

# FIELD STUDY OF ROTARY WHEEL DESICCANT SYSTEM USING THE CROMER CYCLE

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## Abstract

The goal of the study is to test under field conditions the effectiveness of an innovative desiccant based cycle for enhanced dehumidification, known as Cromer cycle. Cromer cycle uses a desiccant wheel to humidify the return air entering the cooling coil and to dehumidify the supply air after it leaves the coil. The unique feature of the technology is that the return air not an external heat source regenerates the desiccant. An existing residential air handler is retrofitted for the study. Performance is tested and comparison made for the operation with and without the desiccant wheel. The results indicate that Cromer cycle increases the latent heat ratio of the air handler up to 30% and enables to maintain the space at around 20% lower humidity levels. With the configuration tested, there is a penalty of around 20% reduction in the apparent energy efficiency ratio.

*Keywords:* Air-conditioning, Desiccants, Humidity control

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## Nomenclature

AC	Air Conditioning
RH	Relative Humidity [%]
ASHRAE	American Society of Heating, Refrigeration and Air Conditioning Engineers
LHR	Latent Heat Ratio
EERapp.	Apparent Energy Efficiency Ratio [Btu/h /h]
Rph	Revolutions per Hour
T	Temperature [°C]
Q	Cooling [kJ/h]

## subscripts

in	inside
amb	ambient
lat	latent

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## 1. Introduction

There are two types of load to be removed when a space is to be cooled to a comfortable condition. These are the temperature-associated load (sensible load) and the moisture-associated load (latent load). Conventional vapor-compression air-conditioning (AC) systems perform well when the latent load is 25% of the total load or less. There are many applications (geographical locations with hot and humid climates as Florida, restaurants, etc.) where the latent load is often higher. In such cases the conventional AC system fails to meet the increased latent loads.

The current study is undertaken in order to test under field conditions the feasibility and effectiveness of an innovative desiccant enhanced air-conditioning technology, proposed by Dr. Cromer (1988). The concept is based on installing a desiccant wheel between the return and the supply air streams of a conventional air handler to transfer moisture and heat between the two streams. A general layout of the experimental setup used in the present study is given in Figure 1. The processes that air undergoes when passing through the wheel are as follows: cold air with high relative humidity (RH) leaving the cooling coil 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 thus regenerating the desiccant.

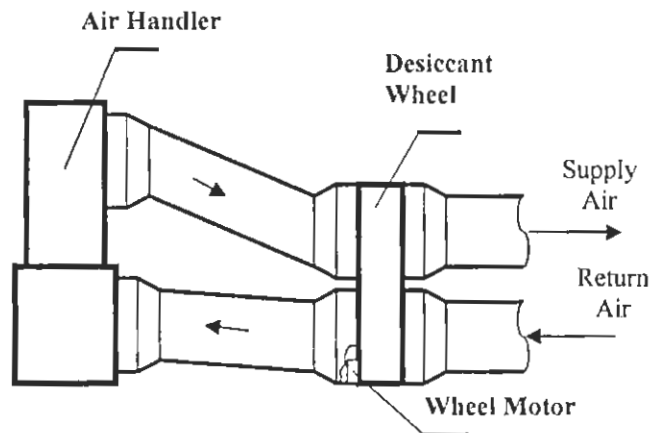


Figure 1. Schematic Diagram of the System

This moisture transfer between the supply and return sides of the air handler has two main advantages. First, release of moisture into the air 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 provides the potential for the moisture transfer. Second, regeneration of the desiccant is accomplished by the return air and thus costs associated with the requirement for an external heat source are avoided.

## **2. Background**

Previous work of other authors indicates that the rotary wheel desiccant system offers certain advantages over other methods for providing comfortable indoor conditions for high humidity climates. Dr. Cromer, the inventor, [1] claims that the technology can increase moisture removal performed by the cooling coil and this is achieved with lower energy consumption compared to the conventional arrangement. Another study carried by Chant and Jetter [2] simulated the process and predicted better performance of the rotary technology compared to other technologies for conditioning space, including heat pipe concept. A simulation of the Cromer cycle done by Rengarajan and Nimmo [3] found it promising with a potential for increased comfort, achieved with increase in energy use significantly lesser than the percentage increase in comfort.

## **3. Objective**

The rotary enhanced dehumidification concept shows promising results under computer simulations and laboratory conditions. It, however, has never been tested in field conditions. Objective of the current study is to test the effectiveness of the Cromer cycle when applied on a real AC system.

## **4. Scope of study and experimental protocol**

For the purpose of the study two residential houses, located close to each other were equipped with the necessary instrumentation. The existing residential AC system of one of the houses, called the Test house, was retrofitted to accommodate the Cromer cycle. The AC system of the second house, called the Reference house, was kept in the standard vapor-compression configuration. The two houses are located close to each other but are different in size and type, and the corresponding AC systems are different. Despite the differences, however, when the indoor conditions of the two houses were compared it was established that the humidity levels maintained by the corresponding conventional AC systems were quite similar. Therefore it was decided that the Reference house could serve as a 'control' for the purposes of the study. Since the ambient conditions vary, collecting data for the Reference house would provide an additional control comparison to estimate to what extent the different comfort conditions maintained in the Test house with the Cromer technology, are due to enhancing the air handler with the desiccant wheel as opposed to the changes in the ambient conditions

An experimental protocol was developed for the study. Thermostats in both houses were set at 24°C and remained unchanged throughout the study. All parameters were scanned, averaged and recorded every twenty seconds. The experimental protocol involved alternate switch of the Cromer equipment in and out of the AC system of the Test house. Data, collected for the periods of operation of the air handler in the conventional configuration, were collected in a baseline set. The data for the periods, when the AC system was enhanced with the Cromer cycle, were collected in the Cromer set. These sets were used to compare the cooling processes on a psychrometric chart using ASHRAE Psychrometric Analysis Software [4].

Indoor conditions maintained in the Test house by the standard AC configuration and with the Cromer equipment were compared.

Several performance characteristics as total cooling, sensible cooling, latent cooling,

latent heat ratio (LHR) and apparent energy efficiency ratio<sup>1</sup> (EERapp.) were calculated and compared for the standard and the Cromer configurations in the Test house.

## 5. Results

Cromer cycle was tested varying some parameters. Those were as follows:

- (1) Segments with two different desiccant types coatings, called Desiccant A and Desiccant B, were tested;
- (2) Two types of geometry of the desiccant covered laminate segments - flat and waved laminate segments; and,
- (3) Two speeds of rotation of the desiccant wheel – 10 rph (a speed found to give optimum performance for the Cromer cycle under computer simulations) and 42 rph (a speed that the inventor found to be the optimum under laboratory test of a wheel, covered with type B desiccant).

The best results were achieved with the combination of desiccant B, waved laminate segments and wheel rotating at 10 rph.

Figure 2 provides comparison on a psychrometric chart of the cooling process that air undergoes in the conventional AC cycle (dotted line) and in the Cromer cycle (solid line).

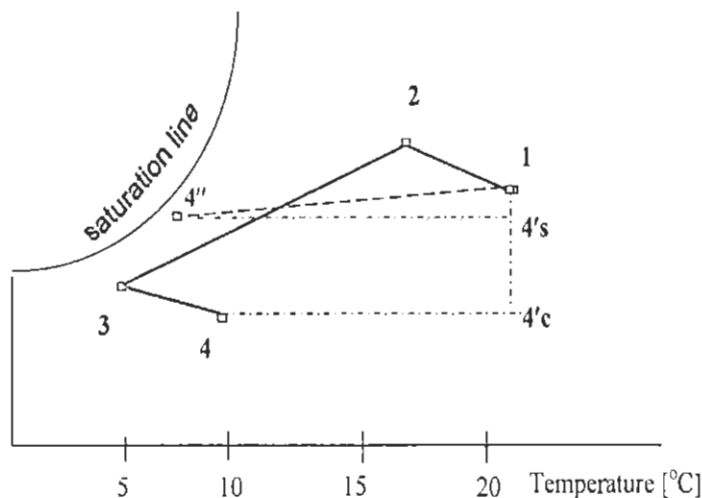


Figure 2. Psychrometric chart of standard AC cycle and the Cromer cycle.

1 = return air, 2 = air before cooling coil, 3 = air after cooling coil, 4 = supply air (Cromer cycle), 4's and 4'c = calculation points, 4'' = supply air (standard configuration)

As it can be seen from observation of the psychrometric processes rotary desiccant system provides certain improvements:

- Quality of the air supplied to the conditioned space is drier, 45-50% RH, compared to 85-90% RH with the standard equipment;
- Latent cooling performed by the system when equipped with the desiccant wheel is higher for one and the same condition of the return air.

<sup>1</sup> Energy efficiency ratio is defined as "Total cooling/Power input" under standard ARI conditions. Here EER was estimated under field conditions, therefore it was called apparent EERapp.

For more detailed evaluation of the performance, pairs of days with similar ambient conditions from the baseline set and the Cromer set were chosen and compared. Days in each pair were chosen based on meeting the following criteria:

- Ambient conditions within each pair were very similar;
- Average ambient temperatures were high throughout the day.

As an illustration following are presented some plots obtained for the most favorable combination of desiccant type, laminates geometry and speed of rotation, tested in this study. The two pairs presented here are 08/06/2002 (Baseline set) and 08/24/2002 (Cromer cycle); and 08/01/2002 (Baseline set) and 08/26/2002 (Cromer cycle) (Figures 3 to 5). Each point on Figures 6 to 9 represents the averaged values of a period when the air handler is 'on'.

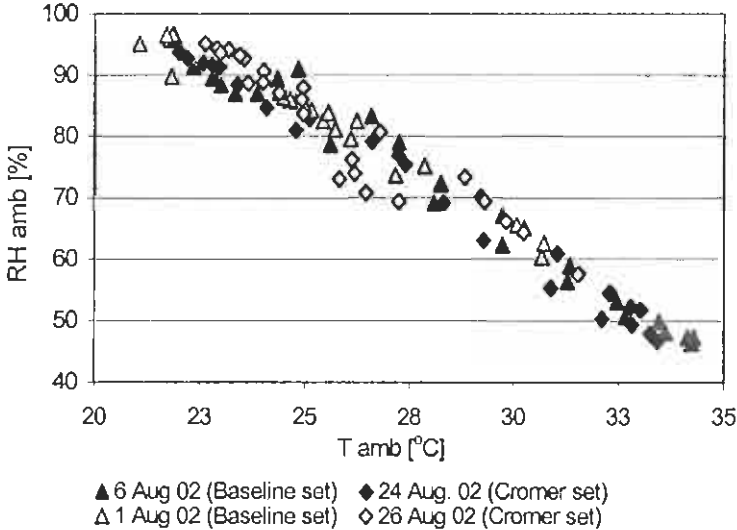


Figure 3. Ambient Temperature vs Ambient Relative Humidity

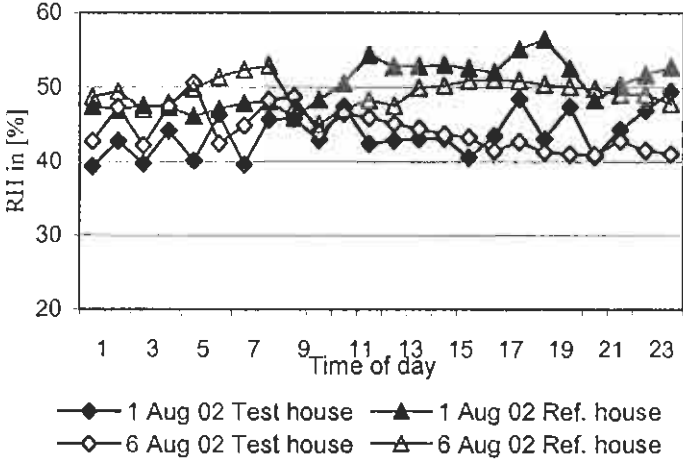


Figure 4. Inside Relative Humidity vs Time of day (Baseline set)

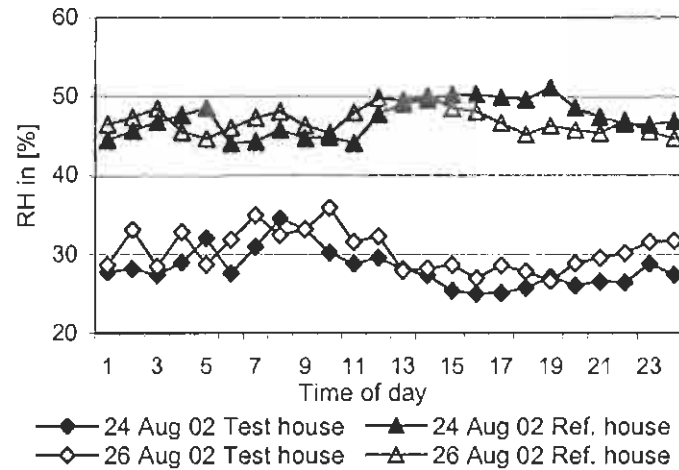


Figure 5. Inside Relative Humidity vs Time of day (Cromer cycle)

When the desiccant wheel is attached to the system the following is observed:

- Decrease in indoor relative humidity levels. Comparing Figures 4 and 5 it can be seen that average inside relative humidity levels in the Test house dropped from 45-50% to around 30% after attaching the desiccant wheel while no similar change is observed in the Reference house. On the graphs the points with higher indoor relative humidity are observed during the night when thermostat setting is satisfied so the air handler is shut down.
- Average 20-25% increase in the LHR (Figure 6). It can be explained with the fact that since the desiccant wheel desorbs moisture into the return air before it reaches the coil, the air is wetter and closer to its dew point. That switches the total cooling toward more latent cooling;
- Despite the drier indoor conditions with the Cromer cycle the latent cooling performed by the coil is approximately the same as in the standard configuration (Figure 7);
- Average 20-25% decrease in the sensible cooling performed by the coil. It could be explained from the reduced inlet air temperature and the reduced air flow due to the desiccant wheel. Because of evaporative cooling the desiccant wheel reduces the temperature of the air before it reaches the cooling coil. However, when the corresponding initial and final states of the air in the standard configuration are compared with the Cromer cycle on psychrometric chart, outlet condition of the air is almost the same. The increased moisture of the air results in a wetter coil that facilitates the heat transfer thus offsetting the negative impact of the reduced air temperature on the heat transfer. Therefore the observed decrease in the sensible cooling is mostly due to the dramatic decrease in the airflow rate, caused by the introduction of the desiccant wheel;
- Decrease in the total cooling performed (Figure 8). With the Cromer cycle sensible cooling decreases while the latent cooling stays approximately the same. This results in a decrease in the total cooling;

- Increased overall power consumption. Power consumption of the wheel motor is negligible (2-4 %) compared to the consumption of the air handler and the condenser unit. Decrease in the sensible cooling, performed by the evaporator coil, inevitably increases the operational time of the AC system. Since only the thermostat setting controls the air handler, for one and the same setting the Cromer configuration takes longer time before it is able to satisfy the thermostat. Therefore the system equipped with the Cromer cycle operates longer and has higher overall energy consumption;

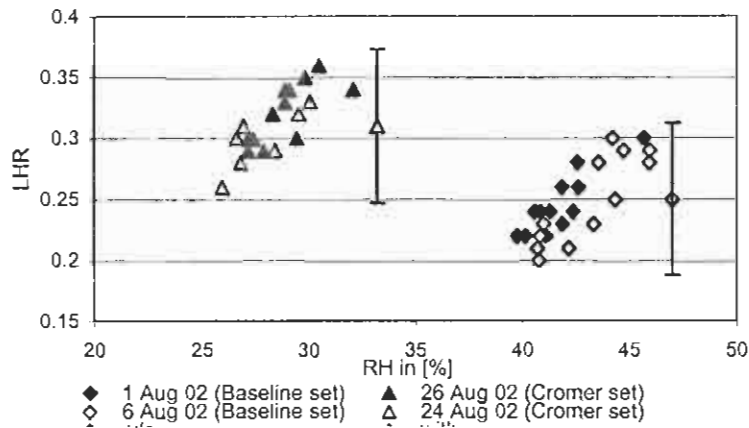


Figure 6. Latent Heat Ratio vs Inside Relative Humidity

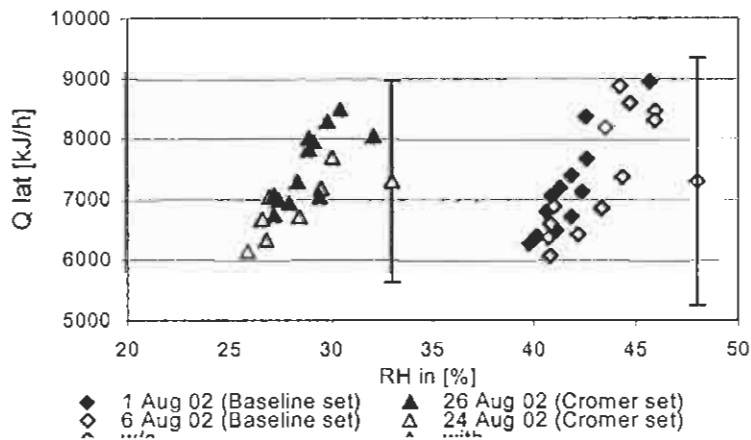


Figure 7. Latent Cooling vs Inside Relative Humidity

- Approximately 20% lower EERapp. (Figure 9). Comes mostly as a result of the reduction of the total cooling performed by the coil;
- With the desiccant wheel in place, when the air-handler kicks on after idle periods longer than 6-7 hours, an unpleasant odor was introduced in the space in the initial 2 to 3 minutes of the operation. This could be explained with the desiccant material picking not only moisture but other gases as well and evaporating them back.

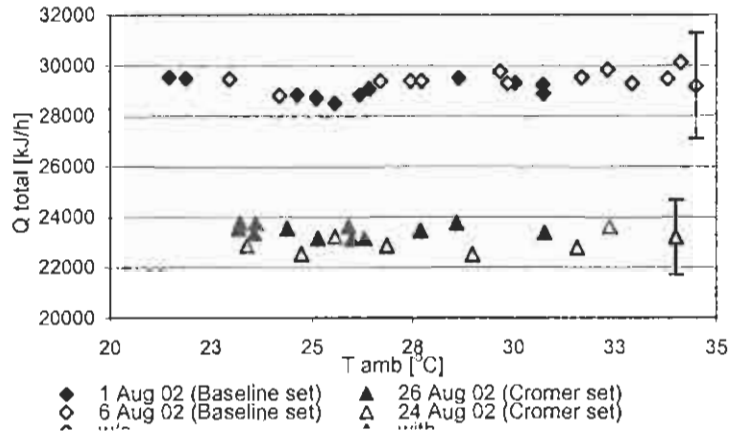


Figure 8. Total Cooling vs Ambient Temperature

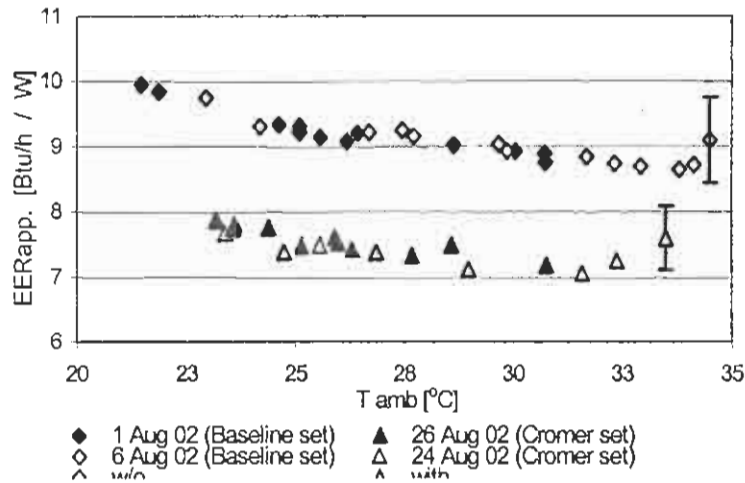


Figure 9. Apparent Energy Efficiency Ratio vs Ambient Temperature

## 6. Conclusions

The objective of the present study was to test the performance of the Cromer cycle in field conditions. In summary, the field study of the Cromer cycle technology confirmed its feasibility. Under one and the same thermostat setting, an AC system retrofitted with the Cromer cycle maintains lower indoor RH levels in the space. The retrofitted system, however, accomplishes the AC at a higher overall energy consumption.

The following additional observations were made in regard to the Cromer cycle operation:

- The Cromer cycle increases the latent heat ratio of the AC system;
- The Cromer cycle increases the moisture removal capabilities of the cooling coil;
- The Cromer cycle enables a conventional AC system to maintain lower indoor humidity levels;
- With the Cromer cycle in place the RH of the air in the supply ductwork is considerably lower. This way the requirement of the ASHRAE Standard 62 that calls for

maintaining the humidity in the ducts below 70% is accomplished, something that is really very difficult to satisfy with the conventional AC vapor compression configuration. Drier ducts prevent fungus and bacteria from growing so the space conditioned is at a lower risk from such contamination;

- Introduction of the Cromer cycle equipment increases the pressure drop in the system thus reducing the airflow rate;
- Accommodation of the desiccant wheel, at least in the configuration tested in the present study, requires considerable additional space;
- The Cromer cycle reduces the sensible cooling performed by the cooling coil, which results in longer run time to satisfy the thermostat setting. Therefore under one and the same thermostat setting the Cromer cycle has a higher overall energy requirement compared to the standard configuration;
- Because of the reduction of the sensible cooling the EERapp. of the AC equipment drops;
- For a short period (2 to 3 minutes) of operation after a longer idle period, an unpleasant odor is introduced into the space.

## 7. Future work

In the present study thermostat setting was kept one and the same and remained unchanged throughout the study. Since however, indoor relative humidity levels are much lower with the Cromer cycle, the rotary desiccant system provides an opportunity to meet ASHRAE comfort zone conditions at higher thermostat setting. This could result in reduced energy consumption in favor of the Cromer cycle.

Another aspect that could be considered for future tests is that for Cromer cycle applications it would be better if the motor of the blower is located before the cooling coil. This way the heat input of the motor would offset the pre-cooling of the air resulting from the air passing through the regeneration side of the desiccant wheel.

The pressure drop introduced by the desiccant wheel could be compensated by installing a larger air-handling unit for Cromer cycle applications.

## Acknowledgements

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