The Experimental Parameters Effect on The Performance of Cromer Wheel System in Airconditioning Unit

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ABSTRACT

The main aim of the present study is to design and test the dehumidify system for air-conditioning unit and testing rig to find out the performance of using polymer technique to control the inside conditions, that are represented by relative humidity and temperature in testing room by using desiccant wheel (Cromer cycle), and testing the effect of some parameters which can improve the performance of this system. An air-conditioner unit of 2tons capacity was installed in this system and used one type of desiccant material (silica gel) was used in this work. Two thicknesses of desiccant material and two widths (channels depth) were studied 3.5mm with channel depth 5cm and 2.5 mm with channel depth 20 cm and wheels diameter of 90cm.Four rotational speeds for desiccant wheel were studied (36, 45, 60, and 90) rph and the regeneration temperature was used to control the inlet regeneration air temperature using a number of electrical heaters. The series of test showed that, the best COP, efficiency and relative humidity control within the conditioned space was for the silica gel at thickness 2.5mm and channel depth 20cm. The maximum adsorption and desorption rate was 0.5427g/kg and 1.322g/kg respectively at 36 rph and (36.5 ^{o}C) regeneration temperature and the best COP of A/C was about (5.12) at 36 rph and (42 ^{o}C) regeneration temperature. Experimentally the best sensible and total efficiency that can be achieved was (18.1%) and (17.98%) at 45 rph and (30.6 ^{o}C) regeneration temperature and (17.88%), (17.76%) at 36rph and (30.91^{o}C) regeneration temperature. The best latent efficiency was (6.2 %) at 45 rph and (43.26 ^{o}C) regeneration temperature.

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تأثير العوامل العملية على أداءِ دورة كرومر في وحدةِ تكييف

الخلاصة

الهدف الرئيسي من الدراسة الحالية هي تصميم واختبار المنظومة الامتزازيه وإمكانية معرفة أداء وتأثير هذه التقنية في السيطرة على الظروف الداخلية المتمثلة بالرطوبة النسبية ودرجة الحرارة لغرفه الاختبار من خلال استخدام ألعجله المجففة (دورة كرومر) واختبار بعض العناصر التي تحسن من أداء هذه المنظومة. تم الاستعانة بمنظومة تبريد سعة 2 طن واستخدام نوع واحد من أنواع مواد الامتزاز لغرض إجراء الاختبارات اللازمة عليها وهي مادة السيليكا جل. سمكان للمادة المجففة وعرضين تم دراستها 3.5 مليمتر بعرض5 سنتيمتر و2.5 مليمتر بعرض 20 سنتيمتر كل هذه العجلات الامتزازيه صممت بقطر 90 سنتيمتر. كذلك تم تدوير الويل بأربع سرع دورانيه مختلفة هي (36 , 45 , 60 و 90) دوره بالساعة واستخدام حرارة التجديد للسيطرة درجة حرارة الهواء الذي يستخدم لتنشيط المادة الامتزازية عن طريق استخدام عدد من المسخنات الكهربائية . من خلال النتائج وجد إن أفضل كفائه ومعامل أداء كان للسيلكا جل عند سمك 2.5 سنتيمتر وبعرض 20 سنتيمتر. حيث وجد إن أفضل نسبة امتزاز وتحرير للرطوبة كان0.5427 غرام/ كيلوغرام و1.322 غرام / كيلوغرام على التوالي عند سرعة دوران 36 دوره بالساعة و (36.6 ^{o}C) درجة حرارة تجديد وأفضل معامل أداء للمنظومة كان (5.12)عند سرعة دوران 36 دوره بالساعة و (^{o}C 42) درجة حرارة تجديدِ . عمليا أفضل كفاءةِ محسوسة وكليّةِ يُمْكِنُ أنْ نصلَ إليها كَانتَ (18.1 %) و(17.98 %) عند سرعة دوران45 دوره بالساعة و درجة حرارة تجديدِ (^{o}C 30.6) و(17.88 %)، (17.76 %) عند سرعة دوران 36 دوره بالساعة و(30.91^{o}C) درجة حرارة تجديدِ. ً أفضل كفاءة كامنة كَانتْ (6.2 %) عند سرعة دوران 45 دوره بالساعة و(^{o}C 43.26) درجة حرارة تجديدِ.

Nomenclature		
Symbols	*Definition*	*Unit*
a	*moist air*	_
da	*desiccant*	_
C	*Specific heat*	*kJ/kg.^{o}C*
h	*heat transfer coefficient*	*W/m^2.^{o}C*
T	*temperature*	*^{o}C*
Y	*moisture content of air*	*kg/kg*
η	*efficiency*	*%*

INTRODUCTION

Use of desiccant is one solution to the problem of high humidity and prevents increasing inside air conditioning space.

The air conditioning industry is continually looking for an improved desiccant material. Specifically, research within the field of air conditioning technology has focused upon the development of new desiccant materials capable of removing both sensible and latent energy that generate inside space (as a result increasing the temperature and moisture content) within a single process as shown in Figure.(1) [1].During warm humid summer weather, heat and moisture energies are stored in the supply section of the wheel and as the wheel rotates, the stored energies are transferred from the supply inlet air to the exhaust air streams and this results in a cooler dryer outlet air [2].Traditionally; the desiccant market has been dominated by ceramic materials. The popularity of these materials can be attributed to their low cost and high availability in addition to their ability to easily take on water, a result of their porous construction. Notwithstanding, ceramics do lack certain desirable characteristics in desiccant applications.

Wilson, et.al. (2005) [3] studied control volume models for humid air and desiccant materials which are implemented and finally the operation of the desiccant wheel is simulated. Comparison of the dynamic and steady state results from open literature, manufacturer data as well as experimental result is used to validate the model.

Huda Jasim Mohammad (2008) [2] was studied how can be control the indoor relative humidity and conserve the energy consumed by the air conditioner unit by using adsorbent system. An air conditioner unit of 2 tons capacity was used in conjunction with desiccant wheel to achieve the Cromer cycle. The unit was constructed and installed in a test room of (6.5m length ×2.8m width ×2.37m height). Two types of desiccant materials were tested namely silica gel and active carbon. The series of test showed that, the best COP and relative humidity control within the conditioned space is for the active carbon. The best COP is about (1.5948) as compared with traditional cycle, for active carbon wheel of (5) cm thickness and (42) rph rotational speed. The latent heat ratio for Cromer cycle is 0.5714 for the same unit with Cromer cycle using 5 cm thickness silica gel at a speed 42 rph. The A/C unit under consideration without Cromer cycle was found to be 0.18032.

Chaoqin Zhai, et.al. (2008)[4] They installed and provided a solid desiccant based ventilation system and cooling/heating as needed, to the Intelligent Workplace of Carnegie Mellon University, as part of the Intelligent Workplace Energy Supply System. Since its installation, extensive testing data have been collected and analyzed to characterize the operating performance and cost of each major component, namely the enthalpy recovery module, the active desiccant module, the heat pump module, and the overall system. It has been determined that the active desiccant wheel is expensive to operate due to the high price of natural gas in the current fuel market. In order to improve the energy efficiency and reduce the operating cost of the overall system, it has been proposed to regenerate the active desiccant wheel using the rejected heat from a bio diesel engine generator.

ONE DIMENSIONAL EQUATION ANALYSIS

The governing differential equations for the one-dimensional rotary wheel total enthalpy exchanger model were derived using a control volume technique. Simultaneously, using the theories of conservation of energy and conservation of mass, finite difference equations were derived. The control volume analysis used to illustrate conservation of energy is represented in Figure (2).Figure (3) represents the sample that tested in the present study. This section is similar to sample that actually found inside desiccant wheel and can be observed the air passages that contain in desiccant material.

COEFFICIENT OF PERFORMANCE (COP)

This value calculated by dividing the refrigerant effect that represents the different of enthalpy of cooling coil to work of compressor,[5].

$$COP = \frac{R.E}{W_{COMPERESSO\quad R}} \tag{1}$$

DETERMINATION OF ENERGY EFFICIENCIES

Three efficiencies are used to evaluate an exchanger's overall steady-state performance: sensible efficiency, latent efficiency, and total efficiency [1].

Sensible Efficiency

The sensible efficiency of the system describes the exchanger's ability to remove heat from one air stream and transfer it to another. The sensible efficiencies evaluated by using

$$\eta_s = \frac{(Y a_1 - Y a_2)}{(Y a_1 - Y a_3)} \tag{2}$$

The sensible efficiency of a total enthalpy exchange system is represented as the difference in the inlet and exit temperatures of the supply air, temperatures at locations 1 and 2 in Fig. (4) as compared to the difference in inlet supply air and inlet exhaust air temperatures of locations 1 and 3 in Figure (4) [1].

LATENT EFFICIENCY

The energy associated with the phase change between liquid and vapor states is called latent energy. The latent efficiencies evaluated in this project are determined from [1].

$$h_L = \frac{(Y a_1 - Y a_2)}{(Y a_1 - Y a_3)} \tag{3}$$

TOTAL EFFICIENCY

The total efficiency of the system describes the exchanger's ability to remove total sensible and latent energy from one air stream and transfer it to another. The total efficiencies for all numerical models evaluated in this project are determined from [1].

$$h_{tot} = \frac{Cda(\mathrm{T}a_1 - \mathrm{T}a_2) + (\mathrm{Y}a_1 h_{g1} - \mathrm{Y}a_2 h_{g2})}{Cda(\mathrm{T}a_1 - \mathrm{T}a_3) + (\mathrm{Y}a_1 h_{g1} - \mathrm{Y}a_3 h_{g3})} \quad (4)$$

EXPRIMENTAL WORK

The test room has the dimension ($4.1\,m \times 2.4\,m \times 2.5\,m$).A (2Ton) air-conditioning is used in this study. The room internal load is simulated by create latent load that represent the vapor of water and the sensible load that represent effect the heaters inside the space in addition to the outdoor load .

Desiccant Wheel

The main part of this system is the desiccant wheel that holds desiccant material. The wheel is to rotate through both supply and return air, and holds the moisture from supply air and releases it to the return air. Its diameter and width are (90 and 7.5) cm respectively and made from iron .The center of wheel (hub) diameter is (11.5) cm .The wheel is supported by a shaft of (28mm) diameter and two bearings as shown in Figure (5).And its contains a number of slots used to fix the galvanized plate (material plates) shown in Figure (6). Table (1) summarizes the parameters that are used in this test depending on some references that reached to better state recommended the parameters. Implemented these parameters and redesigned it with using new shapes for desiccant material, new rotational speed and different regeneration temperature.

Table (1) Summary of the parameters that are used in this test

Parameters	Type of materials	Desiccant wheel (1)	Desiccant wheel (2)
Thickness (mm)	Silica gel	2.5	3.5
Width (mm)		200	50
Speed (rph)		36 , 45 , 60 ,90	
Regeneration temp(^{O}C)		30 , 36 , 42	

Desiccant Material

One type of desiccant materials was used in this work. This material is silica gel. Three wheels are made for silica gel material in this test; each wheel carried a different thickness of desiccant material.

Temperature , Relative Humidity And Air Velocity Measurements

The dry bulb temperatures and relative humidity were measured using digital (Temperature Humidity Meter) model (**HT- 315**) and electronics sensor (**probe**) with the aid of selector switch. The velocity of supply and return air was measured by used (Digital Anemometer).

From figure (7) can be show the test rig this system and The locations of temperature and relative humidity measurement are shown in schematic diagram in Figure (8).

RESULTS AND DISCUSSION

Figure (9) shows the effect of wheel rotational speed on the COP of both traditional cycle and the cycle uses desiccant wheel. It can be seen from this figure that the enhancement in cop when using desiccant wheel. The maximum cop of the A/C unit is achieved when the thickness of desiccant material is 2.5mm and width of 20cm at 36 rph of wheel rotational speed and 42^{o}C regeneration temperature. With increasing the wheel rotational speed the exit temperature from the wheel (at regeneration region) decreases which cause a decrease in cooling coil temperature. This leads to decrease in evaporator temperature and that result in decrease in the Refrigerant cooling effect (R.E) therefore the COP decreases.

Both Figures (10), (11) show the effect of wheel rotational speed on sensible, latent and total efficiency of desiccant wheel system with a channel depth of 20 cm. it can be observed the efficiency of the cycle increases when the wheel rotational speed decreases .It reaches its maximum value for sensible and total efficiency (about 18%)at 45 rph under regeneration temperature of 30^{O}C.The reduction in cycle efficiency can be summarized by, the increase in rotational speed makes the contact time of air – desiccant material very short and there is no enough time to transfer heat and moisture.

Figures (12) and (13) show the effect of regeneration temperature on sensible, latent and total efficiency of desiccant wheel system. The figures show the sensible and total efficiency decrease with increasing the amount of regeneration temperature, because the increasing regeneration temperature at the same rotational speed, the difference in temperature on two sides of desiccant wheel in regeneration region will be increased to reach maximum value of about 18% at regeneration temperature of 30 ^{o}c at rotational speed 45 rph. But the latent efficiency increases when regeneration temperature increase to reach the highest value of about 6.2 % at 42 ^{o}c and 45 rph.

Figures (14) show the effect wheel rotational speed on efficiency of two desiccant wheels with different channel depth. From these figures can be seen the amount of efficiency that increasing when decrease the wheel rotational speed to reach the maximum value at 36 and 45 rph.

Figures (15) and (16) illustrate the difference between the results obtained from the desiccant wheels with different channel depth as a function of the difference in regeneration temperature.

CONCLUSIONS

The main aim of the present study is test the performance of the Cromer cycle in the field condition.

The following conclusions can be drawn in regard to the Cromer wheel operation and numerical model through testing the adsorption system:

1. The increasing in channel depth improves the performance system.
2. The best COP can be achieved at rotational velocity of 36 rph and 41.9 ^{o}C of regeneration air inlet temperature.
3. The best total efficiency for this system at rotational velocity is 36 rph and 45rph at 30 ^{o}C of regeneration air inlet temperature.
4. It is recommended to keep the regeneration temperature between (30^{o}C-36^{o}C) to obtain maximum efficiency (for silica gel).
5. The air in the supply duct is much drier that when using Cromer cycle.
   Using Cromer cycle increases the coefficient of performance of the A/C unit system by 13.7 %.

REFERENCES

[1] JoAnna Christen Staton "Heat and Mass Transfer Characteristics of Desiccant Polymers" M.S. Virginia Polytechnic Institute and State University, 1998.

[2] Huda Jasim Mohammad "Performance study of air conditioner unit using Cromer Cycle" Ms.c Thesis, Technical College - Baghdad, 2008.

[3] Wilson Casas, Katrin Proelss and Gerhard Schmitz "Modeling of Desiccant Assisted Air Conditioning Systems" Technique University Hamburg – Hamburg Germany 2005.

[4] Chaoqin Zhai*1, David H. Archer*2 and John*3 C. Fischer "Integration of the active desiccant wheel in CHP system design", of Architecture Carnegie Mellon University, Department of Mechanical Engineering Carnegie Mellon University and SEMCO Incorporated 1800 East Pointe Drive Columbia, MO 65201August 10-14, 2008.

[5] ASHRAE (2009) Hand book –fundamentals.

[6] Bronislava Veltcheva, "Field Study of the Rotary Desiccant System Using the Cromer Cycle", thesis submitted to University of Florida, 2003.

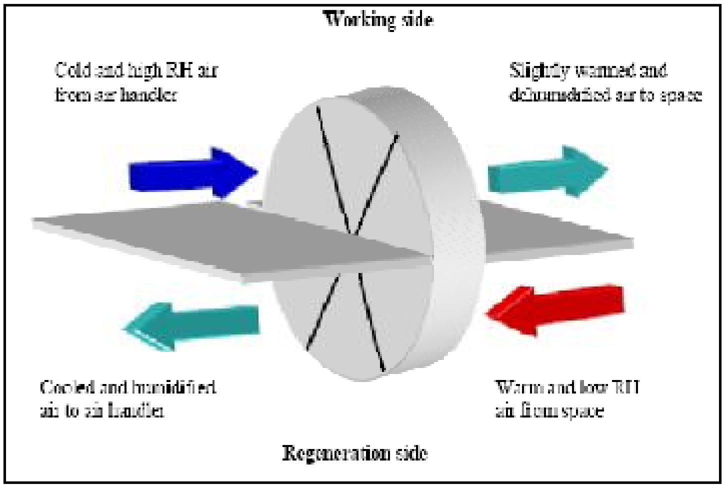

Figure (1)Desiccant wheel operation [6]

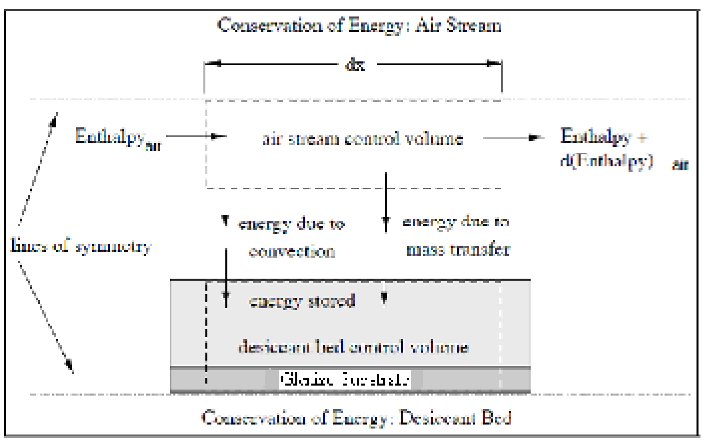

Figure (2) Control volume schematic representing Conservation of energy for rotary wheel

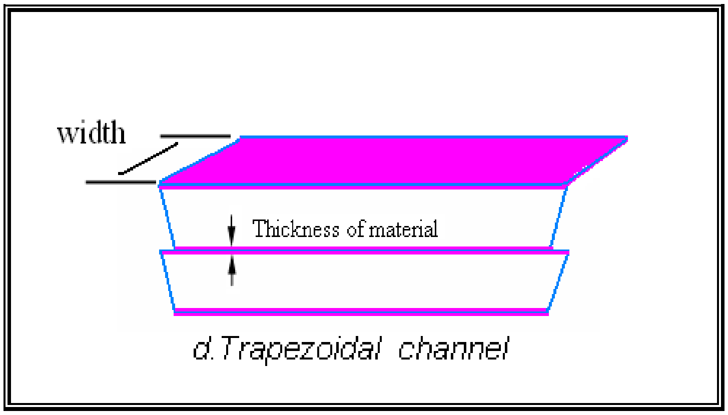

Figure (3) Channel geometry used in present study

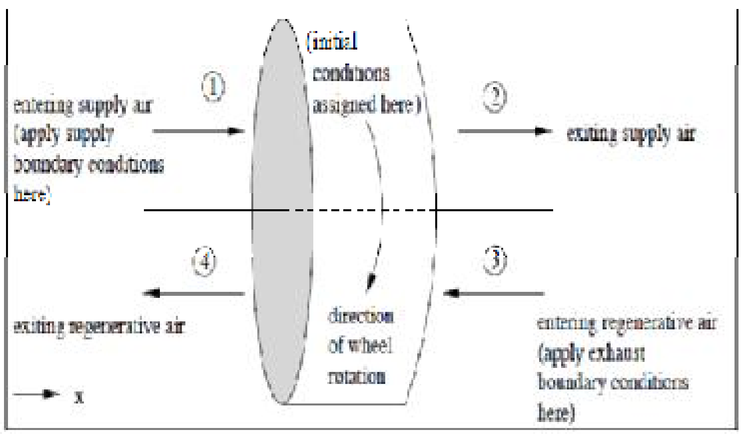

Figure (4) Representative rotary wheel total enthalpy exchanger environments.

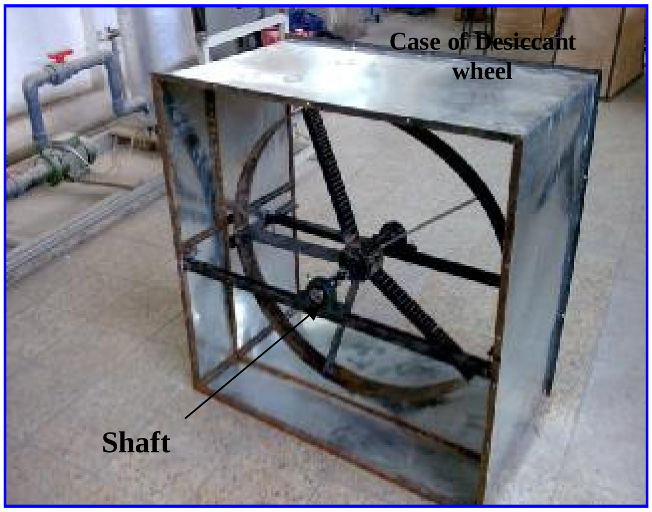

Figure (5) Case of desiccant wheel

Figure (6) fixed desiccant material on wheel

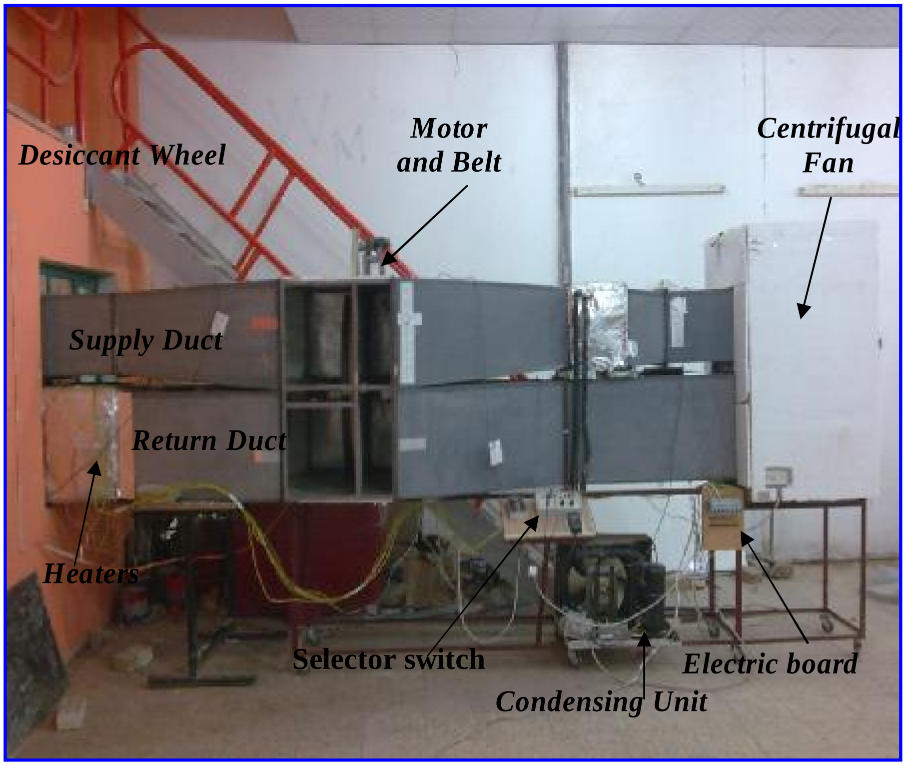

Figure (7) Test rig

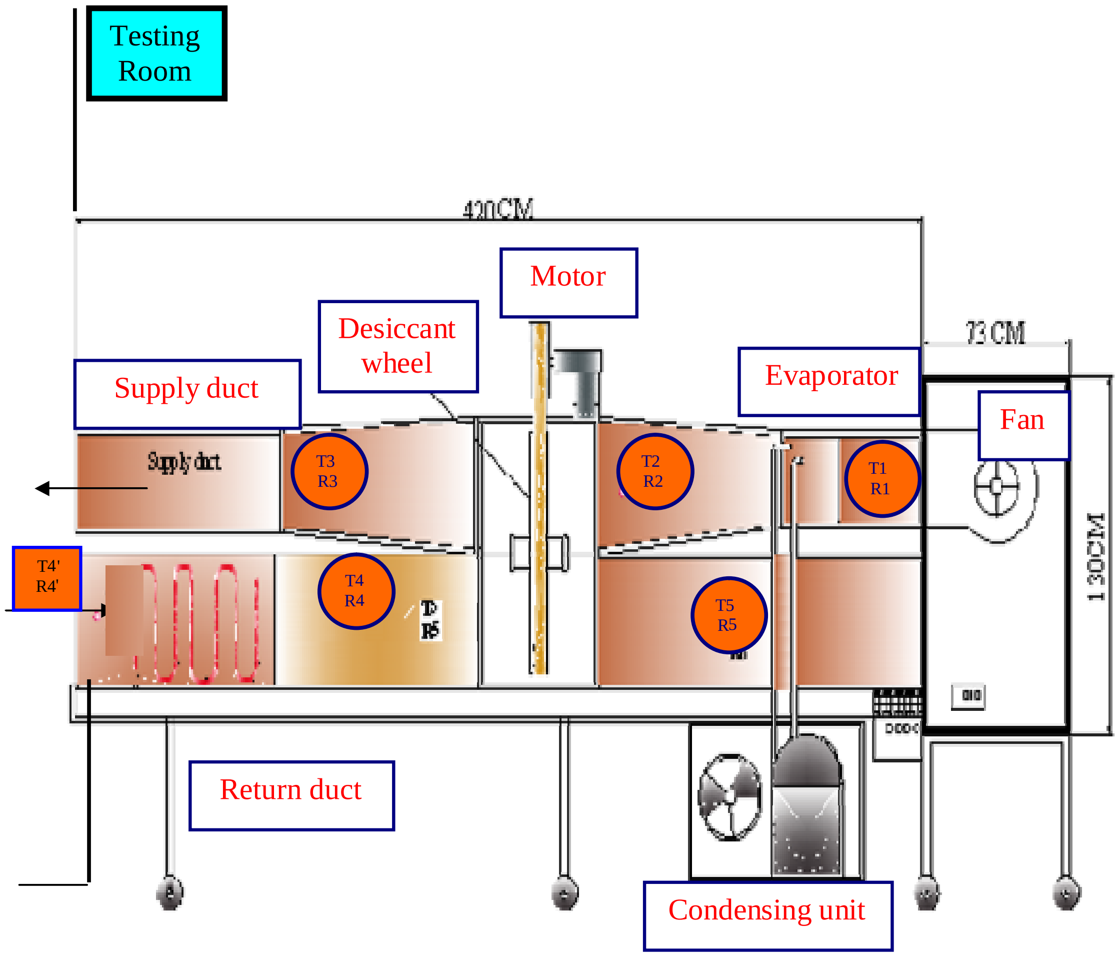

Figure (8) Schematic Diagram

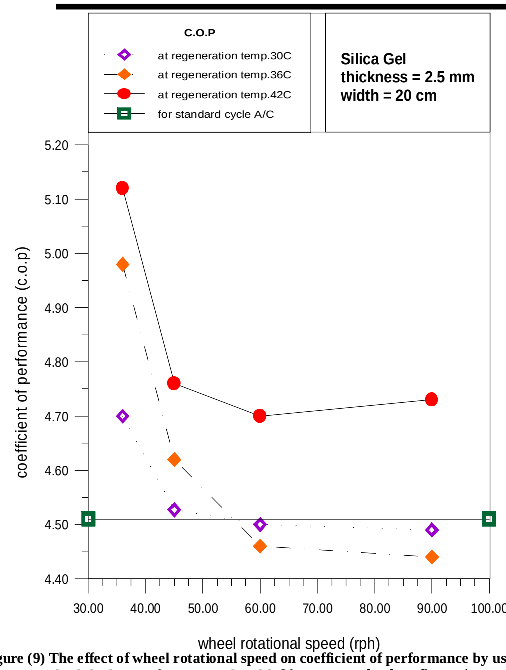

Figure (9) The effect of wheel rotational speed on coefficient of performance by using desiccant wheel thickness of 2.5mm and width 20cm,vs standard configuration system A/C.

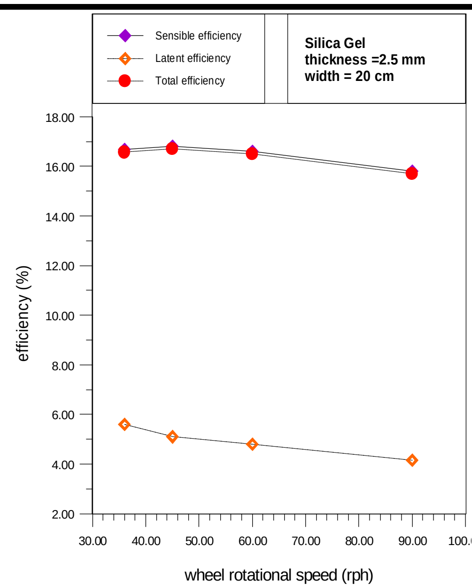

Figure (11) The effect of wheel rotational speed on efficiency by using desiccant wheel thickness of 2.5mm and width 20cm at regeneration temperature of 36 °C.

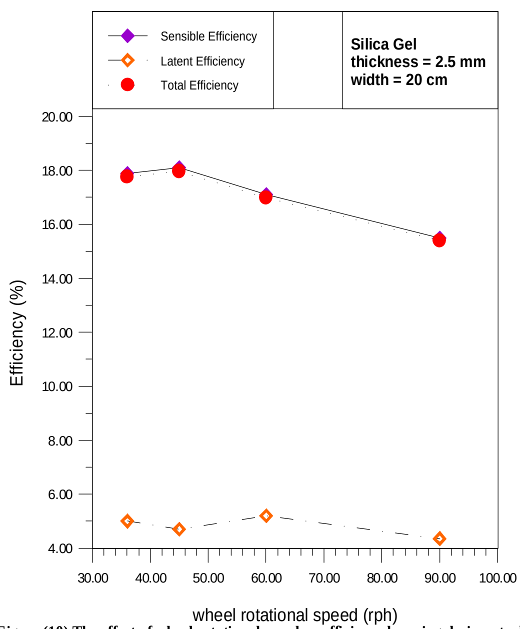

Figure (10) The effect of wheel rotational speed on efficiency by using desiccant wheel thickness of 2.5mm and width 20cm at regeneration temperature of 30 °C.

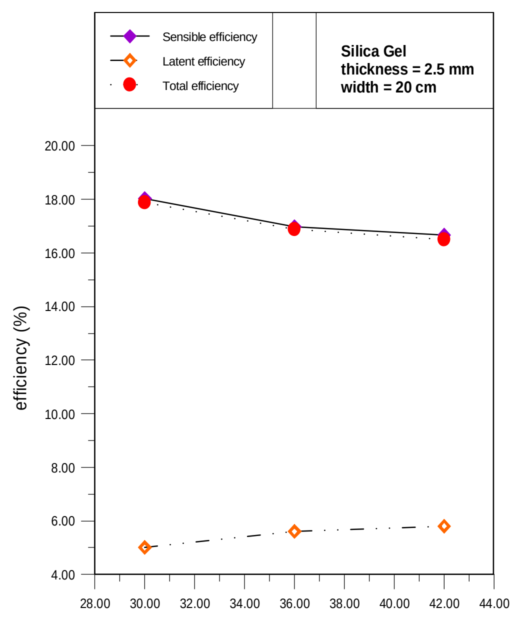

Figure (12) The effect of regeneration heat on efficiency by using desiccant wheel thickness of 2.5mm and width 20cm at rotational speed of 36 rph.

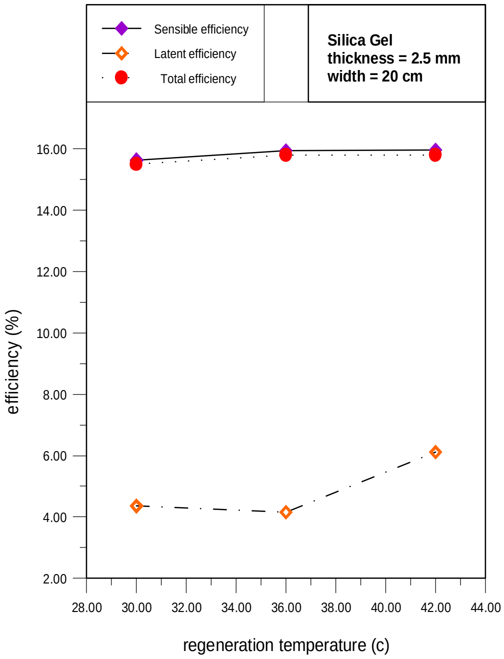

Figure (13)The effect of regeneration heat on efficiency by using desiccant wheel thickness of 2.5mm and width 20cm at Rotational speed of 90 rph

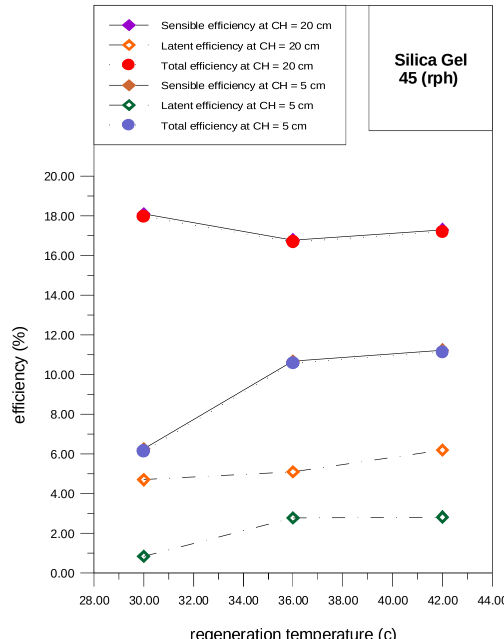

Figure (15) The effect of the regeneration heat on efficiency under condition of 45rph.

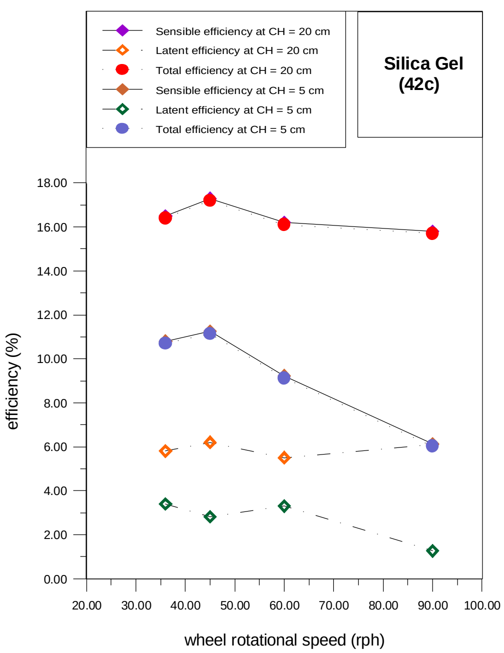

Figure (14) The effect of the wheel rotational speed on efficiency under condition of 42 °C.

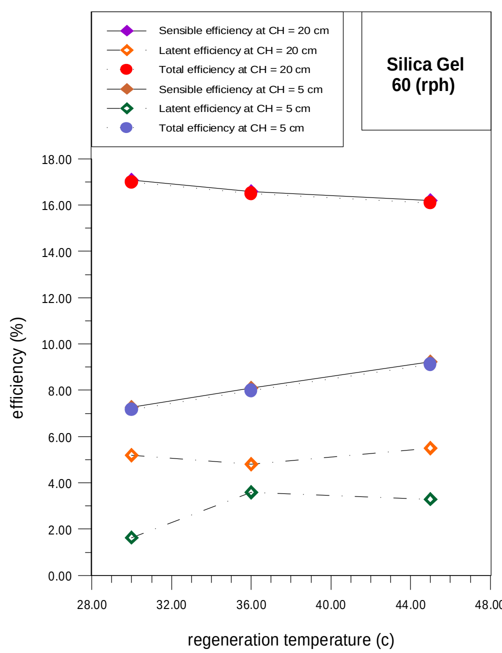

Figure (16) The effect of the regeneration heat on efficiency under condition of 60rph.