Design and development of low power air cooler using Maisotsenko cycle

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Abstract:A Direct evaporative cooling system cannot cool air below wet bulb temperature, while indirect evaporative system is not much efficient in producing required temperature drop for its given size and usually works on two different fluids. The maisotsenko cycle combines both evaporative cooling and Indirect evaporative cooling in same system and gives higher COP. Maisotsenko cycle can cool beyond wet bulb temperatures, the theoretical limit being the dew point. The crossflow recuperator bleeds the product air into wet channels and exhausts it after addition of moisture by evaporation of water absorbing latent heat, thus imparting cooling effect to dry channel air for usage without additional humidity. The paper aims to develop a low power air cooler that runs on the same Maisotsenko cycle. Along with reduction in power consumption, cost reduction was also an aimed for and hence the cooler is made from easily available materials, Photo paper is used for the Heat and mass exchanger unlike other costly materials that are usually preferred.

***IndexTerms* - Air Cooler, Maisotsenko Cycle, Cross Flow Recuperator, Sub-Wet bulb Cooling, Heat and mass exchanger.**

I. INTRODUCTION

Today’s air conditioning systems work mostly on VCR cycles that consume very large amount of energy for cooling. In typical case such systems may consume around 30-40% of total energy consumption of a house. Also these systems require refrigerants for their working cycles. Many of these refrigerants are banned because of being harmful to ozone layer or having high global warming potential. On the other hand the evaporative cooler uses water for it, which evaporates and humidifies the air making it uncomfortable. These coolers also have higher water consumption. Such coolers cannot cool beyond wet-bulb temperature so a system that is more efficient than the existing systems is needed for present cooling needs that give both benefits of VCR systems and evaporative coolers. Direct evaporative coolers have benefit of having low power consumption than VCR as it works on adiabatic cooling. Their drawback is that it adds moisture into the product air stream. An indirect evaporative system can prevent such problem but it has lower efficiency than evaporative coolers [1].

II. MAISOTSENKO CYCLE

The Maisotsenko cycle is a psychrometric process that works by combining both direct and indirect evaporative cooling in one system and is more efficient than both. The cycle has ability to cool the ambient air of any temperature effectively that is not very humid. It is a regenerative thermodynamic cycle that reuses cooled air from the cycle for even more cooling of the incoming hot air to achieve even more effectiveness. The direct and indirect evaporative coolers use less power and are also low cost systems but have certain thermodynamic limitations that prevent their widespread usage on large scale and replace VCR systems. Maisotsenko cycle overcomes the thermodynamic limitations of these cooling systems.

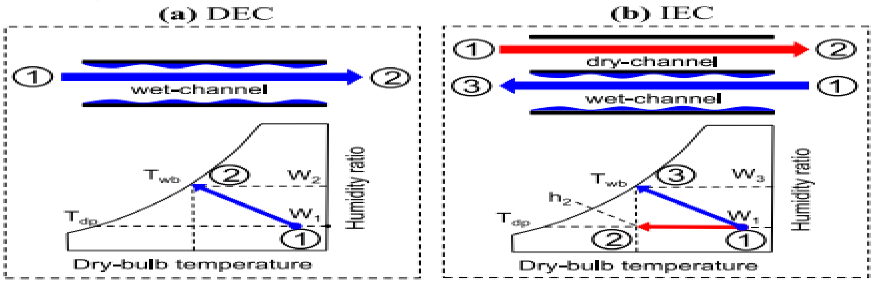

Fig. 1: The Maisotsenko cycle

The M-Cycle combines the thermodynamic processes of heat transfer and dew point evaporative cooling by utilizing the psychrometric renewable energy available from the latent heat of water evaporating into the air [1].

III. OBJECTIVE

The need for human comfort with ever growing energy demand requires innovation in the present technologies used to provide controlled climatic conditions in confined space for human needs. VCR systems although widely used are intensively energy consuming. Maisotsenko developed a new psychrometric process for air conditioning with very low power consumption known as M-cycle. Air coolers based on this process are available commercially although not widely in use. This coolers use heat and mass exchangers made of patented cellulose sheets that can work as dry and wet sides as required in M-cycle.

Our project aims at developing an experimental model of such an air cooler that works on M-cycle for cooling. For this project we decided to use Glossy Photo paper sheets instead of the patented cellulose sheets. These papers have one glossy surface and hence can work as dry and wet channels on either side. The choice of this material for the project was done to test its usability in M-cycle coolers. The material also has an advantage of being easily available and cheap compared to other alternatives and requires no special processing in using or even manufacturing it for the purpose.

The project also aims to make the air cooler light weight and portable for daily usage. The cooler will be both low power consuming and water consuming.

The introduction should state the objectives of the paper and give a review of earlier works. Theoretical considerations, mathematical derivations, technical details and experimental results should be left for subsequent sections. While referring to the research work / results of other researchers throughout the entire paper the authors must mention the reference number [1] with details in the reference section. For more than two references, the reference may be numbered [2, 3] likewise. Do not use “Ref. [3]” or “reference [3]”. Do not mention authors’ names in the paper except the reference section where complete details of the author along with title and publication details has to be mentioned.

IV. DESCRIPTION OF AIR COOLER

A) HEAT AND MASS EXCHANGER

The HMX is the core part of the entire air cooler as it is the component responsible for actual cooling and the execution of the Maisotsenko cycle. The HMX is manufactured by using A3+ size of photo paper 210GSM and double sided duct tapes of thickness 4mm.

These materials are very easily available and also cheap compared to any material used for making the HMX. Choosing such material is justified as it fulfills the requirement of Maisotsenko cycle of having Dry and wet channels on either side of the conducting wall. Photo paper fulfils the requirement as it has a glossy finish on one side and fibrous paper on the other. Hence the photo paper can successfully accomplish the role of a conductive wall that allows heat transfer but prevents mass transfer as it is impermeable to water due to glossy finish on dry side. The double sided tape acts as a channel divider for the plates formed of photo paper.

The construction for the wet and dry channels is made by applying the tape on the photo paper in 90° orientation thus making it cross flow type. The whole distribution for the wet channels is also done after making the channels.

Fig. 3: 3-stacks of sheets sticked together

B) EXPERIMENTAL SETUP AND MEASUREMENTS

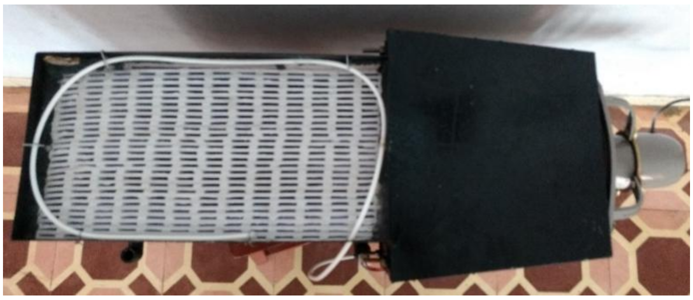

Fig. 4: Experimental setup

Table 1 Specifications of parameters used in experiment
Parameter Design value

Wall material	Aluminum coated fiber (Felt)
Wall thickness	0.5 mm
Length of dry channel	0.508 m

Length of wet channel	0.203 m
Width of channel	25 mm
Channel gap	4 mm
Felt water absorption ability	280 g/m^2
Fabric (Felt) conductivity	0.04 W/m K

Fig. sheets of air cooler

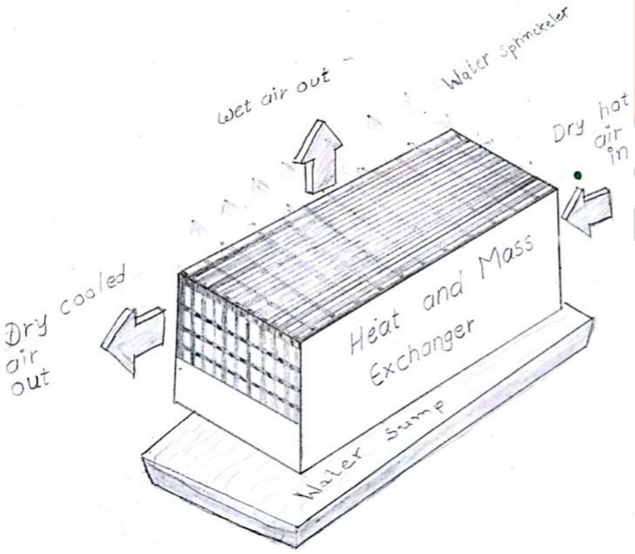

Fig. diagram of heat and mass exchanger

4 EXPERIMENTAL RESULT & DISCUSSION

The air cooler was subjected to various inlet conditions for testing to check its performance. The cooler provided satisfactory results for different test conditions. It was a challenge to find right ambient conditions for the testing as a heating element and humidifier to provide controlled inlet conditions was not used due to time and financial constraints. Although the conditions under which the testing is done are actual prevalent conditions and represents the different cases in which the cooler might be used. For thorough analysis over wide range of parameters very controlled conditions would be required.

Even then the cooler works as expected and has been tested for the prevalent ambient conditions in Anand as of writing this report. The results of the tests inlet outlet temperature are tabulated in the table below.

Table 2 Inlet and Outlet Temperature table

Inlet Temperature (^{0}C)	Location	Outlet Temperature (^{0}C)
35	Outdoor (noon)	27
33	Indoor (noon)	27
30	Indoor (early morning)	26

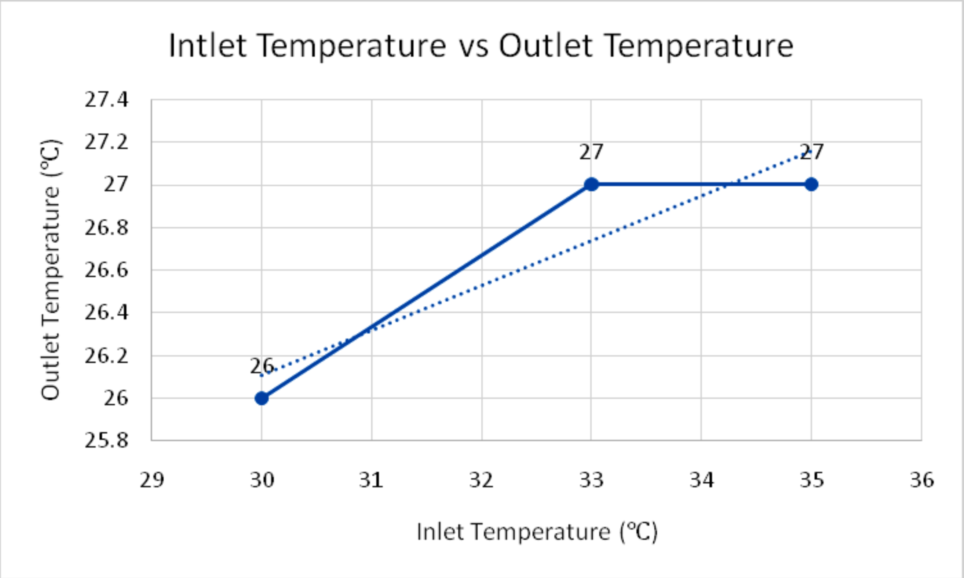

Figure 4 Graph of Inlet Temperature vs Outlet Temperature

It is clear from above data that ambient air is successfully cooled to the temperature which is recommended by ASHRAE as comfortable for humans. The cooler tends to increase the relative humidity of the outlet air but that does not make the occupants uncomfortable as it a result of reducing the temperature of the air, and not due to additional moisture in the air stream. As a result the specific humidity of the air stream remains constant throughout its cooling from inlet to outlet product air.

As we can see from the tabulated readings the cooler reduces the temperature of 350C is reduced to 270C which corresponds to 80C temperature drop. While the relative humidity increases from 50% to 81% and the specific humidity remains constant.

5 EFFECT OF WATER TEMPERATURE

The tests were performed with water from tap that was at room temperature and also ice cold water at 30C. It was found that the temperature of water has affected whatsoever on the cooling capacity of the cooler. The results are consistent with the tests confirmed by Khalid [4] for effect of water temperature. Hence it is desirable to use normal tap water for the cooler unlike ice cold water used in regular evaporative coolers.

6 CONCLUSION

The cooler has performed as desired and gives the output air temperature in the range of the values recommended by ASHRAE. The dew point effectiveness of the cooler at 350C and 50% relative humidity was found to be 66.83% with outlet temperature of 270C. The COP of the cooler at that condition was found to be 50. For the inlet conditions of 330C and 300C the COP was 37.55 and 25.03 respectively.As the temperature increases the dew point effectiveness increases. It must be noted that the M-cycle cooler works better under higher temperature ambient conditions with lower humidity and its effectiveness decreases as the temperature decreases.

7 REFERENCES

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