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Performance and evaluation of desiccant based air conditioning system.

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ABSTRACT
This Project work presents study and experimental analysis of Desiccant based air conditioning system.The main purpose of this project is to increase the efficency of air conditioning system.In the convenstional air conditioning system cooling coli has two load latent load and sensible load. Cooling has to cool the air and simultaneously to dehumidify it.It increases load on cooling coil and affects performance to the system. To increase the efficiency the air conditioning system desiccant materials are used at the inlet of the air conditioning test rig. Desiccant materials attract moisture based on differences in vapor pressure. Due to their enormous affinity to absorb water and considerable ability to hold water. Due to use of desiccant material load on the cooling coil reduces since moisture is absorbed by desiccant; cooling coil has to take only sensible load. Analysis is done using different desiccant materials and based on the observation, power consumption before and after desiccant is calculated. From this conclusion is made that desiccant material improves the efficiency of air conditioning test rig
Keywords – Desiccant material, reduced latent heat load, less power consumption, high efficiency

I. INTRODUCTION

One of the important aspects of air conditioning is to provide the comfort environment for the mankind in all the condition. Comfort conditions not only improve human living but also improve the performance. Comfort is primarily decided by temperature and humidity .for comfort feeling; relative humidity must be within specified range i.e. relative humidity 55-60% ,and dry bulb temperature 22-26℃ to maintain the comfort conditions[1] by controlling temperature and humidity, conventional air conditioners are most commonly employed where the dehumidification of air is achieved by bringing the temp. Below the dew point in the cooling coil to condense water vapour. However, reheating is needed in most of the cases due to high latent load. Consequently a conventional A.C. consumes large amount of electrical energy especially in hot and humid climatic conditions due to high latent load which is decided by the outside humidity contents. The higher ventilation rates translate into greater cooling loads-in particular, greater latent loads during cooling seasons when the relative humidity within a building must be kept sufficiently low to inhibit the growth of micro-organisms that cause health problems and also may damage building materials. As a result, air dehumidification [2] has become a very important part of the HVAC function. The basic idea of desiccant air conditioning is to integrate the technologies of desiccant dehumidification and evaporative cooling together.

To increase the efficiency the air conditioning system desiccant materials are used at the inlet of the air conditioning test rig. Desiccant materials [3] attract moisture based on differences in vapor pressure. Due to their enormous affinity to absorb water and considerable ability to hold water.

In this project different types of desiccant materials are used and then the analysis of the air-conditioning test rig is done. Then the results are plotted and it is compared with various types of desiccant materials. Best desiccant material is selected amongst all.

II. REVIEW OF EXISTING SYSTEM

1.1 Conventional Air conditioning:
In Conventional Air Conditioning system dehumidification of air is achieved by bringing the temperature below the dew point temperature in the cooling coil to condense water vapour [4]. Figure 1.1 shows general psychometric process.

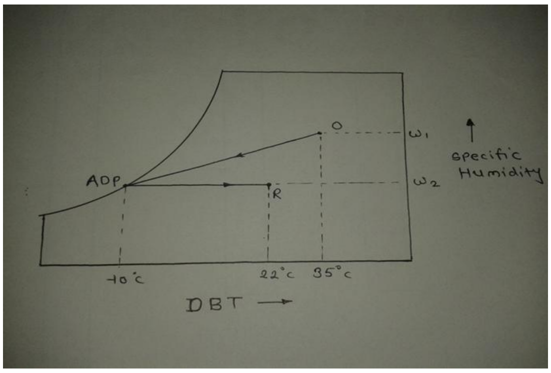


Figure 1.1 Psychometric Process

Disadvantage of conventional air conditioning is that it has to deal with sensible load as well as latent load. It consumes large amount of electricity. It has to cool the air up to dew point temperature to carry out latent load and preheating can be done. Due to that energy cost increases.

III. System Description

Figure 2.1: Experimental setup

2.1 System

1. Base Stand: This is made up of square tube and sheets this is painted specially with powder coating. All equipments are mounted on base stand.
2. Air conditioner : the air conditioner working on simple vapour compression cycle consists following items

- Compressor : the compressor is used for pumping the refrigerant through the system it is hermetically sealed type having capacity of 1 ton
- Condenser: the function of condenser is to convert high-pressure vapour into high pressure liquid refrigerant. It is air cooled finned type condenser. A fan is used to force the over the condenser.
- Expansion device (capillary tube): the function of expansion device is to reduce the pressure of liquid R22 refrigerant. When the liquid refrigerant passes through the capillary; due to throttling its pressure as well as temperature decreases.[5]
- Evaporator [6]: it is refrigerator or actual cooler where the cooling air is required. Heat is removed from air flowing over evaporator by the low temperature refrigerant in the form of latent heat.

3. Cabinet: this is made up of plywood. It has doors at front with watching window, inlet/outlet duct and recirculation duct of 250*250 mm^2 cross sectional area. The doors inside duct can be adjusted for partial/complete recirculation of air. This also has heater load bank and evaporator blower. Overall dimension (L 0 H); 800*1000*1500mm^3.
4. Instruments/parts in control room :

- Electrical air heater with dimmer (4KW) : air heater is provided for additional loading facility. Heat generated is controlled using dimer mounted on control panel.
- Wet and Dry bulb thermometer: the temperature of air measured by ordinary thermometer is known as dry bulb temperature. Using DBT and WBT the relative humidity of air can be determined. In this system three WBT and DBT thermometer are used. One is placed at inlet of the duct, one after the evaporator and one is placed in the control room chamber. [7]
- Evaporator blower: the axial fan blower fitted in the chamber sucks air and it flow over the evaporator coil before entering the chamber.
- Steam Injection Facility: this is used to inject the steam generated in steamer. Injecting system into control room carries out humidification of air.
- Preheater (500W): it is used to increase the temperature of air flowing over the evaporator.

2.2 Material Used for Experiment [8]

2.2.1 Silica gel – a brief description and history

Silica gel is a chemically inert, non-toxic material composed of amorphous silicon dioxide. It has an internal network of interconnecting microscopic pores, yielding a typical surface area of 700-800 square meters per gram; or, stated another way; the internal surface area of a teaspoon full of silica gel is equivalent to a football field. Water molecules are adsorbed or desorbed by these micro-capillaries until vapor pressure equilibrium is achieved with the relative humidity of the surrounding air.

2.2.2 Titanium Silica Gel

Titanium silica gel is an adsorbent. Water is attracted and held to the walls of many fine pores within the material. Munters has developed a patented method for manufacturing titanium silica gel in Honey Comb wheel form, which results in a strong and stable structure, yielding ideal drying performance in a wide range of applications.

Advantages

- Moisture removal capacity: Titanium silica gel can hold up to 40% of its dry weight in water when in equilibrium with air at saturation.
- Non-overloading desiccant because titanium silica gel is a solid, insoluble desiccant, it is not possible to “wash out” the desiccant from the wheel. This means no special precautions are required even when it is exposed to air at 100% relative humidity.
- Stability: Silica gel does not undergo any chemical or physical change during the adsorption process. It is inert, stable, and non-toxic.
- Wash ability: the permanent nature of the desiccant makes it possible to literally wash a wheel in water if dust or other particulate block the air passageways.

- Chemical resistance: Titanium silica gel is a stable material and is resistant to most chemicals. In particular, it is resistant to acids and sulfur products which may be found in the combustion products of a direct fired gas burner.

2.2.3 Calcium Chloride

Calcium chloride can serve as a source of calcium ion in an aqueous solution, as calcium chloride is soluble in water. This property can be useful for displacing ions from solution. Calcium chloride has a very high enthalpy change of solution. A considerable temperature rise accompanies its dissolution in water. The anhydrous salt is deliquescent; it can accumulate enough water in its crystal lattice to form a solution. Drying tubes are frequently packed with calcium chloride. Kelp is dried with calcium chloride for use in producing sodium carbonate. Adding solid calcium chloride to liquids can remove dissolved water. These hygroscopic properties are also applied to keep a liquid layer on the surface of the roadway, which holds dust down.

2.2.4 Magnesium Sulfate

Magnesium sulfate (or magnesium sulphate) is an inorganic salt (chemical compound) containing magnesium, sulfur and oxygen, with the formula $MgSO_4$. It is often encountered as the heptahy dratesulfate mineral epsomite ($MgSO_4 \cdot 7H_2O$), commonly called Epsom salt. Anhydrous magnesium sulfate is used as a drying agent. The anhydrous form is hygroscopic (readily absorbs water from the air) and is therefore difficult to weigh accurately; the hydrate is often preferred when preparing solutions (for example, in medical preparations.

Anhydrous magnesium sulfate is commonly used as a desiccant in organic synthesis due to its affinity for water. During work-up, an organic phase is saturated with magnesium sulfate until it no longer forms clumps. The hydrated solid is then removed with filtration or decantation. Other inorganic sulfate salts such as sodium sulfate and calcium sulfate may also be used in the same way.

(a) (b) (c)

Figure 2.2: Desiccants

(a): silica gel
(b): magnesium sulphate
(c): calcium chloride

IV. Working of project

Desiccant cooling consists in dehumidifying the incoming air stream by forcing it through a desiccant material and then drying the air to the desired indoor temp.to make the system working continually, water vapour absorbed must be driven out of the desiccant material (regeneration) so that it can be dried enough to absorb water vapour in the next cycle. This is done by heating the material desiccant to its temperature of regeneration which is dependent upon the nature of desiccant used. A desiccant cooling system therefore, comprises principally three components, namely the regeneration heat source the dehumidifier (desiccant material), and the cooling unit.

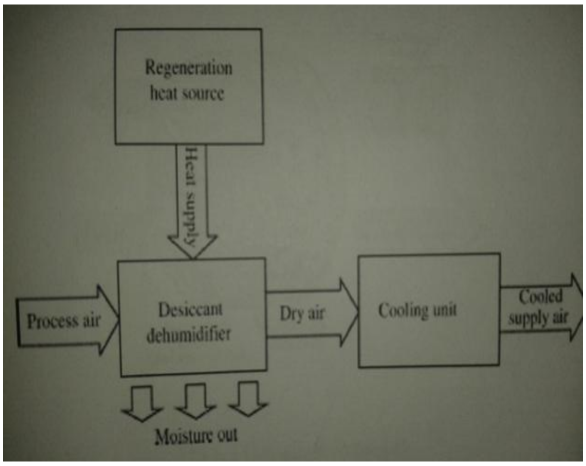


Figure 3.1: Principle of desiccant cooling

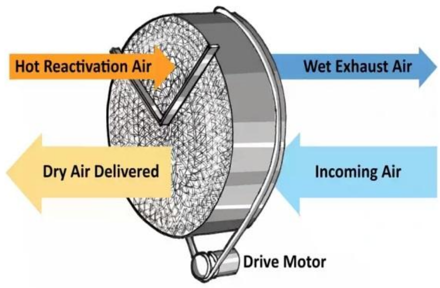
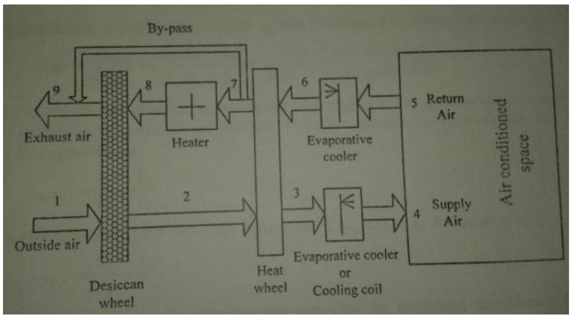


Figure 3.2: Desiccant wheel

Desiccant dehumidification associates with evaporative cooling

The system presented in figure, the supply outdoor air stream at the state one is passed through rotary desiccant wheel [9]. Its moisture is partly but significantly absorbed by the desiccant material and the heat of adsorption elevates its temperature so that a warm and rather dry air stream exits at the state 2. The air stream is then cooled successively in the heat exchanger from the state 2 to state 3, and then in an evaporative cooler from state 3 to state 4. Another evaporative cooler is used to cool down the return air from state 5 to state 6 and cold air stream serves as heat sink to cool the supply air in the heat exchanger. Consequently, its temperature is risen when exiting the heat wheel at the state 7. At this point, it is ready to undergo a complementary heating to which a temperature high enough at state 8 inorder to be able to regenerate the desiccant material. A certain portion (about 20%) of the return air stream, at the state 7, bypasses the heating source in order to reduce the regeneration heat consumption.



Psychometric Process:

The main concepts about chemical dehumidification, successively employed during the analysis, are herein synthetically presented [10]. Air that has to be treated before supplying in indoor ambient is called "process air". The moisture contained in humid air partially condenses in the chemical desiccant. It is adsorbed because of the vapour partial pressure difference between process air and desiccant surface. So the process air temperature increases because of the conversion in sensible heat of both condensation heat and heat due to the adsorption chemical process. Therefore, process air specific humidity decreases while temperature increases. For this reason, before supplying to the space, process air must be cooled (Fig. 1b) by means of one or more of the following components: direct expansion or chilled liquid cooling coil (CC); indirect evaporative cooling (IEC); rotary or static heat recuperator (HTX).

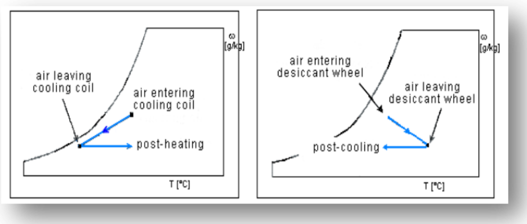


Figure 3.3: Psychometric processes

V. Experimental Procedure and Working

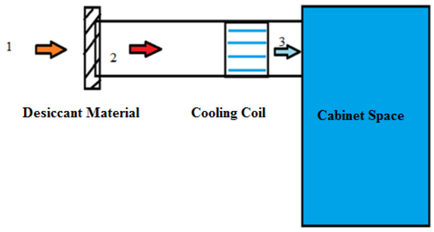


Figure 4.1 Experimental Setup with Desiccant Bed

Where,
Condition 1= Before Desiccant Material
Condition 2= After Desiccant Material
Condition 3= After Cooling Coil

4.1 Procedure

The outside atmospheric air is sucks through a blower which is situated at the end of the duct. While passing air inside the duct it is passed through the desiccant bed as stated by condition 1 in fig 7. As the property of desiccant is to absorb moisture from air, the relative humidity [11] of air is going to be decreased and the temperature of air is going to be increased. As per the project requirement, to cool the air, it is passed over a cooling coil. Cooling coil is nothing but the evaporative coil of a VCR system. Now the dehumidified and cool air is supplied in cabinet where temperature and humidity is to maintain according to requirement.

4.2 Desiccant Beds

Here the desiccant beds for the experiment are made. The Size of beds are made such that they can easily fitted at the inlet of the duct.
Dimensions of the Duct are as follows
Area= 250*250 mm^2
Width= 20 mm

A) Before Experiment B) After Experiment

Figure 4.2: Experimental change of desiccant bed

4.3 Calculations

The values are calculated for before desiccant material for month of September**:**

From experiment we have the values DBT and WBT condition before desiccant and after desiccant material.

4.3.1. Vapor pressure of air (p_v):

From Steam Tables the saturation pressure at $t_{wb}=21^0$c,
We get, $(p_{vs})_{wb}$=0.02485 bar

Since, by Carrier's equation [12]

$$Pv = (Pvs)wb - \frac{\{P - (Pvs)wb\} * \{tdb - twb\}}{1527.4 - 1.3twb}$$

$$Pv = 0.02485 - \frac{\{1.0133 - 0.02485\} * \{27 - 21\}}{1527.4 - (1.3 * 21)}$$

$$\underline{\mathbf{Pv = 0.0208\ bar}}$$

4.3.2. Specific Humidity, W:

Assuming Atmospheric Pressure as P=1.0133 bar

$$W = 0.622 * \frac{Pv}{P - Pv}$$

$$W = 0.622 * \frac{0.0208}{1.0133 - 0.0208}$$

W=0.0130 kg/kg of dry air

4.3.3. Relative Humidity, Φ:
From Steam Tables the Saturation vapor pressure at DBT of 27^0c,

$$Pvs = 0.03564\ bar$$

$$\Phi = \frac{Pv}{Pvs}$$

$$\Phi = \frac{0.0208}{0.03564} * 100$$

Φ= 58.36%

Similarly, we can calculate the values of $P_{v,}$ W and Φ for remaining months and Desiccant Materials.

VI. Observations

5.1 Tables

5.1.1 Before Desiccant Material

Month	DBT1	WBT1	R. H. (Φ1)	SP. H. (W1)
September	27	21	60	0.0136
October	30	23	55	0.0148
January	28	19	45	0.0110
February	30	19	35	0.0100
March	32	18	25	0.0070
April	35	20	25	0.0088
May	36	25	40	0.0150

Table 5.1.1 Before Desiccant Material

5.1.2 after desiccant material(silica gel)

Month	DBT2	WBT2	R. H. (Φ2)	SP. H. (W2)
September	28	21	55	0.0124
October	31.5	23	49	0.0142
January	30	23.5	37	0.0103
February	31	18.5	30	0.0084
March	32.5	17.5	21	0.0062
April	36	19.5	20	0.0072
May	37.5	24.5	34	0.0138

Table5.1.2 after desiccant material(silica gel)

5.1.3After Desiccant Material (Calcium Chloride)

Month	DBT2	WBT2	R. H. (Φ2)	SP. H. (W2)
September	28	21.5	56	0.0134
October	31	23	51	0.0145
January	29	19.5	41	0.0105
February	30	18	31	0.0082
March	33	18	21	0.0068
April	36	19.5	21	0.0075
May	37	24	35	0.0140

Table 5.1.3 After Desiccant Material (Calcium Chloride)

5.1.4 After Desiccant Material (Magnesium Sulfate)

Month	DBT2	WBT2	R. H. (Φ2)	SP. H. (W2)
September	28.5	21.5	56	0.0134
October	31.5	23.2	51	0.0147
January	29	19	40	0.0100
February	30.5	18.5	31	0.0084
March	33	17.5	20	0.0064
April	36	19.5	20	0.0074
May	37	24.5	37	0.0144

Table 5.1.4 After Desiccant Material (Magnesium Sulfate)

Where,
DBT = Dry Bulb Temprature in ^{0}c
WBT= Wet Bulb Temperature in ^{0}c
R.H. (Φ)= Relative Humidity in %
SP.H.(W)= Specific Humidity in kg/kg of dry air
From the above tables it is observed that the amout of moisture absorbed by silica gel is greater than other materials.

5.2 5.2 Energy meter readings

Sr. No.	Material	Energy consumed In kw
1.	Without desiccant	0.101
2.	Silica gel	0.05286
3.	Calcium chloride	0.05927
4.	Magnesium sulfate	0.06632

Table 5.2 Energy meter readings

5.3 Bar chart of energy consumption

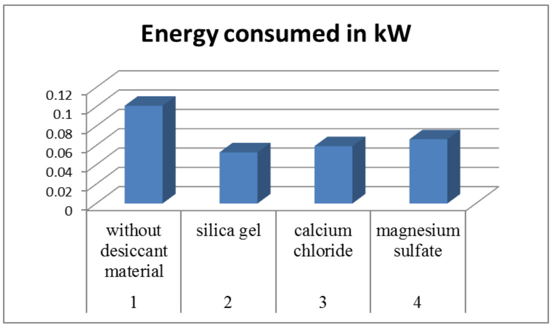


Figure 5.3: Energy consumption Vs desiccant materials

From table,

1. Energy consumed by silica gel $= (1 - \frac{0.101 - 0.05286}{0.101}) * 100$
   = 52.34%
2. Energy consumed by calcium chloride $= (1 - \frac{0.101 - 0.05927}{0.101}) * 100$
   = 58.69%
3. Energy consumed by magnesium sulfate $= (1 - \frac{0.101 - 0.06632}{0.101}) * 100$
   = 65.67%

II. CONCLUSION

From experimental readings which are drawn in graphical way, it is clear that the energy consumption by use of desiccant material is less than without dessicant.

REFERENCES

[1] http://epb.apogee.net/res/refcomf.asp
[2] http://en.wikipedia.org/wiki/Dehumidifier
[3] http://www.thomasnet.com/about/desiccants-22064802.htm
[4] http://en.wikipedia.org/wiki/HVAC
[5] http://www.brighthubengineering.com/hvac/58365-throttling-devices-or-expansion-valves-used-in-refrigeration-and-ac-systems/
[6] http://en.wikipedia.org/wiki/Evaporator
[7] http://www.engineeringtoolbox.com/dry-wet-bulb-dew-point-air-d_682.html
[8] http://www.sorbentsystems.com/desiccants_types.html
[9] Desiccant cooling air conditioning: a review. K. Daou, R.Z. Wang, Z.Z. Xia.
[10] http://www.brighthubengineering.com/hvac/41262-what-is-psychrometric-chart-components-of-psychrometric-chart/
[11] http://ww2010.atmos.uiuc.edu/%28Gh%29/guides/mtr/cld/dvlp/rh.rxml
[12] http://www.interactmedia.co.za/index.php?option=com_content&view=article&id=2977:carrier-formulae&catid=84:current-raca