ISSN: 2278-0181
IC-QUEST - 2016 Conference Proceedings

Solid Desiccant Assisted Hybrid Air-Conditioning System

Dr. Suhas C. Kongre[1]
1Professor, A S. Polytechnic, Wardha, India.

*Chavali Shriramshastri[2]
*2Assistant Professor Dhole Patil College of Engineering Pune, India.

Ramesh K. Rathod [3]
3Assistant Professor Dr. DY Patil School of Engineering, Lohagaon Pune, India

***Abstract:*--In the present scenario of "green" and "sustainable" HVAC design approaches and solutions, integrated & hybrid system design is one of the most preferred technique that are important for achieving good indoor air quality with respect to thermal comfort and energy efficiency. In this paper, design & development of experimental setup of hybrid air-conditioning system is carried-out and the results are analysed and compared with the conventional VCRS based air-conditioning system. It is observed that, hybrid air-conditioning system can handle the latent load very efficiently without burdening the total load over the cooling coil of air-conditioning system. The cop of the hybrid system was found to be 1.13. The conventional vapour compression based air-conditioning system consumes high grade electricity power. Under high ventilation loads or low sensible heat ratio conditions, the conventional system is not designed to handle the continuous supply or increased volume of outdoor air necessary to comply with minimum ventilation standards as recommended by ASHRAE.**

I. INTRODUCTION

Conventional vapour-compression cooling systems are not designed to handle temperature and humidity loads separately. Consequently; larger capacity of air handling units (AHU's) are installed with oversized compressors, to dehumidify the incoming air and are often operated for longer durations at low temperatures. Due to these factors the efficiency of the system reduces and requires reheating for the dry & cold air, to achieve required degree of comfort. Both consequences are costly. Desiccant systems, however, can supplement conventional air conditioners. Incorporating vapour compression refrigeration system (VCRS) along with desiccant system can tackle the temperature and humidity loads separately and more efficiently. The compressor size reduces and eliminates excess chilling capacity. Desiccant cooling systems are energy efficient and environmentally benign.

The work has been carried-out in two stages: Design of Air-conditioning system based on Psychrometric load calculations and the Development of experimental setup by prioritizing the appropriate assembly of the equipments. With the increase in supermarkets, convention centres, corporate buildings etc. use of air-conditioning has resulted in appreciable demand for electricity; that is generated by conventional power plants. The conventional vapour compression based air-conditioning system consumes high grade electricity power. Under high ventilation loads or low sensible heat ratio conditions, the conventional system is not designed to handle the continuous supply or increased volume of outdoor air necessary to comply with minimum ventilation standards as recommended by American Society of Heating Refrigeration Air-conditioning Engineer's (ASHRAE). For the development of hybrid air-conditioning system, sufficient data was generated in setting the input parameters.

II. DEVELOPMENT OF HYBRID AIR-CONDITIONING SYSTEM

Experimental setup was designed and developed for investigating the performance of solid desiccant assisted hybrid air-conditioning system by expanding the facility of the solid desiccant dehumidifier wheel, heat recovery wheel, conventional vapour compression cooling coil and conditioned space. Photographic view of the solid desiccant assisted hybrid air-conditioning system for 100% ventilation cycle is shown in Figure.1.

Figure: 1. Photographic View of Solid Desiccant assisted Hybrid Air-Conditioning System setup

In this system the outside hot & humid process air 'ODC' is passed through the desiccant dehumidifier wheel. The system is designed for 100% ventilation cycle. The principle of operation and its working is explained with respect to the processes shown on Psychrometric Chart. Refer. Figure: 2.

The description of the notations used on the chart is as follows.

ODC - Outside Design Condition

IDC - Inside Design Condition

2 - Condition of Process air leaving Desiccant wheel

3 - Condition of Process air leaving heat Recovery wheel

ADP - Apparatus dew point temperature/Temperature maintained in Evaporator (cooling) coil
4 - Condition of air leaving Evaporator (cooling) coil

5 – Room/Conditioned space dew point temperature

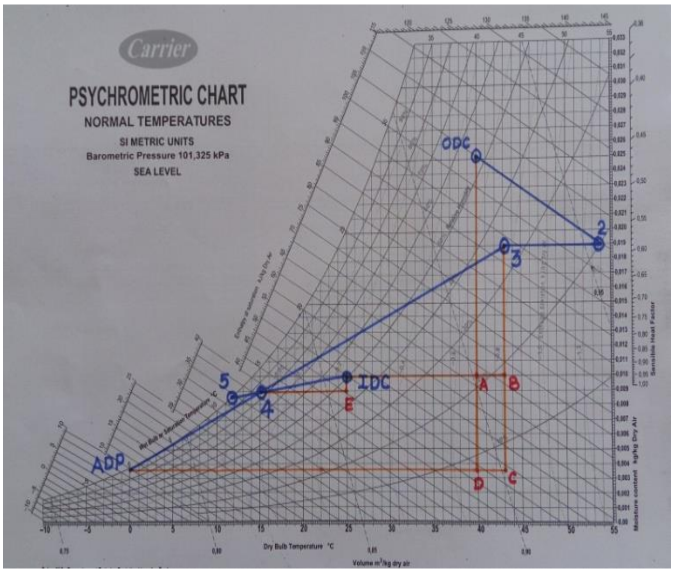

Figure: 2 Psychrometric process plot on chart

The desiccant dehumidifier wheel removes the moisture from the process air and the heat of adsorption gets released in the process air, thereby increasing the temperature of process air leaving the desiccant wheel, point ‘2’. The process air leaving the desiccant wheel is sensibly cooled by the regeneration air stream (outside air) in the heat recovery wheel. Heat recovery wheel is an air-to-air heat exchanging wheel, where the process air gets sensibly cooled by exchanging heat with the regeneration air stream. The high temperature regeneration air stream; which is preheated in the heat recovery wheel and heater section, is passed through the desiccant dehumidifier wheel to remove the adsorbed moisture for reactivation. The sensibly cooled process air in heat recovery wheel ‘3’ is then passed over the cooling coil; maintained at requisite apparatus dew point temperature as per the sensible heat factor ratio, to maintain the conditioned space as per the comfort conditions to be achieved. The condition ‘4’ represents the condition of air entering the conditioned space i:e point of intersection of “3 – ADP line” and the Room Sensible Heat Factor (RSHF) line.

Sensible heat factor (SHF) is defined as the ratio of sensible heat load to the total heat load.

$$SHF = \frac{SensibleHeatLoad}{SensibleHeatLoad + LatentHeatLoad}$$

$$SHF = \frac{SensibleHeatLoad}{TotalHeatLoad}$$

With the increase in latent heat load; the SHF decreases, thus decreasing the room ADP.

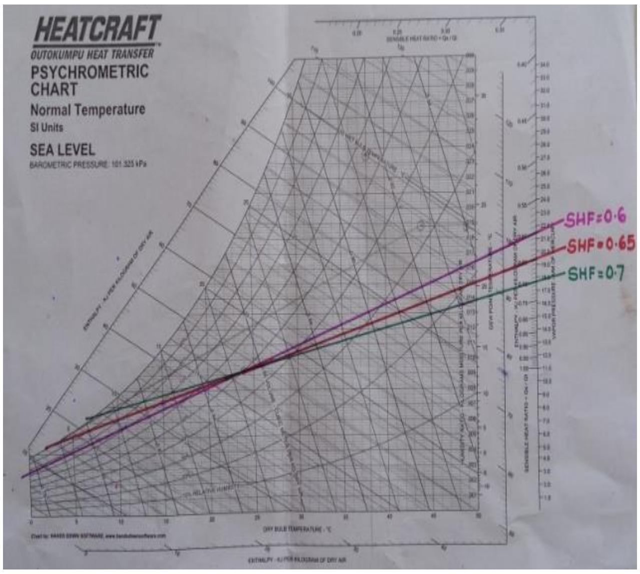

Figure: 3 RSHF line on Psychrometric Chart

From the Figure.3, it is observed that; for the value of SHF=0.7, the RSHF line meets the saturation curve at 7^0C and with SHF=0.65, the RSHF line meets the saturation curve at 20^0 C. When the SHF=0.6 or below, the RSHF line meets the curve well below 0^0C and thus the load on cooling coil increases.

Series of experiments were carried out for different outdoor conditions for maintaining the temperature and relative humidity of the conditioned space as 24^0C to 26^0C dry bulb temperature (DBT) and 50% Relative Humidity (RH or Ø) as per the ASHRAE specified standards for comfort zone. Results were analysed for 100% ventilation cycle for different outdoor conditions to measure the performance of the system and; are compared with the stand alone conventional VCRS based Split type air-conditioning system

III. Analysis of Results of Hybrid Air-Conditioning System

The analysis is carried out for the below mentioned outside condition and the processes are shown on Psychrometric chart as shown in Figure.4.

Outside Design Condition,
ODC = 38^0 C &, Ø=57%
Inside Design Condition,
IDC = 25^0 C& , Ø=50%
Condition of Process air leaving Desiccant wheel, **2:**
DBT = 49^0 C& Ø = 26.2%
Condition of Process air leaving heat Recovery wheel, **3:**

DBT = 43^0 C& Ø = 35.8%
Apparatus dew point temperature
ADP = 5^0 C (Temperature maintained in Evaporator (cooling) coil)

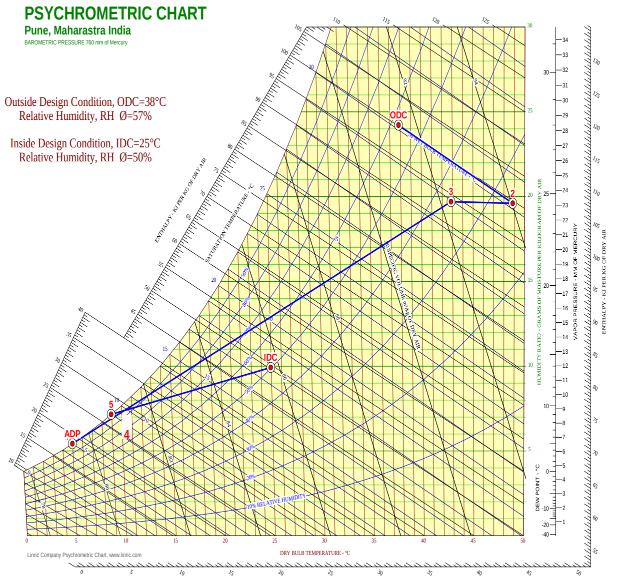

Figure:4. Psychrometric Plot of Process

Condition of air leaving Evaporator (cooling) coil, **4**
DBT = 11^0 C& Ø = 93%
The results obtained are tabulated in the following table 1 as follows:

Table 1: Load calculations from Psychrometric chart

Description about various loads	**Value in KW**
Sensible heat load of infiltrated outside	13.74
Latent heat load of infiltrated outside process	36.23
Sensible heat load of infiltrated outside process air using Desiccant wheel	17.74
Latent heat load of infiltrated outside process air using Desiccant wheel	25.8
Sensible heat load on cooling coil	38.39
Latent heat load on cooling coil	36.8
Total heat load on cooling coil	75.19
Sensible heat load on cooling coil stand alone VCRS system	34.39
Latent heat load on cooling coil stand alone VCRS system	47.23
Total heat load on cooling coil stand alone VCRS system	81.62
Room sensible load to be handled	15
Room latent load to be handled	6.26
Room total load	21.26

IV. CONCLUSION

From the results obtained, it is observed that the sensible load on the cooling load with the hybrid air-conditioning system increases but the latent heat load to be handled by the system decreases. Thus, overall load to be handled by the hybrid system decreases than that of the conventional vapour compression air-conditioning system. The cop of the system was found to be 1.13. With the increase in supermarkets, convention centres, corporate buildings etc. use of air-conditioning has resulted in appreciable demand for electricity; that is generated by conventional power plants. The conventional vapour compression based air-conditioning system consumes high grade electricity power. Under high ventilation loads or low sensible heat ratio conditions, the conventional system is not designed to handle the continuous supply or increased volume of outdoor air necessary to comply with minimum ventilation standards as recommended by ASHRAE.

REFERENCES

[1] P L Dhar, S K Singh "Studies on solid desiccant based hybrid air-conditioning systems". Applied Thermal Engineering, vol. 21, pp. 119-134, 2001

[2] Kenneth M Elovitz "Understanding what humidity does and why", Article published in ASHRAE Journal, pp.75-81, April 1999

[3] Michael D Larranaga, Mario G Beruvides, H W Holder, EnushaKarunasena, David C Straus "DOAS & Humidity Control", Article published in ASHRAE Journal, pp.34-40, May 2008

[4] Handbook: Indoor air quality Handbook: "A practical guide to indoor air quality investigations", TSI incorporated 2003

[5] Handbook: Indoor air quality Handbook: "Revised: A practical guide to indoor air quality investigations", TSI incorporated 2013

[6] Handbook: Indoor air quality guide: "Best Practices for design, construction and commissioning", developed by ASHRAE Oct. 2009

[7] S. Jain , P.L. Dhar, Evaluation of solid desiccant-based evaporative cooling cycles for typical hot and humid climates, Int. J. of Refrigeration, 18 (5)(1995) 287–96.