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ANALYSIS OF THE PERFORMANCE OF A DESICCANT MATERIAL SYSTEM THAT REMOVES HUMIDITY USING A LIQUID DESICCANT CARRIED OUT AT LOW TEMPERATURE AND LOW CONCENTRATION

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Abstract: The process air that is introduced into the conditioned area is the first stream, and the reactivation air that is employed to refresh the desiccant material is the second stream. Because of this, two key phenomena are addressed and researched: dehumidification, which is done so that interior comfort requirements may be satisfied, and humidification, which is done so that a cooling effect may be generated. Drying, chilling, and humidifying are the three basic operations carried out by a desiccant system. One of the benefits of these systems is the potential to cut down on the quantity of electrical energy that is utilised. Therefore, the usage of desiccant cooling provides the promise for cost reductions. This is especially true in situations in which the latent cooling load contributes a large share of the total cooling burden. For instance, it was observed that employing desiccant cooling in a supermarket, as opposed to a standard vapour compression system, resulted in a cost savings of sixty percent for the air conditioning system. Therefore, research that can possibly lead to a desiccant system that is reliable, energy efficient, and cost competitive is important. The goal of this research is to evaluate the performance of a desiccant coated fin tube heat exchanger for the dehumidification of ambient air. To explore the efficacy of an inner-cooled activated charcoal coated fin-tube heat exchanger in removing the heat that is generated during the process of dehumidification.

Keywords: Liquid Desiccant, Dehumidification, Vapor Compression, Air-Conditioning System

I. INTRODUCTION

The act removing heat from or adding heat to an area in order to either cool or heat the average temperature of that space is referred to as air-conditioning. Both residential and commercial settings are suitable for the installation of air conditioning systems. This helps to increase thermal comfort as well as the quality of the air within the conditioned space. Electric refrigerant-based air conditioning units can range in size from those that are small enough to be carried by a single adult and that are effective enough to cool a small bedroom to those that are massive enough to be installed on the roof of office towers and that are effective enough to cool an entire building. In most cases, a refrigeration cycle is utilized to bring about the desired cooling effect; however, evaporation and free cooling are also viable alternatives. The cycle is driven by heat. Materials in either liquid or solid form might be used for this purpose. After that, the liquid desiccant is regenerated, and once again, a low-grade heating source like solar energy is used for this process. The capacity of certain desiccants to absorb inorganic and organic air pollutants is an additional advantage that comes along with their primary function of removing moisture from the air. This investigates the rate at which moisture is extracted from the air by a solar-powered solid desiccant air conditioning system that makes use of silica gel in addition to a number of other composite desiccants. For the purpose of desiccant regeneration, an evacuated solar boiler was employed.

Sivak analyzed the possible increase in power consumption for cooling in 50 of the nation's most populous metropolitan regions as well as the impact that this increase might have on emerging nations. In all, roughly 38 of these metropolitan cities are located in regions with temperate temperatures, and 24 of these metropolitan areas are located in developing nations. Seven of these cities are located in India, while the other eight are located China. As a result, the need for air conditioning will continue to grow in the years to come, and with it, the negative effects that it has on the environment.

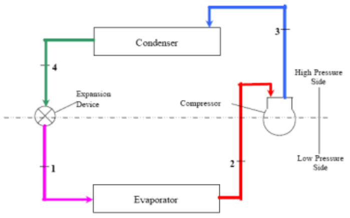

Figure 1: Diagram of a traditional vapour compression air-conditioning system [2]

As a consequence of this, the air that has been cooled is brought back up to the desired temperature before it is introduced into the room. The act of simultaneously heating and cooling a space results in a significant quantity of wasted energy, which in turn decreases the system's overall performance. Additionally, moist circumstances provide a breeding ground for germs, which leads to a decline in the quality of the air within the building.

The purpose provides the highest possible level of comfort for people inside the interior environment while also ensuring the highest possible level of indoor air quality. Either the condensation of water vapour or the use of appropriate absorbents like those found in desiccant cooling systems may be utilized to regulate the level of moisture or latent heat that is present in the air. A desiccant system solely contrasts to typical ventilation cooling and dehumidification systems (VCSs).

II. EXPERIMENTAL SETUP AND DESCRIPTION

The experimental setup is manufactured after originally being conceived as the first step. which is also used for the purpose of providing comfort conditioning. Both the dehumidification and the regeneration process modes are carried out in simultaneously by this configuration's two activated charcoal desiccant covered fin tube heat exchangers. The solar evacuated tube system provides the heat necessary for the regeneration process. If you alter the desiccant material that is used in the apparatus, you will get a variety of different outcomes. Activated charcoal and silica gel are going to be the materials that are used in the experiment.

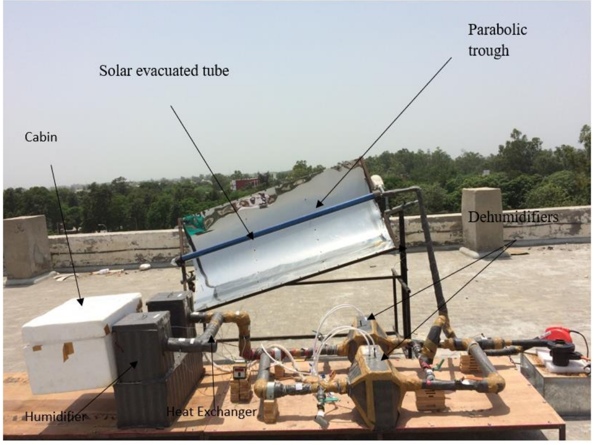

Figure 2: Experimental setup

The following elements are included in the apparatus for the experiment:

- A heat exchanger with fin tubes
- Humidifiers that have a tank for chilling the air
- Hydraulic pump
- Solar power installation using evacuated tubes
- Valves
- Cabin
- Heat exchanger using a concentric tube configuration
- Blower

Heat exchanger made with fin tubes

The heat conductivity of aluminium is k = 230 w/mk, which is rather high. The diameter of the coil is 2 millimetres. In order to achieve dehumidification, a composite desiccant made of activated charcoal is adhered to the fins with the assistance of adhesive (Fevicol Heat x). Heat x can withstand high temperatures of up to 170 degrees Celsius. it create bonds in 10-15 minutes.

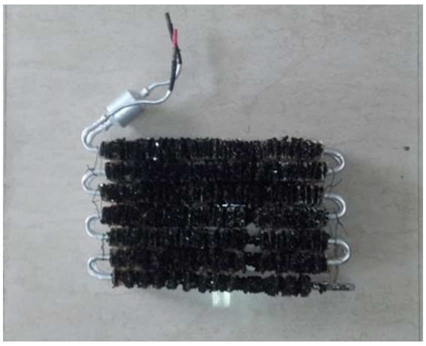

Figure 3: photographic view of desiccant coated fin tube heat exchanger

Table 1: Parameters of the solid desiccant material

Parameter's	Value
Activated Charcoal Size (mm)	2-3
Activated Charcoal quantity (kg)	2.5
Glue quantity (kg)	0.7
Blower (rpm)	13000
Gaps between fins (mm)	1.5-2.5

III. EXPERIMENTAL RESULTS AND DISCUSSION

The solar-powered air conditioning system with the composite desiccant coated heat exchanger is put to the test over the months of May through July in a variety of various environmental settings. The experimental apparatus may be found at UIET Kurukshetra, which is located in India at [29°57' latitude north] and [76°49' longitude east].

PERFORMANCE INDICES

The moisture removal capacity (SH), the thermal coefficient of performance (COP), the efficiency () of the air-air heat exchanger, and the effectiveness () of the humidifier are the performance metrics that are used to evaluate the effectiveness of the solar-powered desiccant dehumidification cooling system unit. These metrics are used in the process of determining the overall performance of the system

1) **Moisture removal (ΔSH)** is defined as the difference between the humidity ratio of the activated charcoal desiccant coated heat exchanger's input and exit (ACCHE).

$$\Delta SH = SH_1 - SH_2 \text{ ------------------------------------ } (1)$$

Where,

ΔSH : Moisture removal in grammes per kilogramme

SH_1 : The relative humidity of the air, measured in grammes per kilogramme, when it enters the ACCHE

SH_2 : Specific humidity of process air in g/kg at outlet of ACCHE

2) **Coefficient of performance (COP)** the ratio of the cooling effect to the heat that is delivered by the system is what is meant by the term "efficiency."

$$COP = \frac{\text{Cooling effect}(Q_{cooling})}{\text{Total heat supplied}\,(Q_{reg})}$$

Cooling effect ($Q_{cooling}$) is defined as the total amount of heat extracted from the space to be cooled.

$$Q_{cooling} = m_a\,(h_{ain} - h_{aout})$$

Total heat supplied (Q_{reg}) is defined as the total amount of heat supplied to the system.

$$Q_{reg} = m_{ha} C_p (T_{ain} - T_{haout})$$

$$COP = \frac{m_a\,(h_{ain} - h_{aout})}{m_{ha}\,C_p(T_{ain} - T_{haout})} \text{ -------------------------------- ---- } (2)$$

3) **Effectiveness** (€) of the air-air heat exchanger is defined as ratio of actual heat transfer to the maximum possible heat transfer.

For parallel flow heat exchanger:

$$Q_{actual} = m_h c_{ph}(T_{hi}-T_{ho}) = m_c c_{pc}(T_{co}-T_{ci})$$

And $$Q_{maximum}= C_{min}\,(T_{hi}-T_{ci})$$

Where,

m_h,m_c: Mass flow rate of hot and cold air of heat exchanger in kg/srespectively

T_{hi}: Temperature of hot air at inlet of heat exchanger in degree celsius

T_{ho}: Temperature of hot air at outlet of heat exchanger in degree celsius

$m_h$is more than m_c and $c_p$is same for both hot air and cold air

Therefore, $m_c c_{pc} < m_h c_{ph}$

Therefore, we get $C_{min} = m_c c_{pc}$

$$Q_{maximum}=m_c c_{pc}(T_{hi}-T_{ci})$$

Effectiveness of heat exchanger

$$\in_{\text{Heat Exchanger}} = \frac{Q_{actual}}{Q_{maximum}}$$

$$\in_{\text{Heat Exchanger}} = \frac{T_2 - T_3}{T_2 - T_5}$$ --- ----- (3)

4) **Efficiency (η)** which provides some indication about the level of effectiveness possessed by the humidifier. The degree to which the temperature of the air coming out of the humidifier is comparable to the wet-bulb temperature of the air coming into the humidifier is what is being monitored.

$$\eta_{\text{Humidifier}} = \frac{(T_{dbi} - T_{dbo})\times 100}{T_{dbi} - T_{wb}}$$ ---------------------------------- -------- (4)

Where,

T_{dbi} -Dry bulb temperature of inlet of humidifier-1

T_{dbo}- Dry bulb temperature of outlet of humidifier-1

T_{wb}-Wet bulb temperature of inlet of humidifier-1

Effect of Inlet Cold Water Temperature

The temperature of the cold water that is introduced into the system has a significant impact on how well it operates. After dehumidification, the temperature of the process air will be reduced due to the low temperature of the cold water that is introduced into the system. It is necessary to take into account the trail from table 2 with the numbers 18, 12, 11, 2, 8, and 3. The DBT of the ambient air ranges from 31.8 degrees Celsius to 37.2 degrees Celsius, and the specific humidity ranges from 12.72 grammes per kilogramme to 15.96 grammes per kilogramme

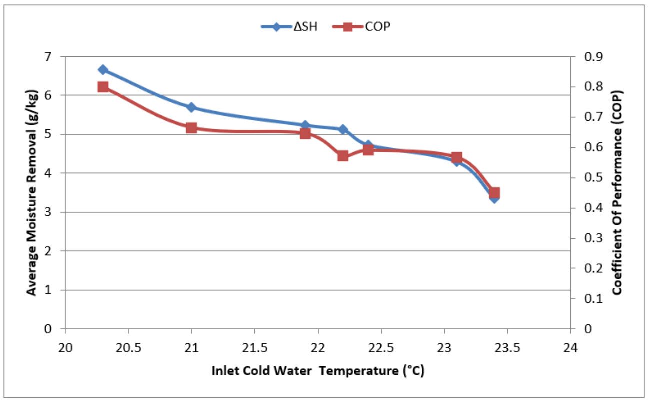

Figure 4: Effect of inlet cold water temperature on Moisture removal and COP

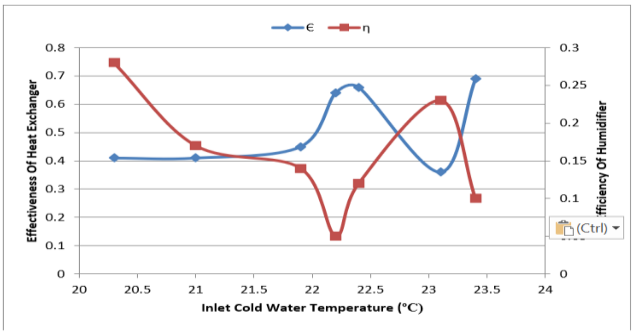

Figure 5: Effect of inlet Cold water temperature on the Effectiveness of Heat transfer and Efficiency of humidifier

According to the results of certain calculations, the amount of moisture extracted by ACCHE-A keeps climbing until it reaches its highest possible value of 6.66 g/kg. When the point of saturation is reached, the outlet humidity ratio of the process air begins to increase. This happens when the moisture that is being absorbed by the desiccant material. After 31 minutes, the operational modes of ACCHE-A and ACCHE-B are swapped over to one another. In other words, in order to renew the adsorption material, ACCHE-A is supplied with hot air rather than cooling water and ambient air, while ACCHE-B enters the dehumidification mode with the cold water. Moisture removal during the ACCHE-B process has the potential to achieve a maximum of 6.45 g/kg, much like the dehumidification process that occurs during the first half of the cycle. During this half cycle, the ACCHE-B offers air that is both dry and cooled. The device is able to continue supplying dry and cold supply air from either of its two ACCHE by switching between the two fin tube heat exchangers that are located inside it. The duration of the whole process cycle is around 31 minutes. During the process of dehumidification, up to 6.66 g/kg of moisture may be removed from ACCHE-A, but only 6.45 g/kg of moisture can be removed from ACCHE-B.

Table 2: System performance parameters

	removing moisture (g/kg)	COP
ACCHE-A	6.66	0.79
ACCHE-B	6.45	0.75
Desiccant dehumidification Unit (average values)	6.55	0.77

The amount of moisture that may be removed from a desiccant dehumidification unit is up to 6.66 g/kg when both of its dehumidification processes are considered together. It has been discovered that the desiccant dehumidification unit has a COP that ranges from 0.77 to 0.79 at an ambient temperature of 37.2 degrees Celsius, with 0.77 being the most common value. Table 4 is a listing of the average parameters that were measured by both ACCHEs during the whole cycle.

IV. CONCLUSIONS AND SCOPE FOR FUTURE WORK

By applying an activated charcoal coating to a fin tube heat exchanger, the primary purpose of this experimental setup is to reduce the amount of moisture in the air and bring the temperature down.

As a result of the tests, we may draw the following conclusions:

1. Because the necessary temperature range for the hot air utilised in regeneration is relatively low (120-140 degrees Celsius), the low-grade thermal energy that is produced may be used for practical purposes such as solar energy and industrial waste heat.
2. The findings indicate that the system is able to provide constant and steady air that has been cooled and dehumidified in accordance with the comfort conditions for a whole day by shutting the ACCHE off after 31 minutes. 3.

It has also been discovered that a drop in the temperature of the cold water that enters the system results in an improvement in the performance of the system, which means that a greater amount of dehumidification may be accomplished.

4. The ACCHE has the ability to manage both sensible and latent heat while also having a strong capacity for dehumidification.
5. The examined unit is practical in climates that are both hot and humid. The average amount of moisture removed and the coefficient of performance (COP) both increase when the temperature of the ambient air dry bulb rises.
6. The configuration produces more improved outcomes when the surrounding temperature is between 33 and 38 degrees Celsius.

SCOPE FOR FUTURE WORK

In this paper, an experimental investigation on the performance of ACCHE was carried out under a variety of diverse climatic circumstances. Activated charcoal is being employed as a desiccant material in a fin tube heat exchanger in this experimental study effort that is being carried out. Despite this, there are a great deal of other concerns that may be looked at. The following kind of research should be considered for the future:

1. The performance of the system may be further examined by utilising alternative desiccant materials or by varying the quantity of desiccants in mixtures. One example of this would be combining silica gel, activated charcoal, and activated alumina in varied ratios.
2. The system's capacity for dehumidification and cooling rate may be determined by implementing various alterations to the design of the heat exchanger, such as expanding the surface area of the fins or using a heat exchanger that operates in reverse flow.

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