhouse effect due to the emission of CO_2 and the other economic factors have encouraged researchers to develop alternative cooling technologies. In the northern latitudes of the India, summers are very hot combined with humidity leading to heat strokes and other inconveniences. Solar air conditioning systems are extensively used for human comfort in homes, offices and plants. They also find application in animal shelters, poultry farms, green houses, textile mills and for product cooling. This solar air conditioning system can attribute to high cost of air conditioners, increased electricity consumption and lack of adequate service infrastructure. It is estimated that, about 30 million evaporative coolers used mainly during the summer months and nearly 5 million air conditioners are in use in India. Together, they represent a total load of 39 million kW. Hence the use of solar conditioning system is estimated to save about 24 million kW of electrical energy.

Methodology:

From the above discussion it is clear that, evaporative air conditioning systems are better alternatives to the conventional air conditioning system.Our project on air conditioning uses evaporative cooling system and also this air conditioning is innovative three in one technology that provides hot water, cooling and heating indoor air and uses fraction of electricity and halves greenhouse effect.

Material table

SL NO.	COMPONENTS	MATERIALS USED
1.	Desiccant wheel	Silica gel as a desiccant material & GI sheet metal as a frame.
2.	Heat exchanger	Maruti 800 Car Radiator.
3.	Indirect evaporative air cooling system	Aluminium pipes wound with cotton cloth.
4.	Fabricated outer box arrangement and stand	GI sheet metal.
5.	Piping System	PVC pipes
6.	Reservoir	Plastic tank
7.	Insulating material	Thermocol foam
8.	Energy storing device	Battery of 12V DC
9.	Temperature measuring device	Thermocouple of K type with 4 channels

Working of our solar powered evaporative air conditioning system

The process begins with typical solar hot water systems, where water is heated by solar collector and stored in hot water tank .This hot water is then used throughout the home reducing the need of gas or electricity. A portion of hot water is used in our solar air conditioning unit (fig 2) which is divided into two compartments. The hot water enters the heat exchanger in the 1st compartment of the unit. Similar to car radiator, the heat exchanger uses the hot water to heat outside air drawn into the 1st compartment of vent. At the same time the outside air drawn in 2nd compartment into the desiccant wheel.Desiccant wheel is most critical part of the system. It is used to dry out the air before it enters into the home. Slowly turning desiccant material in the wheel continuously absorbs moisture in the compartment. Then absorbent material dries out in the 1st compartment. The desiccant material is dried out using hot dry air generated by the heat exchanger. This air is then exhausted outside the home .The dry air from the desiccant wheel flows through indirect evaporative cooler in 2nd compartment which creates cool dry air to house.

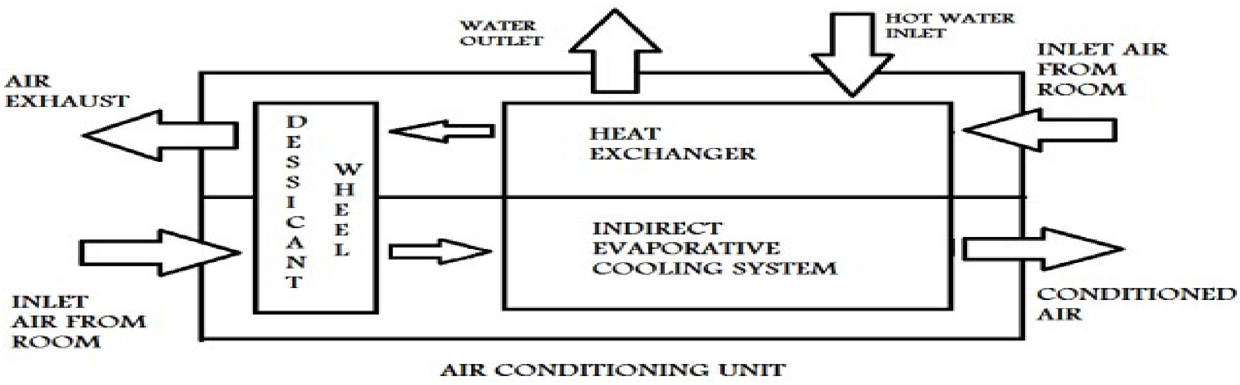


Fig. 2 Principle of Solar powered evaporative air-conditioning system

This cool dry air is then fed into the home in order to cool down the rooms. In winter, solar heated air used directly to warm the house. In these way our solar powered indirect evaporative cooling can be used all year air conditioning system.

Indirect evaporative coolers & their basic principle:

Indirect Evaporative Cooling (IEC) systems can lower air temperature without adding moisture into the air, making them the more attractive option over the direct ones.

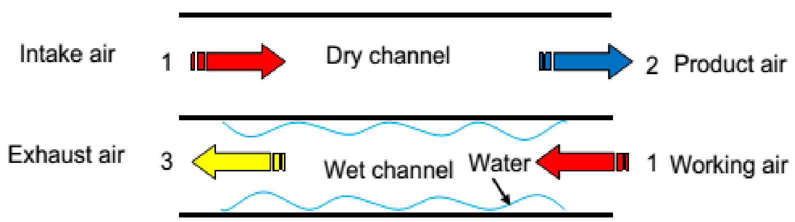


Fig.3principle of indirect evaporative cooling

In an indirect evaporative air cooling system(fig.3), the primary (product) air passes over the dry side of a plate, and the secondary (working) air passes over the opposite wet side. The wet side air absorbs heat from the dry side air with aid of water evaporation on the wet surface of the plate and thus cools the dry side air; while the latent heat of the vaporized water is transmitted into the working air in the wet side.

Dehummidification techniqe used in air conditioning:

Desiccant-based dehumidification: Desiccants are solid or liquid materials that attract moisture. Materials for HVAC desiccation are selected on the bases of their ability to hold large quantities of water, their ability to reactivated and cost. To continually absorb moisture, a desiccant needs to be regenerated (dried) by passing hot air over it. When a desiccant wheel is used, the drying of process air and the regeneration of the desiccant can occur concurrently (fig.4). For the desiccant wheel used in this experiment, heat was provided by a heating coil supplied by hot water from a gas-fired water heater.

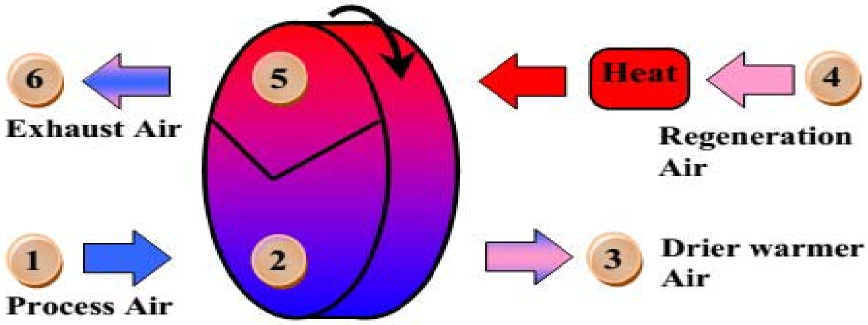


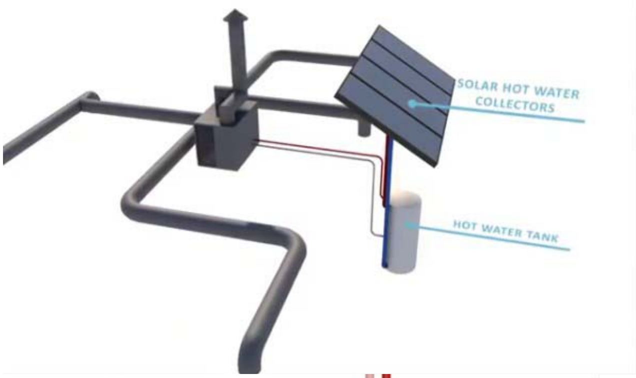
Fig.4 Principle of desiccant-based dehumidification:

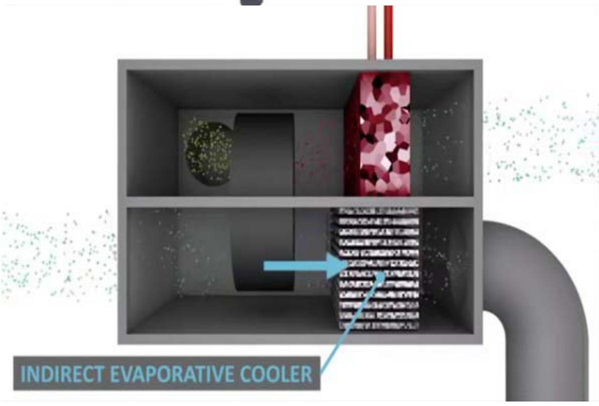
Humid air enters the rotating bed of dry desiccant .As air passes through the bed, the desiccant attracts moisture from the air. Air leaves the desiccant bed warm and dry. A second air stream is heated and passed through the desiccant bed to raise its temperature. Heated desiccant gives off its collected moisture to the reactivation air stream coming from heater. The moist reactivation air is vented outside, carrying excess humidity from the building. The desiccant air cooling system used in this project comprises active desiccant dehumidification with indirect evaporative cooling. The desiccant wheel was controlled independently using a humidistat that sensed the wet-bulb temperature of the space. A thermostat was used to activate the indirect evaporative cooler when there was a need for space cooling. This arrangement lets the air conditioning (sensible wheel +indirect evaporative cooler) focus on temperature control while the desiccant is directed towards humidity management. One or the other or both may operate, depending on ambient conditions.

Engineering design drawings:

Compartment arrangement with solar panel

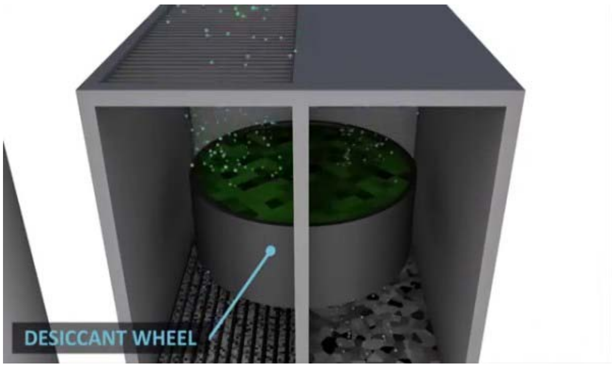
Inner view of compartment





Desiccant wheel

Indirect evaporative cooler



Compartment body Exploded view

Wheel frame assembled body

Accomplished work:

Even though concept is very clear, challenge is to build this project practically. First step was to collect raw materials; we needed good desiccant material such as silica gel, Calcium carbonate, charcoal etc. Among this desiccant material, we found silica gel as a best material to be used because it can absorb more amount of moisture as compared to other desiccant material. We brought silica gel from SwambeChemicals,Vadodara (Gujarat). Silica gel was then was embedded within the GI sheet metal wheel so that air can easily pass through that. By considering volume of 1 m^3 of air entering the compartment, we have builtthe parts of the compartment .The inner surface of the compartment is insulated with thermocol foam to prevent heat loss. We used modified car radiator of Maruti800 as heat exchanger to heat the air. Indirect evaporative cooling system is made up of alumium pipes of 1 inch diameter assembled in inline arrangement (5*5) which is wounded with cotton cloth. Here we are using two fans to pass the air from surrounding to the compartment. Once the compartment is ready we attached the accessories like solar water heater, solar panel and water supply. Right now, the assembly is ready for the experiments to measure its performance and Air-Conditioning Capacity. Thermocouple of K type with four channels is used to measure the temperature at various points of the compartments.

Work done as per the design:

Sheet metal working for outer compartment

Sheet metal bending processOuter Compartment

Car radiator (Maruti 800) **Desiccant wheel with silica gel**

Assembled view of our completed project

Results and conclusions:

Fabricated solar powered evaporative air conditioning system without using any refrigerants. Hence we have achieved environment friendly air conditioning system. It is found that silica gel desiccant wheel is more effective to absorb the moisture content present in the air and can be easily regenerated. We found that Absorption capacity of desiccant wheel is 6 to 7g/kg of air. We have used indirect evaporative cooling system with aluminum pipes and got satisfactory results with COP 0.9 to 1.8 and cooling capacity 105 Watts to 170 Watts. We have successfully used cross flow heat exchanger to heat the air by utilizing solar hot water collector with overall heat transfer coefficient of 140 W/m^2K. We have successfully designed and fabricated air conditioning system that completely operated by solar energy. Hence we have effectively utilized nonrenewable resources. Our air-conditioning system requires 95 Watts of energy which is very low when compare to conventional air conditioning system that requires about 2000-5000Watts. Over a period of 6 months in this project we gained immense knowledge in the field of Mechanical Engineering. Not only did we revise our concepts of design in thermodynamics, but we also got an opportunity to fabricate materials required for the project. We now understand how important is planning in performing a project within a limited timeframe. Although we achieved our objectives for the project, a through test on a warm sunny day still remains. Sizing calculations need to be performed to determine the cooling load of the system we built. Also, the addition of a motor to rotate the wheels will help the overall system performance and regenerate the desiccant material. The strengths of our project include the utilization of renewable energy for air conditioning, a system that is scalable from a residential to a commercial size, an environmentally friendly, low electric consumption, and minimal CO_2 emission system that can perform while eliminating energy hungry components that are found in a traditional air conditioning system. We would have also liked to test the system with more ideal environmental conditions, but were not able to get such conditions before the end of the project. Our system can be used for residential purposes and can be installed on top of the roof or in the lawn outside homes. The cool air will reach the desired room/buildings from a duct connected to the outlet of our system. We have successfully overcome many disadvantages of conventional air conditioning system. Overall success of our project that helped us see how the engineering design process takes place and that it takes team work as well as many design changes to complete a product.

Scope of future work:

Since our project work is a basic step in era of Solar powered evaporative air-conditioning, we are unable to do the detailed analysis of our air conditioning system because of short span of time. There is a lot of future scope in our project. In our project each part can be redesigned so that whole system performance can be increased. We have used simple design of indirect evaporative system, but this system can be replaced by most effective indirect evaporative cooling system made by many researchers so that we can get minimum temperature of about 18˚C to 24˚C . We have used silica gel desiccant wheel as desiccant material, but there are also other desiccant materials present so they can be used and their performance need to be measured. Similarly heat exchanger can be redesigned and different material can be used to get higher heat transfer from hot water to air. Because of many constraints like available fabrication facility, limited time and limited capacity parts available in market we are unable to build most effective design. But these all constraints can be easily overcome by manufacturing industries. So this project can be easily redesigned and commercialized as early as possible in orderto have environmental friendly and energy saving air-conditioning system.