EXPERIMENTAL STUDY OF AIR CONDITIONER UNIT PERFORMANCE USING CROMER CYCLE[+]

دراسة أداء منظومة تكييف عمليا باستخدام دورة كرومر

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Abstract:

An air conditioner unit of 2 ton capacity was used in conjunction with desiccant wheel to achieve the Cromer cycle. The unit was constructed and installed in a test room during July to October 2007, at Technical College –Baghdad. The dimensions of the room are (6.5m length ×2.8m width ×2.37m height). Cromer cycle, including ducting system, desiccant wheel and motor, can be removed from the cycle, so the performance data with and without Cromer cycle can be gathered to investigate the effect of Cromer cycle on the power consumption and relative humidity within the conditioned space. Two type of desiccant materials were tested namely silica gel and active carbon. For each desiccant material, three thicknesses of desiccant materials were studied namely 2.5, 5, and 7.5 cm, also rotational speeds for desiccant wheel were studied, namely 10.7, 21, 42, 54.5, and 60 revolutions per hour (rph). The series of test showed that, the best COP and relative humidity control within the conditioned space was for the active carbon. The best COP was about 1.6 achieved with active carbon wheel of 5 cm thickness and 42 rph rotational speed. The latent heat ratio for Cromer cycle was 0.57 for the air conditioner using 5 cm thickness silica gel at a rotational speed of 42 rph. While the improvements in cycle COP under consideration without Cromer cycle was found to be 0.18. The study shows that Cromer cycle can reduce the indoor relative humidity from 80% to about 60% using active carbon of 5 cm wheel thickness.

المستخلص:

تم دراسة تاثير دورة كرومر على معامل اداء وحدة تكييف سعة ٢طن تجميد، حيث تم بناء الجهاز في الكلية التقنية– بغداد عام ٢٠٠٧ و اجريت التجار العملية في شهري تموز و تشرين الاول من العام ذاته، اجريت الدراسة على غرفة بابعاد ٦،٥ متر طولا و ٢،٨ متر عرضا و بارتفاع ٢،٣٧ مترا. واحتوت دورة كرومر على منظومة مجاري هواء و عجلة المادة المازة والمحرك ومخفض السرع، ويمكن ازالة منظومة كرومر من الدورة بحيث يمكن اختبار اداء الدورة بدون او مع دورة كرومر. تم دراسة تاثير نوعين من المادة المازة هما الكاربون المنشط و مادة السليكا جل، و بسمك ٢،٥ ، و ٥ سم و ٧،٥ لكل منهما. في حين ان السرعة الدورانية للعجلة التي تحتوي المادة المازة كانت ١٠،٧ و ٢١ و ٤٢ و ٥٤،٥ ة ٦٠ دورة في الساعة الواحدة. بينت التجارب التي اجريت على وحدة

[+] **Received on 30/6/2010 , Accepted on 4/5/2011 .**

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التكييف التي تحتوي على دورة كرومر على ما يلي: احسن معامل اداء للدورة مع افضل تحكم في الرطوبة النسبي للفضاء المكيف تم الحصول عليه باستخدام الكاربون المنشط كمادة مازة. في حين احسن معامل اداءكان بحدود ١،٦ عند سمك مقداره ٥ سم للمادة المازة وسرعة دورانية مقدارها ٤٢ دورة في الساعة. وكان مقدار احسن نسبة حرارة كامنة ٠،٥٧ عند استخدام السليكا جل كمادة مازة بسمك ٥ سم وسرعة دورانية مقدارها ٤٢ دورة في الساعة. كان التحسين في معامل اداء الدورة بمقدار ٠,١٨ مقارنة بمنظومة التكييف الاعتيادية وعند الظروف المثلى. بينت الدراسة ان مكيف الهواء الذي يستخدم دورة كرومر ممكن ان يقلل الرطوبة في الفضاء المكيف من ٨٠% الى حوالي ٦٠%، عند احسن حالة كما في اعلاه.

Introduction:

The conventional vapor-compression system meets the latent load of the space by cooling the air below its dew point and as a result water vapor within moist air is condensed. While, when using adsorption method in controlling indoor humidity a common air-to-air energy exchanger called energy wheels (also called enthalpy wheels) are used. Energy wheels are often constructed by winding desiccant-coated corrugated material, such as very thin aluminum sheet, around a core. The desiccant coated aluminum sheet makes up the matrix or medium through which air flows. Energy wheels transfer both heat and moisture between the supplies and exhaust air streams from the ventilating room. During warm humid summer weather, heat and moisture energies are stored in the supply section of the wheel matrix and as the wheel rotates, the stored energies are transferred from the supply air to the exhaust air streams, and this results in a cooler dryer outlet air. During cold dry winter weather, heat and moisture are transferred from the exhaust air of buildings and transferred to the supply air stream. Therefore, with the use of an energy wheel, the same device and airflow configuration can be used for both cold and warm ambient air temperatures. The cycle works at such way is called as Cromer cycle. Unlike other desiccant-assisted cooling technologies, the Cromer cycle does not require external heat source to regenerate the desiccant, but relies on inherent vapor-pressure differential. The processes that air undergoes when passing through the wheel are as follows:-cold air with very high relative humidity (RH) leaves the cooling coil and passes through the working side of the wheel, cooling the desiccant and transferring moisture to it. At the same time, the warmer air with lower RH from the conditioned space passes through the return side of the wheel, absorbing moisture and regenerating the desiccant.

The release of moisture into the air retuning from the space before it enters the cooling coil increases the latent ratio of the coil, enhancing its dehumidification abilities. The RH and temperature difference of the two air streams provide the potential for moisture transfer. The feature of Cromer cycle technology that distinguishes it from other desiccant-based concepts is that the return air (rather than an external heat source) accomplishes regeneration of the desiccant.

Robert Barlow and Kirk Collier, (1981) [1] have used a computer simulation method as well as a simplified psychometric analysis to determine the increase in cooling system performance that can be achieved through the use of non-homogeneous or staged desiccant beds. Jurinak. et. al, (1984) [2] have deduced the performance of open-cycle desiccant air conditioners for residential applications. The performance of these systems was compared to that of vapor compression air conditioners on the basis of primary energy use and cost. Donald, Pe. (2000) [3] have introduced a technology options for dedicated outside air units with a recuperative heat exchanger. An ordinary "new-energy" reheat using hot refrigerant gas were used. A series articles were achieved in his study. These articles conclude with coverage of exhaust-air/outside air enthalpy exchange, heat-powered active desiccant dehumidification, and vapor-compression refrigeration-cycle dehumidification. This series of articles was written to inform owners, designers, and contractors about cost-effective options for delivering dehumidified air to buildings to minimize or eliminate indoor air- quality problems and provide comfort that can lead to optimum productivity . Gerrit Hofker, et. al,(2001) [4] have introduced desiccant cooling systems which combine sportive dehumidification, heat recovery, evaporation and heating to create a cooling process which can offer energy savings compared to conventional air conditioning systems. Charles. Cromer, (2001) [5] Showed that Cromer cycle which used a desiccant wheel can operated in conjunction with a typical air conditioning system. The research included the purchase of "off the shelf" materials and the assembly of a working residential sized Cromer cycle desiccant air conditioning system. Stephan Gin Stet, et. al, (2001)[6] have introduced an open-cycle desiccant cooling systems, that can be operated either in indirect evaporative cooling or in desiccant cooling mode, depending on outdoor air conditions. In addition to the switch point temperature between evaporative and desiccant cooling, the regeneration temperature and the supply air flow rate were key control parameters to achieve optimal cooling performance. Bronislava Veltcheva, [2003] [7] has developed an experimental protocol to the steady operation of A/C system where retrofitted with the Cromer cycle equipment. All data collected for the period of operation of the air handler as a conventional AC unit, were collected in base line set. Camargo, and Ebinuma (2005) [8] have studied a system that can be used in humid climates by coupling desiccant dehumidification equipment to evaporative coolers. The dehumidification occurred by adsorption in a counter flow rotary heat exchanger following the evaporative cooling of the air in evaporative cooler, they analyzed some operating parameters such as reactivation temperature relationship and thermodynamic conditions of entering air. Oyetope Omobayode Abe[2005] [9] Presented an analytical model for predicting the effectiveness of rotating energy wheels using only the characteristics measured on the same non-rotating wheels exposed to a step change in temperature and humidity. A relationship between the step response and the periodic response of an energy wheel is developed using first order linear system design theory.

Expermintal work:

A window type air conditioner of 2 ton capacity was used to study the Cromer cycle experimentally. A test room was chosen in The Technical College –Baghdad, of dimensions 6.5m length ×2.8m width ×2.37m height. Two walls of the room were exposed to outside condition, while the two others walls are subjected to lab conditions. The air conditioner is supplied with a Cromer wheel of diameter of 40 cm, and covered on both sides by a metal screen to hold the desiccant material, as shown in figure 1. The function of the wheel is to rotate through both supply and return air. As the wheel rotate through air duct, it is holds the moisture from supply air and releases it to the return air, as shown in figure 2. To study the effects of desiccant thickness on the Cromer cycle, two wheels were made. The first one is of 2.5cm thickness while the second is of 5cm thickness, which allowed three thicknesses when combined the two wheels together, namely 2.5, 5 and 7.5 cm thickness. The rotational speed of desiccant wheel is controlled by an electrical motor of 0.5 hp and 1350 rpm, with the gear box and different diameter pulleys to give different rotational speeds to the desiccant wheel, namely (10.7, 21, 42, 54.5 and 60 rph). Two types of desiccant materials were used, the first was silica gel with grain size ranging from (4 - 9) mm and the second was active carbon with a grain size of (4 - 6) mm.

Results and discussion:

Figures 3, 4 and 5 show the variation of total, sensible and latent heat removed from supply air by Cromer cycle for different thickness of silica gel. It can be seen from the figures that, the total heat removed from air using Cromer cycle is always less than that removes by standard cycle, this is due to the resistance of desiccant materials to air stream. From Figure 3, it can be seen that the best wheel rotational is 10.7 rph when the silica gel thickness is 2.5 cm, while from figures 4 and 5 it can be seen that, the best wheel rotational speed for both thicknesses of 5 and 7.5cm is about 42 rph . It can be concluded that thick desiccant materials means a shorter time required to adsorb moisture from supplied air stream. Also it can be seen from all figures mentioned above that; there is an increase in the latent load and a decrease in the sensible load as compared with the traditional A/C unit. This is due to the fact that the silica gel desorbs moisture to return air before it enters the cooling coil, i.e, air is saturated and closer to its dew point and this can switch the total cooling load to more latent load.

Figures 6, 7 and 8 show the variation in of total, sensible, and latent load for the A/C unit using Cromer cycle, when the active carbon is used as a desiccant material, for different wheel rotational speed and different active carbon thicknesses. It can be seen from the figures above that, the total load of the A/C unit is improved or at least not changed as compared with the traditional cycle. Figure 6, shows that, the wheel rotational speed has a little effect on the Cromer cycle performance. Since the thickness of active carbon in the 2.5cm, thus little moisture adsorbs by active carbon from air stream. while in figure 7 where the active carbon thickness is 5cm, the performance of A/C unit using Cromer cycle is improved and reaches its optimum value at (42) rph wheel rotational speed, figure 8 shows a reduction in the cycle performance using Cromer cycle, this is due to reduction in air flow rate related to high resistance of desiccant materials to air stream. Thus, less air passes to the conditioned space, which means less cooling effect. The following observations are drawn from the Cromer cycle using active carbon as desiccant materials, an increase of about (35%) in the latent heat ratio (LHR) and increase of about (30%) in the latent load, as compared with that using traditional A/C, also it can be concluded that the best thickness of active carbon is 5cm when the wheel rotational speed is 42 rph, for the present study.

Figure 9, shows the values of total, sensible, and latent heat for the traditional and Cromer cycles for both silica gel and active carbon, for the best thickness of the desiccant material of 5cm, and 42 rph rotational speed. it can be seen from the figure that, the maximum total load is for Cromer cycle using active carbon, while the minimum is for silica gel.

Figures 10 shows the effect of desiccant materials and wheel rotational speed on the moisture removed from and charged to the desiccant materials. It can be seen from the figure that, although the moisture removed from and charged to the air stream by silica gel is greater than that for active carbon, but the COP for A/C working on Cromer cycle using active carbon is greater than that for silica gel, this is due to the high resistance of silica gel to air stream.

Figures 11, shows the effect of wheel rotational speed and desiccant materials on the indoor relative humidity, for the best thickness of desiccant materials. It can be seen from the figure that, all the types of Cromer cycle tend to reduce the indoor relative humidity to the acceptable value within the conditioned space, while the traditional A/C cycle cannot control the indoor relative humidity when there is an extreme increase in the room relative humidity.

Figure 12, shows the optimum performance of Cromer cycle in maintaining the indoor relative humidity within conditioned space vs. desiccant materials thickness. It can be seen from the figure that when the initial indoor RH is about 80%, the traditional A/C cycle fail to decrease the indoor relative humidity to acceptable limit, while all desiccant materials tend to keep the indoor RH within acceptable limits ranging from 60 to 68%. The best performance was for 2.5cm thickness and 10.7 rph wheel rotational speed, which gives about 60% RH, but as mentioned above this configuration gives less COP.

Figure 13 shows the effect of wheel rotational speed on the latent heat ratio (LHR) for different thickness of desiccant materials. The LHR gives an indication to the ability of the desiccant materials in adsorbing moisture from the conditioned space, which means reducing the indoor RH to the acceptable limits, as mentioned in figure 12 the best performance in maintained acceptable relative humidity (RH) was for active carbon of 2.5 cm thickness and 42 rph wheel rotational speed, which gives a high LHR.

Figure 14 shows a comparison between the performances of air conditioner unit using Cromer cycle vs. standard configuration cycle, It can be seen from figure , that the standard cycle is depicted by S_1 and S_2 and, and Cromer cycle which is depicted by C_1, C_2, C_3, , and C_4. The first process of Cromer cycle is C_1-C_2, represents the desorption process through desiccant materials, where desiccant material desorbs the moisture to the air before it enters the cooling coil, process C_2-C_3, represents the cooling and dehumidification process, in this process, the temperature of air reduces and the moisture condenses on the cooling coil, and C_3-C_4, represents the process through the another side of the wheel , where the remaining moisture adsorbs from the supply air. It can be seen from the figure that the processes of Cromer cycle maintained a relative humidity within the room of about 68.4%, while the relative humidity is 89.4% when a standard configuration unit is used.

Figures 15 and 16 show the performance of air conditioner cycle using Cromer cycle, for both best conditions, namely, Silica gel and active carbon thicknesses of 5 cm and wheel rotational speed of 42 rph.

Conclusions:

Using Cromer cycle with the traditional A/C unit can achieve the following:-

1. Control the indoor relative humidity to the limit of human comfort condition of 50% ($\pm$ 10) [10].
2. Using active carbon as a desiccant material, in Cromer cycle, reduces the power consumption.
3. It was found that, the optimum thickness of active carbon material that gives good rolling relative humidity control and reducing power consumptions is 5 cm thickness at (42) rph.
4. Using Cromer cycle with the A/C unit increases the latent heat ratio (LHR) of the room load.

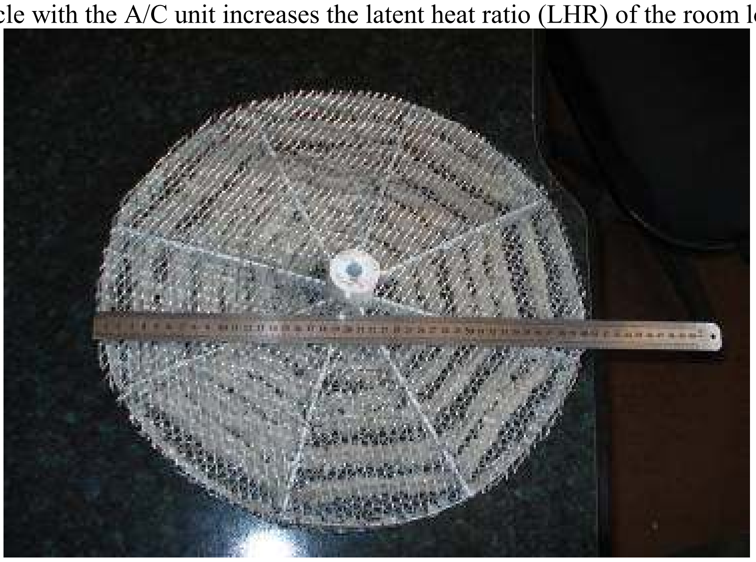

Figure (1) Cromer wheel

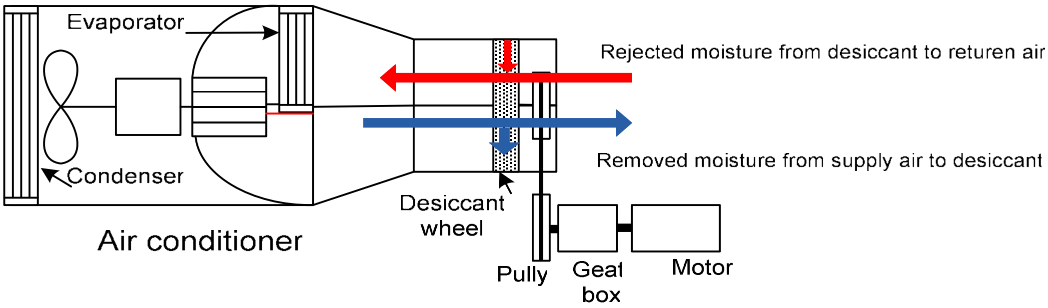

Figure (2) Air conditioner unit with Cromer cycle

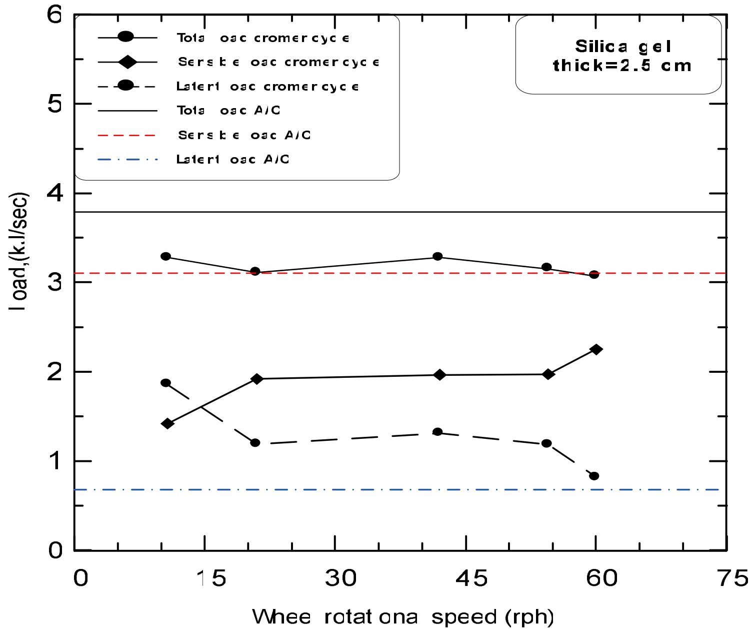

Figure 3 Effect of rotational speed on the room load Silca gel thickness is 2 5 cm

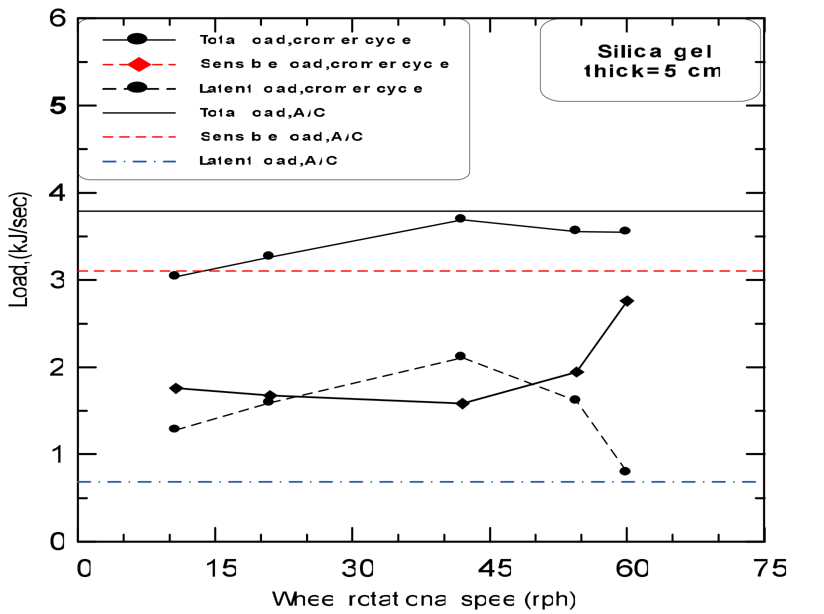

Figure 4 Effect of rotational speed on the room load Silca gel thickness is 5 cm

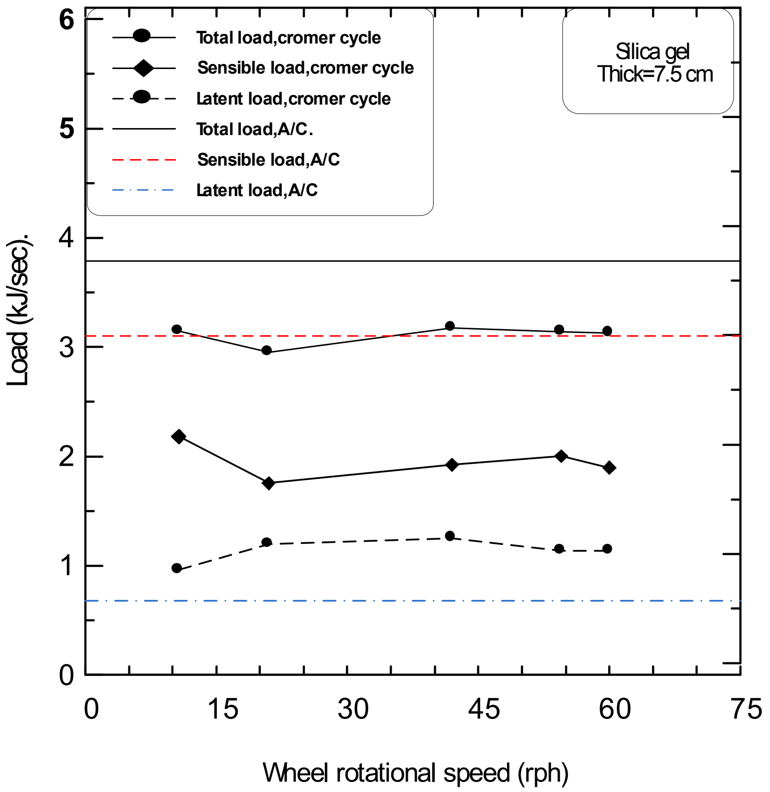

Figure 5 Effect of rotational speed on the room load, Silca gel thickness is 7.5 cm

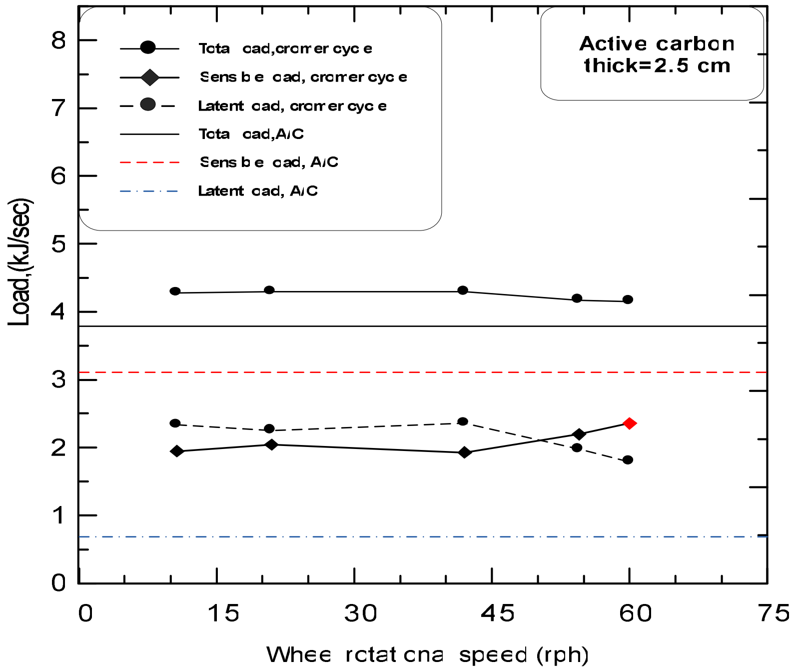

Figure 6 Effect of rotational speed on the room load Active carbon thickness is 2 5 cm

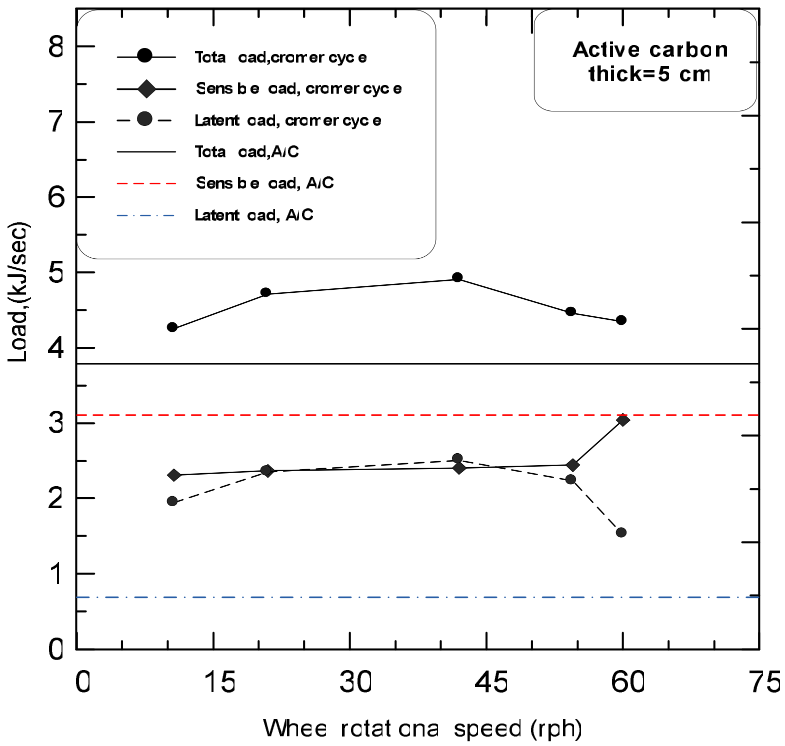

Figure 7 Effect of rotational speed on the room loac Active carbonl thickness is 5 cm

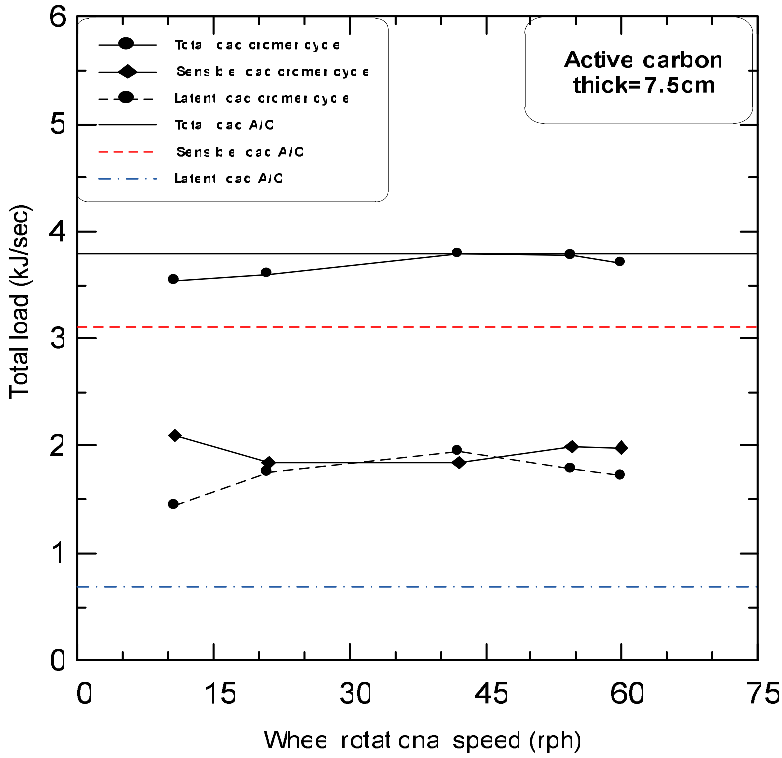

Figure 8 Effect of rotational speed on the room loac, Active carbon thickness is 7.5 cm

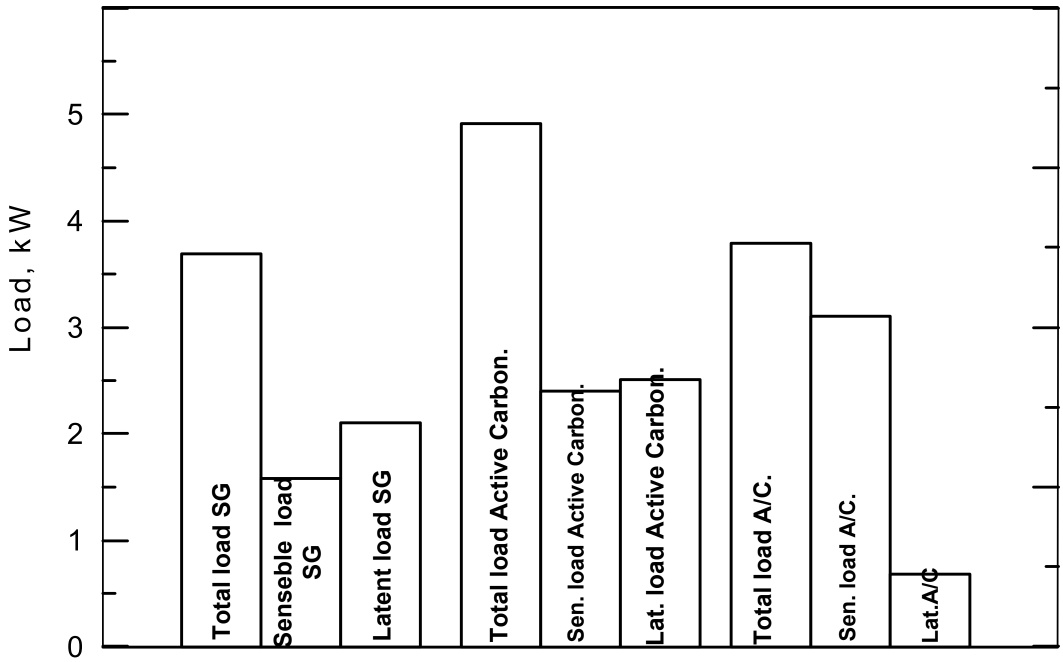

Figure 9 Total, sensible and latent load for best desiccant thickness of 5cm, and best whell rotational speed of 42 rph vs standard configuration cycle

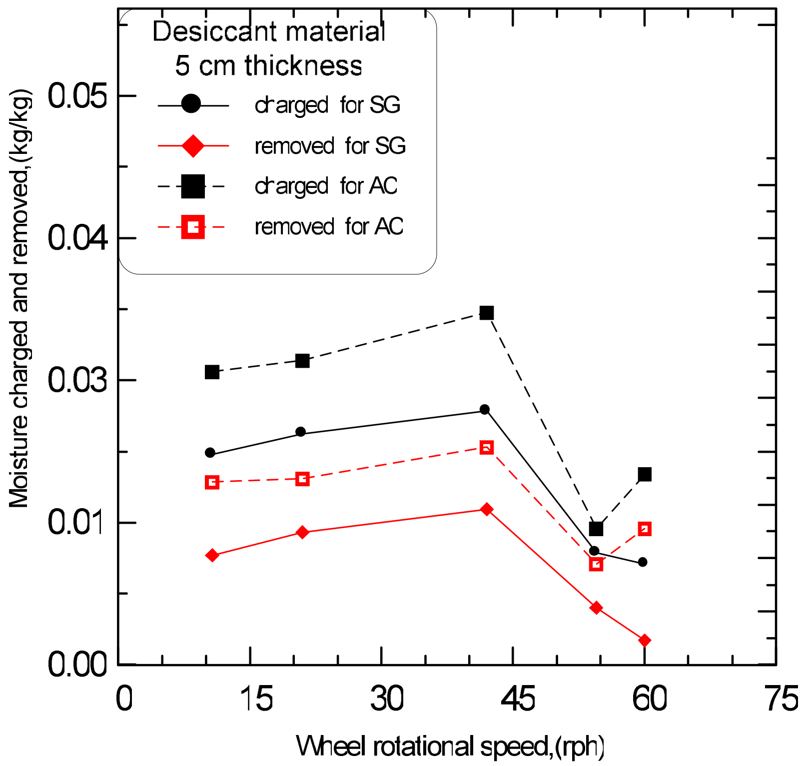

Figure 10 Effect of wheel rotational speed on the moisture charged and removed for desiccant materials thickness of 5 cm

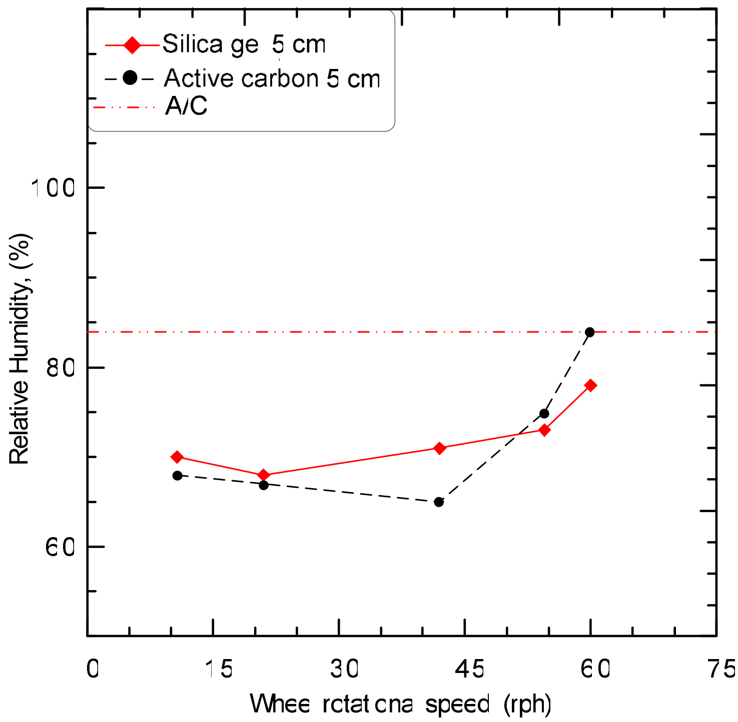

Figure 11 Effect of rotational speed on the roomrelative humidityroom load for different dessicant materials

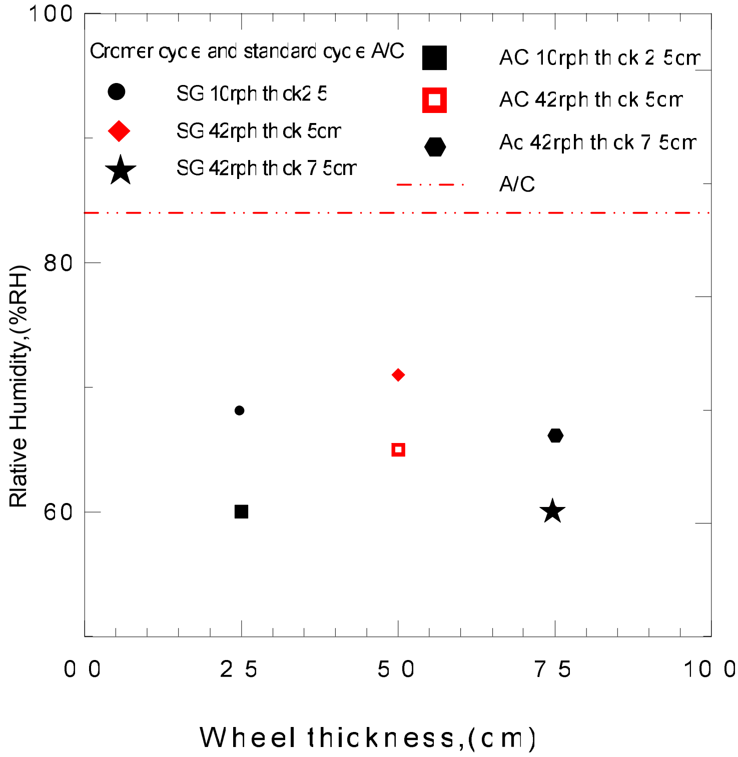

Figure 12 Effect of rotational speed on the relative humidity for different dessicant maerials

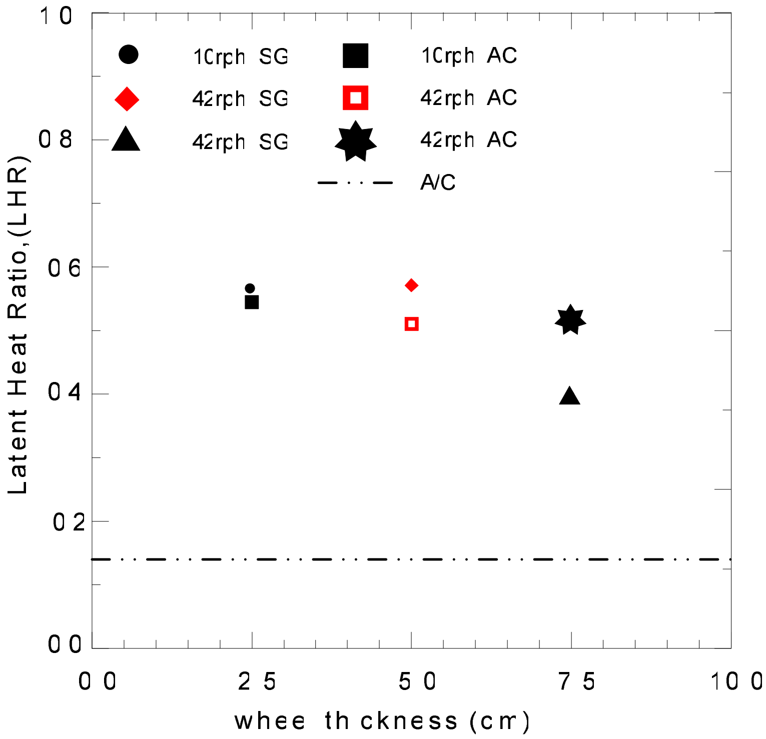

Figure 13 Effect wheel thickness on the latent heat ratio for desiccant materials vs standard configuration system

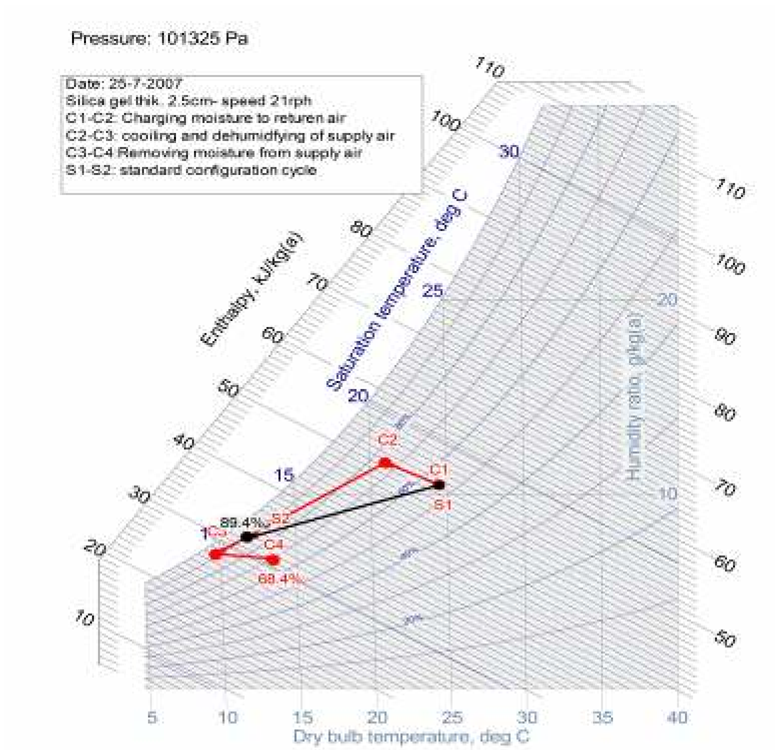

Figure 14 Cromer cycle vs. standard configuration cycle

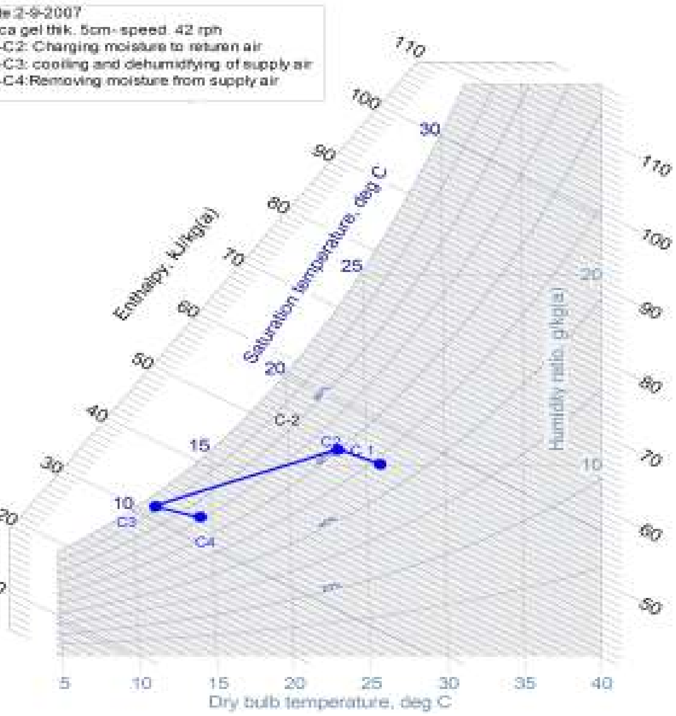

Figure 15 Cromer cycle, silica gel thickness is 5cm and rotational speed 42 rph

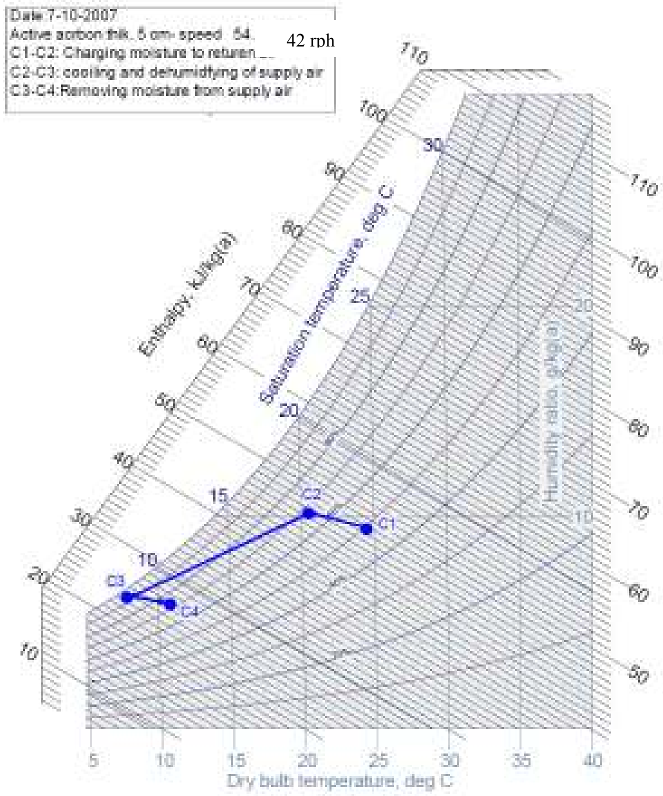

Figure 16 Cromer cycle, Active carbon thickness is 5cm and rotational speed 42 rph

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