Design, fabrication and testing of Evaporative Desiccant Cooling system

GTU Group No. : 8948

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Content

Introduction

- **Project background**

➢ Air conditioning is essential requirement in morden days. Taking from residential to the industrial as well as in commercial sector it has became a primary need. The domestic air conditioning system works on the vapour compression cycle which is easy install as well control. But the various costs associated with it are high. There some environmental problems also coexist. On other hand we can employ desert cooler to achieve comfort condition. But it cannot handle the humidity. These problems can be solved by means of employing the desiccant evaporative cooling.

Problem statement

- The main problem related to conventional air conditioning system is high power consumption and environmental issues related to refrigerant used in air conditioning unit refrigerant. Main problems are listed below:

- ❖ The main drawback of conventional air conditioning is its higher initial cost
- ❖The running cost due to the high power consumption is also high.
- ❖ The use of cfc refrigerants in air conditioning system generate the environmental issues like cl atom crate ozone layer depletion and high power consumption lead to indirect emission of co2 which lead to global warming.
- ❖ For very high cooling load the structure of V.C.R. is vey bulky.

Project objectives

- This project is developed to study the alternative air conditioning system. Its efficiency, effectiveness, and some other important parameters. The main purposes are listed below:

❖ To eliminate the drawbacks of conventional air conditioning system

❖ To reduce power consumption.

❖ To eliminate use of refrigerant by using simple desert cooler.

❖ To utilize waste heat which not used in past technologies.

Scope of project

❖In this project, there is scope to develop domestic desert cooler working very well in a humid climate too which is not possible in case of conventional desert cooler.

❖This can be done by dehumidifying the air before entering the evaporative cooling system and can achieve the same room climate which can be in case of convection Air conditioning of VCR based

❖ By using the low grade waste heat we can achieve the comfort conditioning as the normal air conditioning can.in humid and hot atmosphere like Asian continental this system can be replace the conventional air conditioning system at very cheap cost.

Literature review

RESEARCH PAPER	CONCLUSION
❑ Napoleon Enteria∗, Kunio Mizutan. January 2011. The role of the thermally activated desiccant cooling technologies in the issue of energy and environment.	the desiccant evaporative cooling system is most suitable for domestic purpose to eliminate the drawbacks of conventional air conditioning.
❑ Ouazia, B. A prototype desiccant-based evaporative cooling system for residential buildings. 2009	The desiccant wheel was con- trolled 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 toward humidity management. One or the other or both may operate, depending on ambient conditions.

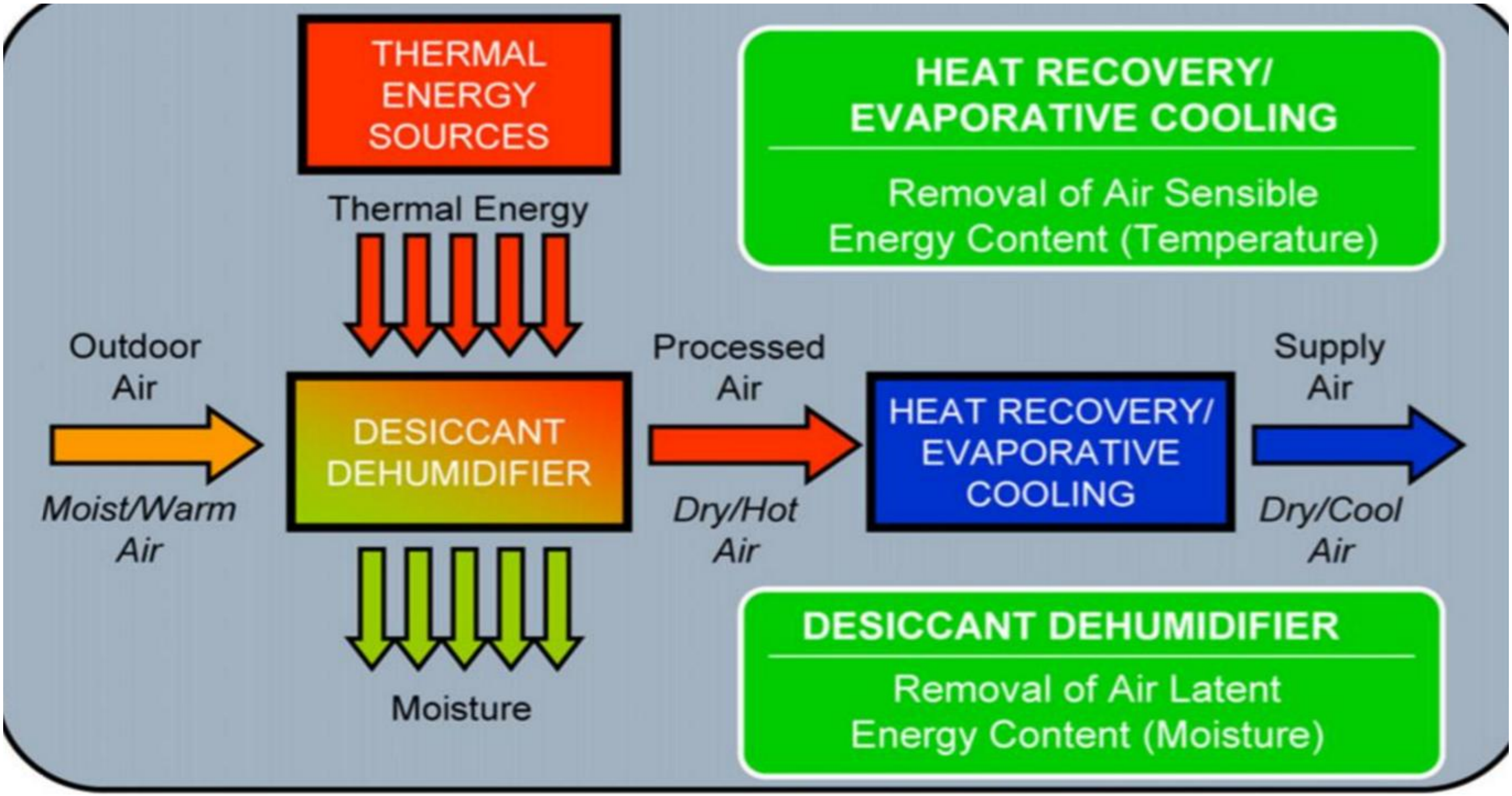
❑ Jae Dong Chung a,*, Dae-Young Lee. Contribution of system components and operating conditioning to the performance of desiccant cooling sys- tem.2011	Various parameters of desiccant evaporative cooling system like sensible heat exchanger, evaporative cooler, desiccant wheel, outdoor condition, regeneration temperature effect the COP of system. For given system the medium temperature solar collector proven sufficient to give the regeneration temperature to the desiccant material.
❑ X. Zheng, T.S. Ge, R.Z. Wang. Recent progress on desiccant materials for solid desiccant cooling systems. July 2014	Besides, they also exhibited faster adsorption and desorption kinetics owing to increased surface area and decreased desorption activation energy. By proper tailoring the textural properties of alumino-silicate zeolites, a good balance can be reached between the regeneration ability and water adsorp- tion capacity aluminum silicate zeolites can be adopted as desiccants in practical dehumidification processes, e.g. rotary desiccant wheel systems
❑ Giovanni Angrisani , Carlo Roselli, Maurizio Sasso. October 2012.effect of rotational speed on performance of desiccant wheel	the velocity that optimizes the dehumidification performances varies in the range 5–10 revolu- tions per hour, depending on operating conditions.

- Lshpaier, C.E.L.nobegra. Parametric analysis of components effectiveness on desiccant cooling system performance.

although all components can influence the overall system performance (COP), the sensible heat wheel and the dehumidifier appear to have a greater influence. For the Ventilation Cycle, reducing the heat wheel effectiveness from the ideal condition (ε_{hw} ¼ 1.0) to 0.8 was seen to reduce COP values by factors of two and higher, and using a lower performance dehumidifier was shown to reduce the COP values by 30%e50%, even though the calculated desiccant wheel effectiveness values was reduced by less than 20%. Recirculation Cycle simulations were also performed, yielding generally lower COP values, which were shown to be less dependent on the exhaust air evaporative cooler and the heat wheel, when compared to the Ventilation Cycle. Finally, one should mention that the analysis method proposed in this work can serve as an effective tool for designing desiccant cooling systems.

❑ Kyaw Thu , Anutosh Chakraborty. Thermo-physical properties of silica gel for adsorption desalination cycle.2011	Type-A silica gel possesses the highest surface area of 863.6 m^2/g. Higher surface area and large pore volume directly contribute to the sizing, compactness and cycle time . Type-A silica gel offer beneficial design features such as lesser requirement of adsorbent material for the same system capacity
❑ Zhuang Wu a, Roderick V.N. Melnik b,*, Finn Borup. model based analysis and simulation of regenerative wheel. 2005	The heat wheel is important component. In order to increase overall efficiency of system we have to design properly according to given condition.
❑ K.C.nag, H.T.chua, C.Y.chung,C.H. loke, Experimental investigation of the silica gel-water water adsorption isotherm characteristics.2001	The regeneration of adsorbent is depend on the correct allocation on temperature as well as the regeneration time for isotherm of silica gel namely type A, type 3A, and type RD. the regeneration process for three different isotherm is varies up to 900C but after that limit the %of water desorbed is nearly same.

Desiccant evaporative cooling system



Simple Desert Cooler

Initial calculation of cooler

- Includes calculation of mass flow area, mass flow rate, and specific humidity in supplied air as well as the decrement in the relative humidity after using the desiccant material.

Flow Area of cooler

L=240mm

A_{Total} =L*L =57600 mm²

$$A_{AIR\ FLOW} = A_{Total} - [(t_{vertical} \times N_{vertical} \times L) + (t_{horizontal} \times N_{horizontal} \times L)]$$

$$= 48360\ mm^2$$

$$= 0.04836\ m^2$$

Mass Flow rate

$$M_{supply} = (A_{AIR\ FLOW} \times V_{avg}) \times \rho$$

$$= (0.2481 mm^3/s) \times (1.1644\ kg/m^3)$$

$$= 0.2888\ kg/s$$

$$= 17.328\ kg/min$$

Calculation of desiccant adsorption capacity

$$\omega_{desiccant} = \omega_{supply} - \omega_{desire\ by\ desiccant}$$

$$= 0.008419 - 0.00683$$

$$= 0.002119\ g/kg\ of\ dry\ air$$

$$\text{M}oisure\ remove\ by\ desiccant\ = Q_{supply} \times \omega_{desiccant}$$

$$= 0.2888\ kg/s \times 0.002119\ g/kg\ of\ dry\ air$$

$$= 0.00061196\ g/s$$

$$= 0.03670\ g/min$$

$$= 2.203\ g/h$$

Ventilation Standards

ventilation standards for different purposes are listed in the following table.

Ventilation Standards

	Application	Smoking	*Air in m³ per person per minute*	
			Recommended	*Minimum*
1	Apartment	Some	0.54	0.40
2	Banking space	Occasional	0.27	0.20
3	Barber shop	Considerable	0.40	0.27
4	Beauty parlors	Occasional	0.27	0.20
5	Bars	Heavy	0.81	0.68
6	Department stores	None	0.20	0.14
7	Director's room	Extreme	1.31	0.81
8	Drug-stores	Considerable	0.27	0.20
9	Factories	None	0.27	0.20
10	Hospital operating room	None	1.2	1.00
11	Hospital wards	None	0.54	0.40
12	Hotel room	Heavy	0.81	0.68
13	Laboratories	Some	0.54	0.40
14	Meeting rooms	Very-heavy	1.35	0.81
15	General Office	Some	0.40	0.27
16	Private Office	None	0.68	0.40
17	Private Office	Considerable	0.81	0.68
18	Restaurant	Considerable	0.30	0.27
19	Theatre	None	0.20	0.14
20	Theatre	Some	0.40	0.27

3) **For 6 person the ventilation air for drawing hall of Apartment**

$$Q_{ventilation\ air} = 6 \times 0.54\ m^3/min$$

$$= 3.24\ m^3/min$$

$$= 0.054\ m^3/s$$

$$Q_{supply} = 0.2481\ m^3/s$$

$$Q_{recir} = Q_{supply} - Q_{venti}$$

$$= 0.1941\ m^3/s$$

	Recirculating	**Ventilation**
D.B.T (^{0}C)	25	43.5
W.B.T(^{0}C)	15	24.4
Specific Humidity (ω) ($\frac{g}{kg\ of\ dry\ air}$) From Psychometric chart	0.0067	0.0146

4) **Relative humidity data**

	Recirculating	Ventilation
D.B.T (^{0}C)	25	43.5
W.B.T(^{0}C)	15	24.4
Specific Humidity (ω) $(\frac{g}{kg\ of\ dry\ air})$ **From Psychometric chart**	0.0067	0.0146

- $M_{supply} \times \omega_{supply} = M_{venti} \times \omega_{venti} + M_{recir} \times \omega_{recir}\ \omega_{supply}$

$$= 0.008419\ g/kg\ of\ dry\ air$$

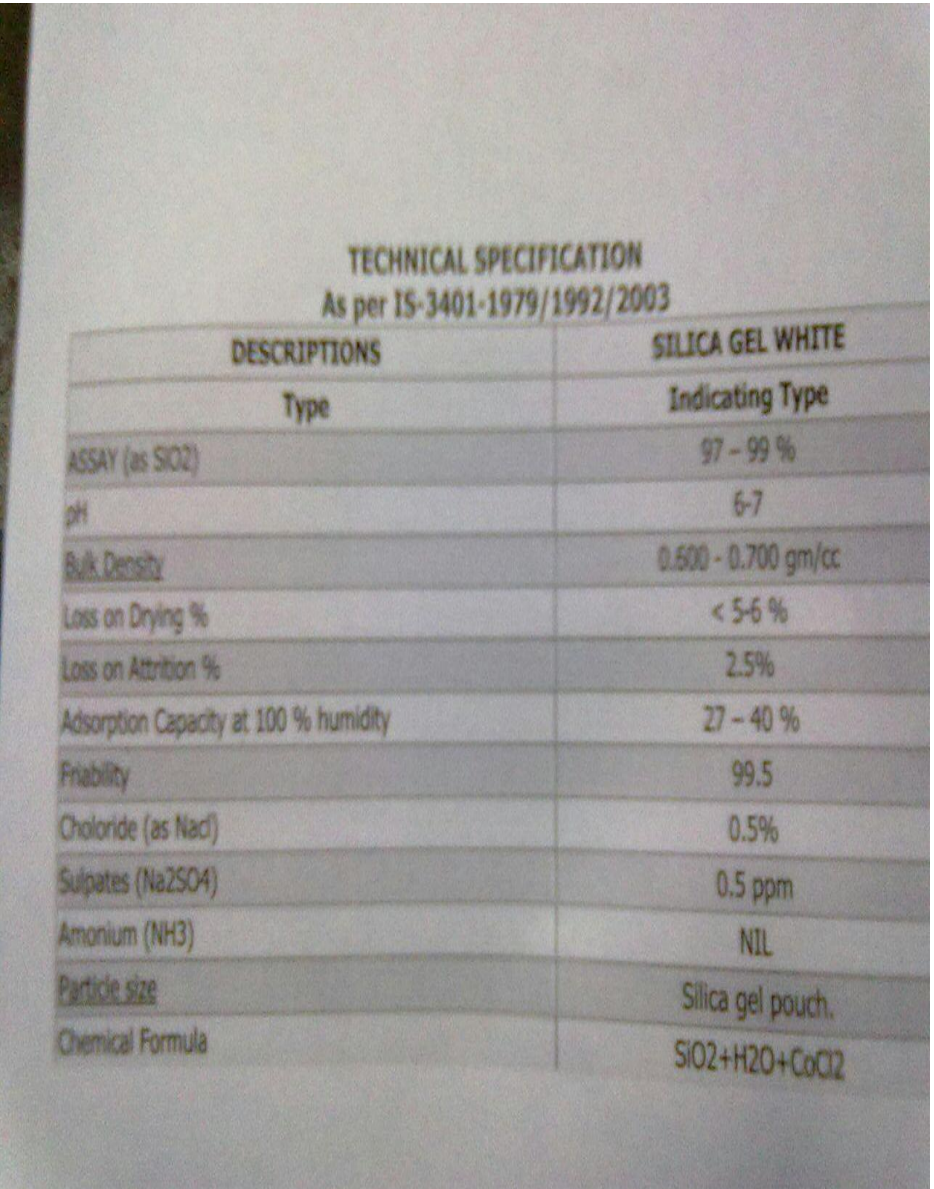
Testing of silica gel layer

- To find the optimum thickness of desiccant material to remove require moisture from the air of high humid condition in humid climate. 1/2 Inch of desiccant grains net layer has been tested.

Observation table for silica gel

	DBT (℃)	WBT (℃)
Air Entering into desiccant layer	29	25.5
Air Leaving desiccant layer	32	23

Properties of silica gel



TECHNICAL SPECIFICATION
As per IS-3401-1979/1992/2003

DESCRIPTIONS	SILICA GEL WHITE
Type	Indicating Type
ASSAY (as SiO2)	97 – 99 %
pH	6-7
Bulk Density	0.600 - 0.700 gm/cc
Loss on Drying %	< 5-6 %
Loss on Attrition %	2.5%
Adsorption Capacity at 100 % humidity	27 – 40 %
Friability	99.5
Choloride (as Nacl)	0.5%
Sulpates (Na2SO4)	0.5 ppm
Amonium (NH3)	NIL
Particle size	Silica gel pouch.
Chemical Formula	SiO2+H2O+CoCl2

Layer of desiccant wheel

FABRICATION

- MAIN COMPONENTS

1. DUCT
2. VALVE MECHANISM
3. REARRANGMENT OF COOLING PADS
4. INSULATING AND SEELING ALL GAPS TO MAKE WHOLE ASSEMBLY AIR TIGHT

MATERIALS

➢PROPERTIES OF MATERIALS

- Thermal conductivity is negligible
- Easy to fabricate
- Cheaper in cost
- Wood and polymers are best suitable for purpose

PARTS OF MODEL

BALL VALVE ASSEMBLY 1

BALL VALVE ASSEMBLY 2

DESICANT BOX

BOX

ENCLOSER

COOLING PAD BOX

BOX

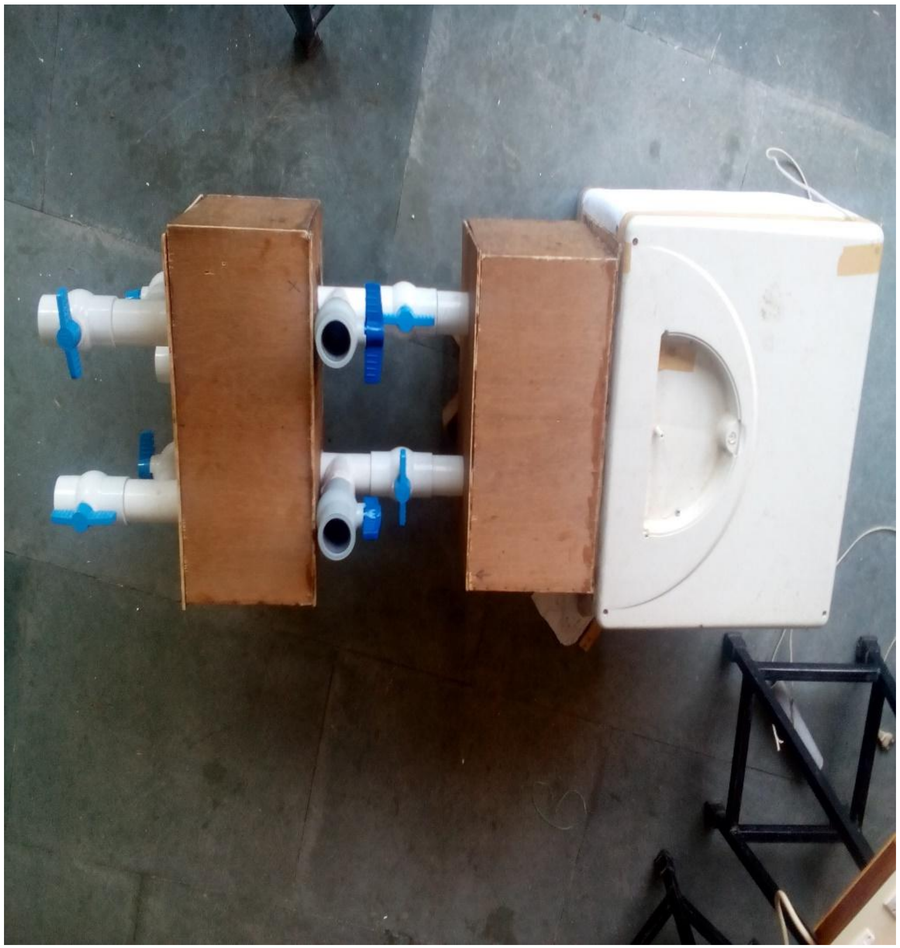
ENCLOSER

SILICA GEL LAYER

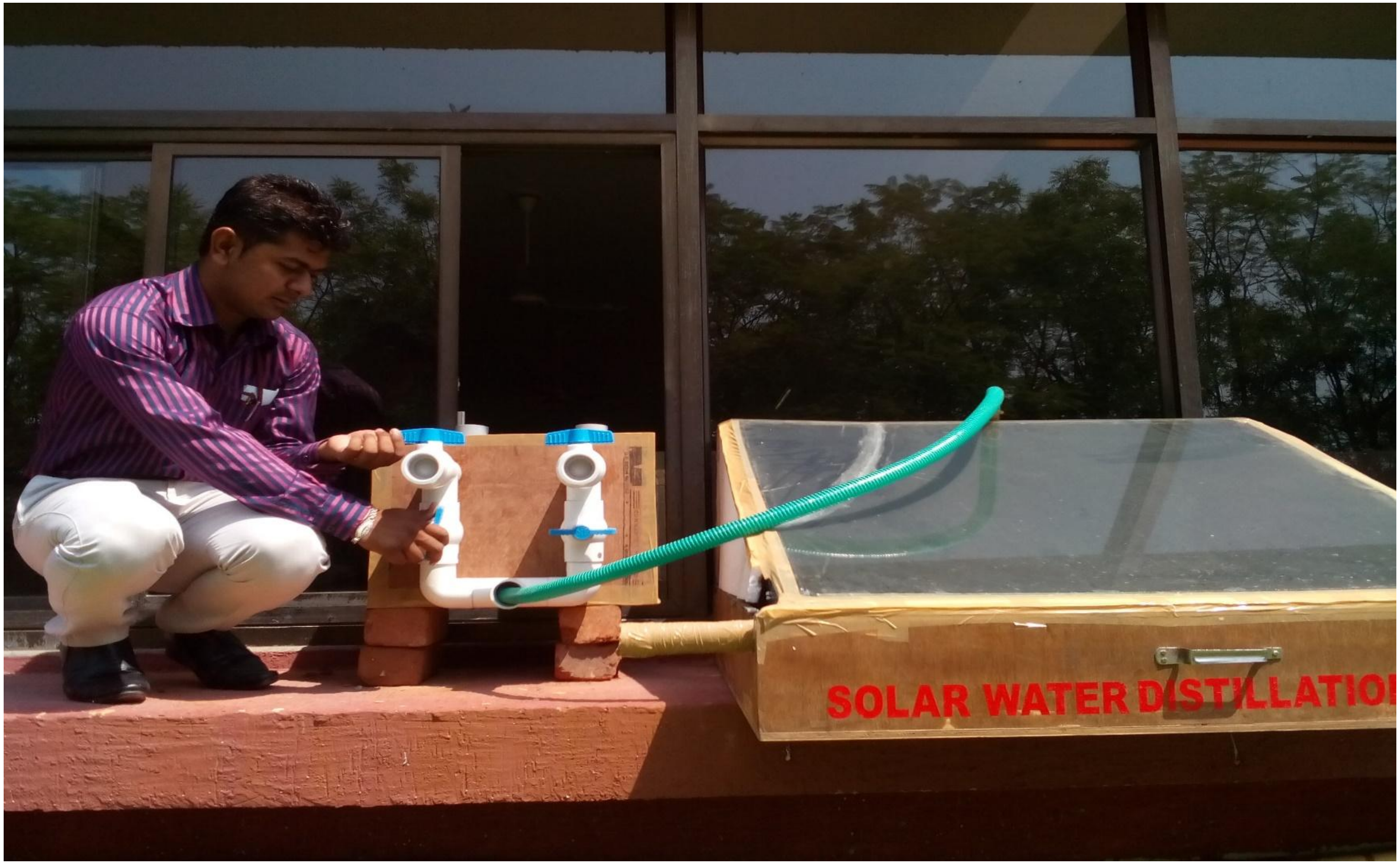
ISOLATED LAYER

LAYERS IN BOX

ASSEMBLY



TESTING



OUTSIDE CONDITION

D.B.T. (^{0}C)	W.B.T (^{0}C)	R.H. (%)
33	26.5	61

INSIDE ROOM (SUPPLY AIR)

D.B.T. (^{0}C)	W.B.T (^{0}C)	R.H. (%)
28.5	24	65

EFFECT OF DESICCANT MATERIAL (DEHUMDIFICATION)

Temp. (Before Regeneration) (^{0}C)	Temp. (After Regeneration) (^{0}C)
33	36

TEMPERATURE MEASUREMENT WITHOUT DESICCANT

Outside Temp. (^0C)	Inside Temp. (^0C)
33	29

TEMPERATURE MEASUREMENT AFTER MODIFICATION

Outside Temp. (^0C)	Inside Temp. (^0C)
33	28

CALCULATION OF C.O.P

- Area of Flow = Width × Length

  = 19.5 × 20.5

  = 399.75 cm^2

  = 0.04 m^2

- Air Velocity = 3.4 m/s

- Mass flow rate = Area × Velocity

  = 0.04 × 3.4

  = 0.136 m^3/s

  = 0.1564 kg/s

- **$Q_{cooling}$ = $m_f \times C_p \times \Delta T$**

  $= 0.1564 \times 1005 \times 4.5$

  $= 707.319$ watt

- Power Consumption (W) = 0.1 kW-h

  = 100 watt

- C.O.P. = Q / W

  = 707.319 / 100

  = 7.07

Conclusion

- Instead of desiccant wheel wooden matrix boxes are adopted for testing. The system has been tested under condition of 33^0c dry bulb and 26.5^0c wet bulb temperature. By using the system along with desiccant material the temperature fall is reduced to 1^0c compared to normal desert cooler. Though the volume flow rate of modified cooler is reduced still **C.O.P. is 7.07** has been achieved

FUTURE SCOPE

- One can automate the whole system by means of control system
- Rotary wheel may use instead of the wooden duct
- Whole system can be more compact
- Source of regeneration may be any non conventional

Any Question?