Improving Performance of Solar Cooler by Using Nozzles

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Abstract-The present air-cooling methods are evaporative coolers, air conditioning, fans and dehumidifiers. But running these products need a source called electricity. Producing electricity is ultimately responsible for hot and humid conditions i.e. global warming. In hot and humid conditions, the need to feel relaxed and comfortable has become one of few needs and for this purpose utilization of system like air-conditioning has increased rapidly. These systems are most of the time not suitable for villages due to longer power cut durations and high cost of products. Solar power systems being considered as one of the paths towards more sustainable energy systems, considering solar-cooling systems in villages would comprise of many attractive features. This technology can efficiently serve large latent loads and greatly improve indoor air quality by allowing more ventilation while tightly controlling humidity. Despite increasing performance and mandatory energy efficiency requirements, peak electricity demand is growing and there is currently no prevalent solar air-cooling technology suited to residential application especially for villages, schools and offices. Also, there is need to increase cooling effect of cooler. Converging-Diverging nozzles can be used to increase the cooling effect. As the air is thrown from fan to room it will pass through this nozzle which will ultimately increase the cooling effect. This project reviews solar powered air cooler with nozzles for residential and industrial applications.

Keywords-Solar system, Converging-Diverging nozzles, cooling and humidification, Evaporative cooling.

1. INTRODUCTION

The human body considered as thermal machine with 20% thermal efficiency. The remaining 80% heat must be disposed of from the body to the surroundings otherwise accumulation of heat results and causes discomfort. The human body works best at a particular body temperature like any other machine but cannot tolerate wide range of variation in environmental temperature like thermodynamic machines. Human beings give off heat, around an average of 100 kcal per hour per person, due to what is known as 'metabolism'. The temperature mechanism within the human body maintains a body temperature of around 36.9^{0}C (98.4^{0}F). But the skin temperature varies according to the surrounding temperature and relative humidity. To dissipate the heat generated by metabolism in order to maintain the body temperature at the normal level, there must be a flow of heat from the skin to the surrounding air. If the surrounding temperature is slightly less than that of the body, there will be steady flow of heat from the skin. But is the surrounding temperature being very low, as on cold winter day the rate of heat flow from the body will be quite rapid, thus the person feels cold, on the other hand on a hot summer day, the surrounding temperature is higher than that of the body, and so there cannot be flow of heat from the skin to the surroundings, thus the person feels hot. In such a situation water from the body evaporates at the skin surface dissipating water from the body evaporates at the skin surface dissipating the heat due to metabolism. This helps in maintaining normal body temperature. But if the surrounding air is not only hot but highly humid as well, very little evaporation of water can take place from the skin surface, and so the person feels hot and uncomfortable.

2. RELATED WORK

A nozzle is a device which increases the velocity of a fluid by decreasing its pressure. In doing so temperature of fluid also decreases. In this cooler the modification is done by introducing nozzle in front of fan. The grid of nozzles is manufactured which is fixed in front of fan through which the air passes. The nozzle is manufactured by cutting two aluminum cones and joining them to form a converging-diverging cone. The pressure in front fan is high and the outside pressure is low, when air passes through nozzles pressure of air decreases and velocity increases thus the cooling of air takes place.

3. PROBLEM STATEMENT

Temperature during summers is very high and to get cooling effect at low cost is difficult so there is a need to increase the cooling effect using cooler. Using an air conditioner is costlier and consumes more energy so there is need to increase cooling effect by using cooler which consumes less power. Electricity generation produces nitrogen oxides and sulphur dioxide emissions, which contribute to smog and acid rain, emit carbon dioxide, which may contribute to Climate change. So, there is need of using non-conventional energy which will ultimately reduce global warming.

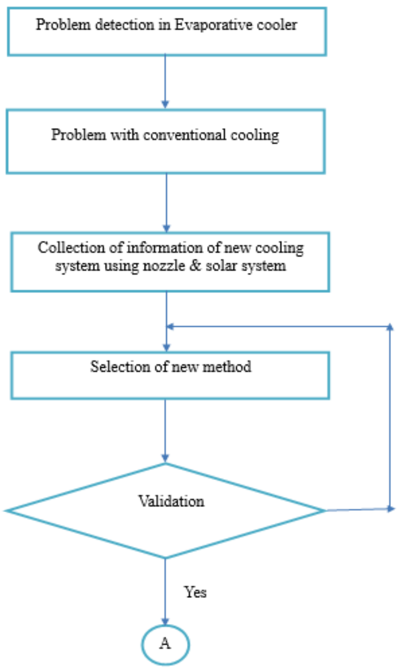
4. OBJECTIVE OF THE PROJECT

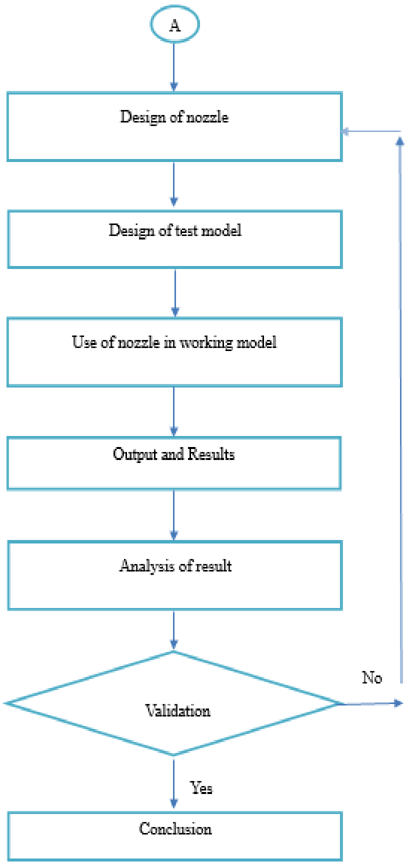
Increase the cooling effect of domestic cooler. To increase the cooling effect by using evaporative cooling as well as using nozzles.
Use of non-conventional energy sources which is abundantly available in nature does not impose any bad effect on earth like global warming, green house effects

5. NEED FOR NON-CONVENTIONAL ENERGY FOR RUNNING COOLER

Fuel deposit in the will soon deplete by the end of 2020, fuel scarcity will be maximum. Country like India may not have the chance to use petroleum products. Keeping this dangerous situation in mind we tried to make use of non-pollutant natural resource of petrol energy.
The creation of new source of perennial environmentally acceptable, low cost electrical energy as a replacement for energy from rapidly depleting resources of fossil fuels is the fundamental need for the survival of mankind. We have only about 25 years of oil reserves and 75 – 100 years of coal reserves. Resort to measure beginning of coal in thermal electric stations to serve the population would result in global elemental change in leading to worldwide drought and decertification. The buzzards of nuclear electric-stations are only two will. Now electric power beamed directly by micro-wave for orbiting satellite. Solar power stations provide a cost-effective solution even though work on solar photo voltaic and solar thermo electric energy sources has been extensively pursued by many countries. Earth based solar stations suffer certain basic limitations. It is not possible to consider such systems and meeting continuous uninterrupted concentrated base load electric power requirements.
Evaporative cooling systems have been used widely in developing world's where cost of using air conditioning can be very high due to costly electricity. India being one such country uses very large amount of desert coolers. In India since majority of people are poor or have moderate living standards so it becomes very important that these evaporative cooling systems uses electricity efficiently. The evaporative cooler performance is directly related to the ability of the padding materials to evaporate water (cool) at given humidity. The cost of acquisition and operation of a cooling system is a fraction of conventional air conditioning and mechanical refrigeration systems. In evaporative cooling process hot air is passed through the wetted pads as a result part of the water will be evaporated and is carried with air
by increasing the specific humidity of air. The major disadvantage of using evaporative cooling system is that this system adds humidity to air which becomes very troublesome in monsoon season. As in rainy season there is already so much humidity in air, adding more water to air make cooling ineffective. The only remedy for this is to add dehumidifier to the cooling system but this raises the cost of the cooling system and makes it equivalent to air conditioning units cost. The factors that determine the performance of cooler is the material used for pads. Many researchers have tried to find the padding materials which can successfully be replaced with the traditional material for effective cooling. found the average cooling efficiency is highest for jute at 62.1%, compared to 55.1% for luffa fibre, 49.9%. theoretically analysed the performance of jute fibre rope bank as media in evaporative systems, determined the relationship among air velocity, cooling efficiency and temperature decrease at cellulose based evaporative cooling pads. Many researchers have almost investigated the cooling pad material highlighting important role of cooling pad in cooling. Present work, focuses on the non-conventional pad material by providing many converging nozzles in place of the cooling pad. This is one way to make cooling systems electricity efficient. This will also make the cooling system

6. METHODOLOGY





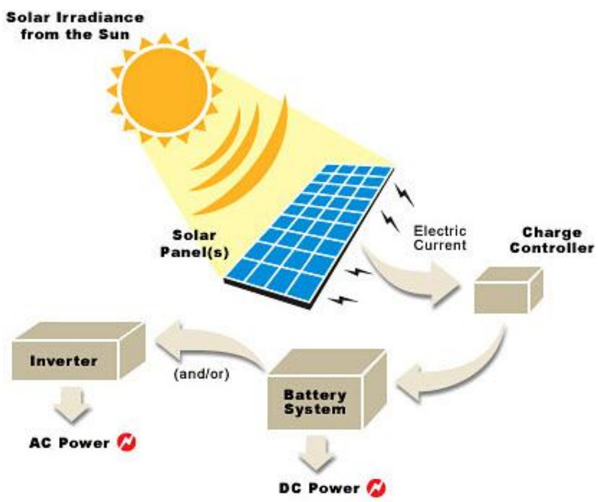
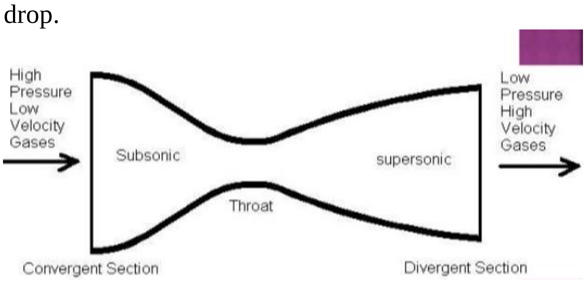


Fig 6.1 Solar Energy Conversion

Solar energy conversion is done by using battery, inverter and charge controller. As sun light falls on solar panel, which converts into electrical energy by photoelectric effect. This electrical energy stored in battery in the form of chemical energy. Charge controller is employed in between solar panel and battery which prevents overcharging. Solar energy conversion process and may protect against overvoltage, which can reduce battery performance or lifespan, and may pose a safety risk. The stored energy directly can use for DC loads or else need to be converted AC (alternate current) by the help of inverter.

6.1. Thermodynamic principle of nozzle

A nozzle is a device which increases the velocity or kinetic energy of a fluid at the expense of its pressure drop.



According to continuity equation , at constant discharge if area of outlet decreases the velocity of outlet increases.

Q=A1V1=A2V2

V2=(A1\A2)V1

Steady flow energy equation,

$$h_1 + \frac{v_1^2}{2} + z_1 g + \frac{dQ}{dm} = h_2 + \frac{v_2^2}{2} + z_2 g + \frac{dw}{dm}$$

Here,

$$\frac{dQ}{dm} = 0\,, \quad \frac{dw}{dm} = 0$$

& change in potential energy is also zero.

$$h_1 + \frac{v_1^2}{2} = h_2 + \frac{v_2^2}{2}$$

change in enthalpy,

$$h1 - h2 = mCp\,(T1 - T2)$$

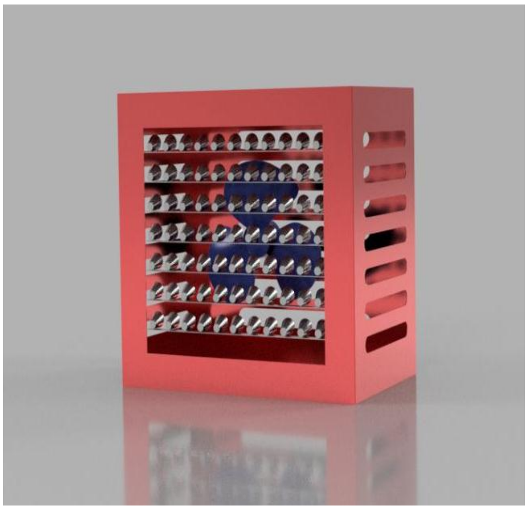
$$\frac{v_2^2}{2} = \text{Cp}\,(T1 - T2) + \frac{v_1^2}{2}$$

Outlet temperature can be calculated as,

$$T2 = T1 - (v_2^2 - v_1^2)/2\text{Cp}$$

7. CAD MODEL

Solar panel consists of number of silicon cells, when sun light falls on this panel it generate the voltage signals then these voltage signals are given to charging circuit. Depending on the panel board size the generated voltage amount is increased. In charging circuit the voltage signal from the board is gathered together and stored in the battery. There are two tanks provided one at the top and another one at the bottom. The water from the top tank is made to pass through the tubes which are fixed between the two tanks. A fan is provided at the centre of the tank in such a way that the supply for the fan is coming from the battery which stores the current from the solar panel. When the water falls from the top tank to the bottom tank due to gravity, the fan is made to run, so that the cool air will be supplied all the way through. At the bottom of the tank, there will be a pump which pumps the water again to the top tank. The power for the pump is coming from the battery connected to the solar panel. The fan and pump is controlled separately with help of manual operated switch**.**



8. SIMULATION OF WORK

8.1 Capacity Solar Panel and Battery required

Hence selected Blower (Fan) Specification: 230v, 50Hz, 18W motor and 11W Pump So to run 30W blower on for 1 hour will take

30*1=30Wh from the battery (Battery capacity is measured in Amp hours)

For 10Ah, 12v battery the watt hours is given by

P=V*I (2)

V=12v and I=40Ah

P= 40*12=480Wh

So, the 30W centrifugal fan runs for

120/30= 4≈ 4h

This means the battery could supply 30W blower for 4 hours.

Energy generating capacity of solar panel over a period of time: To calculate the energy it can supply to the battery, multiply watts by the hours exposed to sunlight, then multiply the result by 0.85 (This factor allows for natural system losses). For the solar 150 W panel in 1 hours sunshine, 150*1*0.85 = 128 Wh

Comfort thermal conditions achieved in the living room. That is room temperature up to 24 °C and relative humidity of 60%. At lower cost cabin is cooled.

8.2 Design consideration in project

Capacity of the fan required for a particular area can be calculated as

Criteria: With supply of water through the cooling pads. So, heat transfer between water and the air is given by following equation

$$m_w^{\cdot}(T_1 - T_2) = \frac{V}{V_{s1}}\left[(ha_1 - ha_2) - (w_1 - w_2)\,T_2\right]$$

where as

mw – Mass of water entering into the cooling pads per minute

V – Volume of air (m3) entering into the room per minute (min)

Vs1 – Specific volume of air entering into the cooling room

ha1 – Enthalpy per kg of dry air atT1

ha2 – Enthalpy per kg of dry air atT2

w1 – Mass of vapor per kg of dry air atT1

w2 – Mass of vapor per kg of dry air atT2 Considered conditions,

T1 = 30 °C

T2 = 25 °C

Relative humidity = 60%

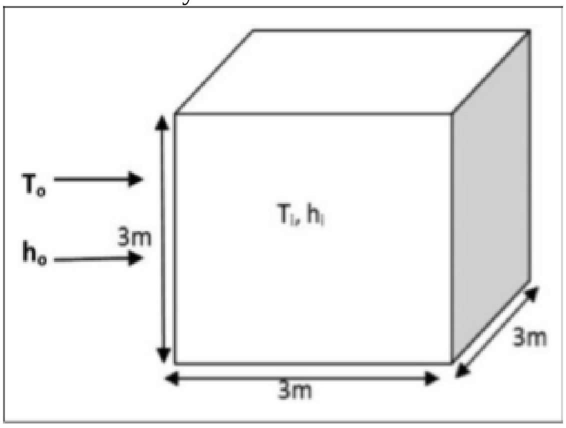


Fig. 8.2.1 Room Considered

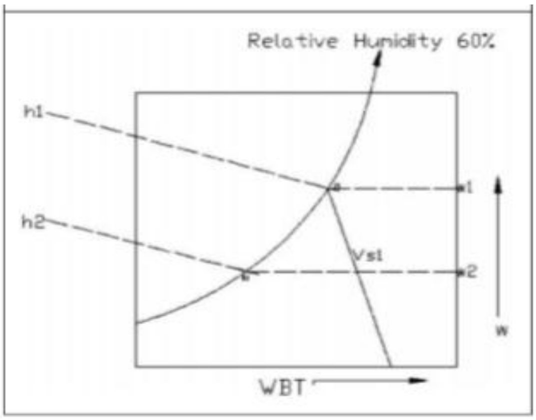


Fig.8.2.2 psychometric chart

From: Psychometric chart,

ha1 = 72.5 KJ/Kg of dry air = 17.31 kcal/kg

ha2 = 56 KJ/Kg of dry air = 13.37 kcal/kg

w1 = 0.016 grams/kg of dry air

w2 = 0.012 grams/kg of dry air

Vs1 = 0.880 m3/kg

Substituting above mentioned values in Equation (1)

$$2*(30-25) = \frac{V}{0.880}\left[(17.31-13.37)-(0.016-0.012)*25\right]$$

$$V = 2.291\,\text{m}^3/\text{min} \approx 2.5\,\text{m}^3/\text{min}$$

So the fan capacity of 2.5 m3/min is selected.

8.3 Design of Nozzle

1. Considering temperature during summers T0=40℃
2. Atmospheric Pressure P1=1.03 bar
3. Assuming expected temperature at outlet to be T1=23℃

□ T0/T1 = (P0/P1)^ [(γ-1)/γ]
□(40+273)/(23+273)=(P0/1.03) ^ [(1.4-1)/1.4]
□P0=1.252 bar

P*/P0 = [2/(γ+1)] ^ [γ/(γ-1)]
□ P* = 1.252 * [2/(1.4+1)] ^ [1.4/(1.4-1)]
□ P* = 0.6614 bar

T*/T0 = [2/(γ+1)] = 2/2.4
T* = (40+273)/1.2
T* = 260.83 K

v* = RT*/P*
v* = (287*260.83)/(0.6614*10^5)
v* = 1.13 m^3/kg

V* = (γRT*)^(1/2)
V* = (1.4*287*260.83)^(1/2)
V* = 323.73 m/s
Flow Rate :-
Q = 1050 m^3/hr
Q = 0.2916 m^3/s
w = 1.225*Q
w = 1.225*0.2916
w = 0.3572 kg/s
w = 0.03572 kg/s …….(For 1 nozzle)

Dimension of Throat :-
A* = wv*/V*
A* = (0.03572*1.13)/323.73
A* = 1.2468*10^-4 m^2
□ D* = 12.601 mm

v1 = RT1/P1
v1 = (287*296)/(1.03*10^5)
v1 = 0.8247 m^3/kg

V1 = 44.72*[cp*(T0-T1)]^(1/2)
V1 = 44.72*[1.005*(313-296)]^(1/2)
V1 = 184.84 m/s

A1 = wv1/V1
A1 = (0.03572*0.8247)/184.84
A1 = 1.5937*10^-4 m^2
□ D1 = 14.24 mm

So we get :-
Diameter of Throat = D* = 12.60 mm
Diameter of exit = D1 = 14.24 mm

8.4 CFD analysis of Nozzle

[A] Temperature Analysis Using CFD

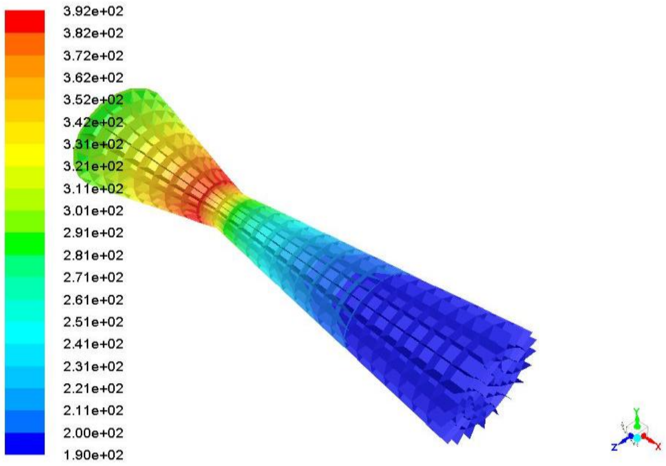


Fig 8.4.1 Temperature Analysis Using CFD

From experimentation we came to know that, the air passing through nozzle at the inlet section having more temperature which is shown in above analysis and temperature of air goes on reducing which is shown by blue section at the outlet of nozzle.

[B] Pressure Analysis Using CFD

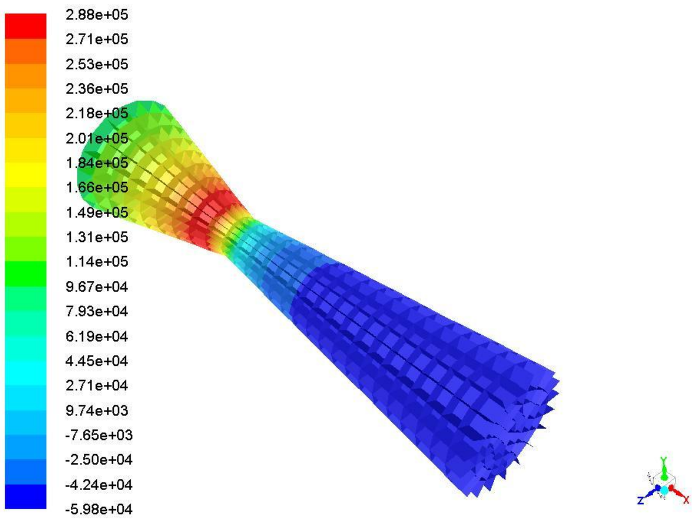


Fig 8.4.2 Pressure Analysis Using CFD

The pressure at the inlet of nozzle is more shown by the above analysis and it goes on reducing there by satisfying the principle of nozzle. Due to the pressure drop in the nozzle there is temperature drop of air. The above analysis proves the theory of reduction in pressure with simultaneous reduction in temperature of air.

[C] Velocity Analysis Using CFD

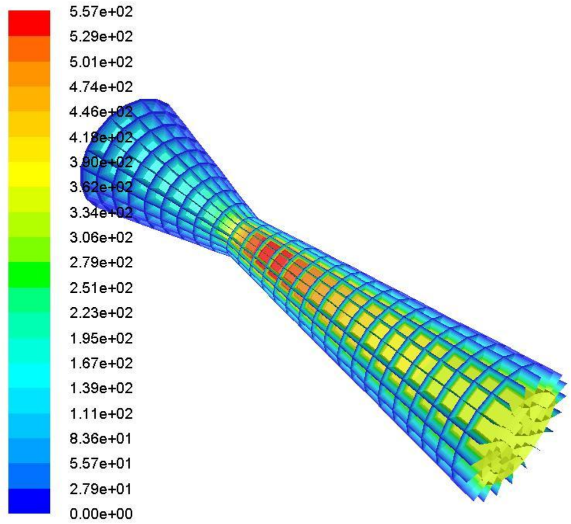


Fig 8.4.3 Velocity Analysis Using CFD

The velocity of air at the inlet is less as compare to outlet shown by above analysis. From above analysis it is proved that the velocity of air goes on increasing, which satisfies the principle of nozzle.

9. RESULT TABLES & DISCUSSION

9.1 Readings Taken In Open Room **(**ROOM TEMP.- 32.8 ℃)

READING NO.	PROCESS	TIME (MIN)	TEMP ℃
1	With nozzle, without Water	10	32.2
2	Without nozzle, without water	10	32.4
3	Without nozzle, with water	10	28.8
4	With nozzle, with water	10	24.6

9.2 Readings Taken In Partially -Closed Room

READING NO.	PROCESS	TIME (MIN)	TEMP ℃
1	With nozzle, without Water	10	31
2	Without nozzle, without water	10	31.4
3	Without nozzle, with water	10	27.2
4	With nozzle, with water	10	27.1

9.3 Readings Taken In Closed Room

READING NO.	PROCESS	TIME (MIN)	TEMP ℃
1	With nozzle, without Water	10	33
2	Without nozzle, without water	10	31.8
3	Without nozzle, with water	10	28.6
4	With nozzle, with water	10	28.5

From above experiment we observed that there is more temperature drop in open room as compare to closed room and partially open room. As cooler always required the fresh flowing air. Problem associated with the close and partially open room is that there is increase in humidity content in air which causes discomfort to human being.

Air coolers are totally depends upon climate condition. Air coolers converts water to vapors water vapors adds to air cool down the air. The humid areas have high water already in the air. So when we run air cooler in high humid areas there is no replace for extra humid to air so making the air cooler functioning in effective. In short, air coolers do not work well in high humid areas. The costal areas have high humidity, making it not effective in high humid areas.

10. CONCLUSION

The study theoretically and experimentally evaluates the potential of cooling air using an isentropic nozzle flow in a cooling system. Here we try to add small converging-diverging nozzles built in front of fan, also throwing air which pass through nozzle and enter the room. From theory we know that when fluid passes through nozzle its temperature at exit decreases by principle of thermodynamics i.e. When the pressure decreases temperature also decreases and velocity of flow increases. Thus using nozzles can provide cooling of air. Also from theory we find that exit velocity is higher than entry velocity. This aids the fan in easy throwing of air. Isentropic nozzle flow coolers can therefore be used to improve the human thermal comfort in residences, schools, commercial centres, hospitals, and industries provided the main parameters for cooling fall within the recommended range. Hence, we did study that cooling systems with nozzle built in pads could be a great method to cooling air by combining with evaporative cooling. This solar product perfectly suits for villages, schools and offices and thus an alternate to the power cut problems. It comprises of many attractive features such as usage of solar energy, cooler and cooling cabin at lower cost. It is eco friendly and natural, electricity savers. Durability of the product is more thus minimizing the cost. No electricity is used so this product saves the energy and saves environment from getting polluted.

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