

SERI/TP-254-3800
UC Category: 231
DE90000349

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August 1990

prepared for
Winter Annual Meeting
American Society of Mechanical Engineers
Dallas, Texas
25-30 November 1990

Prepared under Task No. SB012041

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A Division of Midwest Research Institute

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Prepared for the
U.S. Department of Energy
Contract No. DE-AC02-83CH10093

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Printed in the United States of America
Available from:
National Technical Information Service
U.S. Department of Commerce
5285 Port Royal Road
Springfield, VA 22161

Price: Microfiche A01
Printed Copy A02

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Desiccant Contamination in Desiccant Cooling Systems

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ABSTRACT

This paper presents the results of a desiccant contamination experiment and the impact of the obtained silica gel degradation data on the performance of a desiccant cooling system. A test apparatus was used to thermally cycle several desiccant samples and expose them to "ambient" humid air or "contaminated" humid air. The source of contamination was cigarette smoke. The exposed desiccant samples were removed after 0.5, 1, 2, or 4 months of exposure and their moisture capacities were measured. The silica gel samples thermally cycled with ambient air showed a 5% to 30% loss in their moisture capacity. The silica gel samples thermally cycled with smoked air lost 30% to 70% of their moisture capacity. Using the obtained degradation data in a system, the impact of desiccant degradation on the performance of a desiccant cooling cycle was estimated. Depending on the degree of desiccant degradation, the decrease in thermal coefficient of performance (COP) and cooling capacity of the system was 10% to 35%. It was found that the COP and the cooling capacity of a system after desiccant degradation can be improved by increasing the rotational speed of the dehumidifier. This indicates that a simple engineering solution may exist to alleviate some type of degradations.

NOMENCLATURE

ARI	American Refrigeration Institute
CC	cooling capacity (kJ/kg-air)
COP	thermal coefficient of performance
DCTF	Desiccant Contamination Test Facility
E_{hx}	heat exchanger effectiveness
Le	Lewis number
Ntu_h	number of heat transfer units
RH	relative humidity
SG	silica gel

INTRODUCTION

Desiccant cooling systems thermally regenerated with solar energy, natural gas, or other thermal sources are gaining acceptance for the air-conditioning of spaces. In a typical desiccant cooling system, a desiccant dehumidifier removes the moisture (latent load) from the process air. Then the air is cooled to the desired conditions by a set of regenerative evaporative coolers or by vapor compression coolers. The desiccant material in a dehumidifier adsorbs (or absorbs) moisture from the process air to be dried. Later, the desiccant material is regenerated with hot air (generated by a thermal source) to drive the moisture from the desiccant for the next adsorption cycle.

The useful life of desiccant dehumidifiers for heat-regenerated desiccant cooling applications is a concern of manufacturers and end users. The useful life of a dehumidifier depends mainly on the useful life of the desiccant material in the dehumidifier. The useful life depends on the process and magnitude of degradation, which can be caused by hydrothermal cycling and exposure to contaminants. Based on hypothetical degradation scenarios, our preliminary system performance calculations showed that desiccant degradation can significantly reduce the performance of a desiccant cooling system.

Desiccant degradation has been observed in some *industrial* dehumidification applications in which the process stream contains high concentrations of harsh pollutants. For *residential* and *commercial* air-conditioning applications, degradation is expected to be less. However, no substantiating experimental data exist. Few published studies have quantified the moisture sorption change caused by contamination for typical air-conditioning applications. Farouk et al. (1980) found that the rate of moisture adsorption by three desiccants (molecular sieve, alumina, and silica gel) was reduced 50% by the presence of 5% dust in air typically found in agricultural grain processing areas. They also found that dust particles 10 to 20 μm in diameter did not reduce the equilibrium moisture capacity of desiccants. Moseman and Bird (1982) conducted experiments on degradation of three desiccants during dehydration of natural gas. They found that after only 284 reactivation cycles, the silica gel capacity dropped by almost 20%. With a limited number of data points, Pesaran et al. (1986) found that from 7% to 50% of the moisture capacity

of silica gel can be lost, depending on the regeneration and exposure method.

Comprehensive experimental data are needed on degradation of desiccants under conditions experienced in solar-regenerated desiccant cooling applications. At the Solar Energy Research Institute (SERI), we are conducting an experimental research effort with funding from the Department of Energy (DOE) to obtain such experimental data. SERI's desiccant contamination research strategy is based on the recommendations of a Desiccant Contamination Workshop sponsored by DOE and conducted in Washington, D.C. in June 1987. The major recommendations of the workshop were that controlled contamination experiments should be conducted to obtain the time history of desiccant degradation due to thermal cycling and airborne contaminants. For initial screening, cigarette smoke in a proper mix with humid air was recommended as the first airborne contaminant to be studied. Cigarette smoke, a mixture of gaseous and particulate contaminants, is considered to be the worst contaminant commonly found in residential and commercial buildings. Note that the above experiment is considered an extreme-case screening mechanism, i.e., if the desiccants do *not* sufficiently degrade with cigarette smoke, then desiccant contamination is not an issue.

Based on the workshop recommendations, a test apparatus was built and used to expose 200 samples of six different solid desiccant materials for four months. Then the sorption capacities of the exposed desiccants, as well as virgin samples, were measured. The degradation data obtained on one of the desiccants (silica gel) were used to evaluate the performance degradation of a desiccant cooling system in the ventilation mode. The purpose of this paper is to describe the contamination experiment, present the test results on silica gel samples, and discuss the results of the system performance degradation study.

DESICCANT CONTAMINATION EXPERIMENT

The hardware, function, and purpose of the Desiccant Contamination Test Facility (DCTF) were described in detail by Pesaran and Bingham (1988). In this section, the test facility is described briefly. The purpose of the DCTF is to provide data on the degradation of desiccant materials with time due to hydro-thermal cycling and airborne contaminants. Specifically, the DCTF was designed to

- Cycle desiccant samples between a hot and a warm stream of humid air
- Expose desiccant samples to airborne contaminants such as cigarette smoke
- Simulate the operation of a desiccant dehumidifier in a solar-regenerated desiccant cooling system.

Apparatus

The DCTF consists of two test cells (each can hold 100 desiccant sample tubes), two flow-through heaters, two external booster heaters, air filters, a humidifier, a smoking machine, and an air blower. The components are connected via 3.8-, 5-, and 7.6-cm galvanized steel pipes. After the air is humidified to 0.012 to 0.016 kg water/kg dry air, it is divided into two branches.

In each branch, air passes through a heater and a test cell. The hot heater (2 kW) heats up the air in one air stream to about 120°C; the warm heater (0.5 kW) warms the air in the second branch to about 35°C. The heat from the booster heaters compensates for the heat losses between the heaters and the test cells. Depending on whether the valves in each branch are in the open

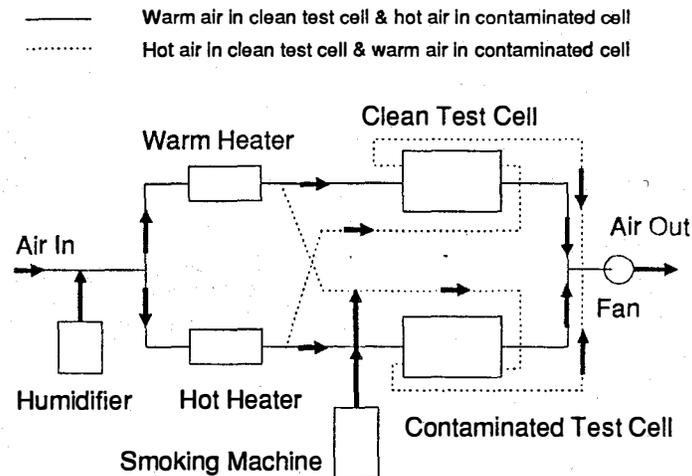


Figure 1. Schematic of the Desiccant Contamination Test Facility

or closed position, hot air can go in only one test cell (for desiccant regeneration) while warm, humid air is going in the other test cell (for desiccant adsorption). After coming out of the two test cells, the air streams in the two branches join in one stream that is exhausted outside the building with an air blower. Cigarette smoke is injected through a pipe connected to only one of the test cells. Figure 1 depicts these configurations schematically.

Note that the desiccant samples in the contaminated test cell of the DCTF represent worst-case scenarios for desiccant materials for each of the following cases:

- The desiccant cooling cycle is in the ventilation mode and the outside air is very polluted.
- The desiccant cooling cycle is in the recirculation mode and the return air from the conditioned space is very polluted.
- The desiccant cooling cycle is in any mode and the regeneration air is very polluted.

When a desiccant cooling system is in the recirculation mode, return air from the conditioned space (containing air pollutants) is first passed through the dehumidifier. In the ventilation mode of a desiccant cooling cycle, the outside air (containing pollutants) is first passed through the desiccant dehumidifier.

Temperatures and humidities of air at the entrance and exit of each test cell were monitored and recorded during the contamination test by a set of thermocouple array and dewpoint hygrometers. The flow rate to each test cell was measured with a turbine flowmeter. The pressure drop across each test cell and absolute pressure were measured with pressure transducers. The measured parameters were collected, stored, and displayed with a voltmeter/scanner and personal computer combination.

The air temperature going into each test cell was between 41°C and 44°C during adsorption and between 80°C and 84°C during regeneration. The air humidity going into each test cell was about 0.014 (± 0.001) kg water/kg dry air. The air flow in each test cell was about 9.5 L/s. The cycle time of 7.4 min between regeneration and adsorption in each test cell was achieved by simultaneous opening and closing of a set of valves energized and de-energized by an electrical repeat-cycle timer.

To obtain design concentration of cigarette smoke in the air stream going through the contaminated test cell, cigarette smoke was generated by a continuous smoking machine. The smoking

machine, specified by SERI and designed and fabricated by Fidus Instruments Corporation, injected fresh smoke at a rate of six cigarettes per hour into one of the air streams of the DCTF, where it was diluted with air (at about 9.5 L/s) to the desired concentration (about 6 mg/m³ of "total particulate matter"). This injection rate was based on twice the concentration of "total particulate matter" in smoking residences, the air flow rate through a test cell, and the emission and burning rates of common cigarettes. According to Wadden and Schiff (1983), the case of 15-425m³ homes with 1 to 3 air changes per hour and 7 to 35 cigarettes burned per hour represents a typical residence. The concentration of "total particulate matter" of smoke in this case is 1.1 to 3.0 mg/m³.

Each test cell holds 100 sample tubes containing desiccants. The sample tubes are held by individual cylindrical brass sleeves. The sample tubes were made of brass, with an outer diameter of 8.7 mm and a length of 7.6 cm. The test cells were insulated during the experiment.

Experimental Procedure

We prepared 10 sample tubes per desiccant for each test cell. Sample tubes were loaded with six different desiccant materials. When possible, two different batches of each desiccant were used to account for batch-to-batch or lot-to-lot variations caused by changes during manufacturing. For example, two different batches of microporous silica gel (Davison Grade 40) were tested. Each test cell could hold 100 desiccant samples, so we prepared 200 desiccant samples for testing in the DCTF. Sample tubes were prepared by loading 1.6 g of particulate desiccants. Metal screens were placed at both ends of each tube to hold the desiccant particles in the tubes. The samples were dried with air at 1.5% relative humidity and 100°C for more than 72 hours. The desiccant tubes were capped on both ends with plastic caps to prevent the desiccant from interacting with the ambient air when not in the test cells. Using a microbalance with a precision of 0.1 mg, we measured the weight of each tube, the weight of the screens, the weight of the dried desiccants, and the weight of the plastic caps. Twenty desiccant sample tubes were prepared in the same manner as the virgin baseline for comparison with samples

The desiccant sample tubes were installed in the two test cells. The ambient air at the designed flow rate, humidity, and temperature was sent through the test cells. Cigarette smoke was injected only into the contaminated test cell. The hot regeneration and warm adsorption air streams were switched between the two test cells at a cycle time of 7.4 min. The experiment has been running 24 hours a day since the contamination experiment began in the middle of August 1989. After 0.5, 1, 2, and 4 months, the appropriate sample tubes from each test cell were removed. At each time, about 20 samples were removed from each test cell and replaced with tubes containing glass beads or desiccant materials. To account for the variation in properties in a single batch of desiccant, we tested two samples from each desiccant batch each time the samples were removed. Each month of testing in the DCTF is equivalent to 6 months of field operation, assuming that a desiccant dehumidifier works 8 hours a day for 6 months a year and that the concentration in the field and in the experiment is the same. Accounting for the higher concentration in this experiment, we expect one month of testing in the DCTF to be equivalent to 1 to 2 years of field operation.

After the samples were removed from the clean and contaminated test cells, their sorption capacity was measured by a gravimetric technique. A set of the silica gel samples (virgin, ambient, and contaminated) was sent to a commercial laboratory for internal pore structure analysis. Another set of samples was evaluated using scanning electron microscopy and x-ray photoelectron spectroscopy. The contaminants deposited on some of

the samples were extracted using a solvent and analyzed using the gas chromatography mass spectroscopy technique. The results of these analyses are discussed in detail by Pesaran and Dresler (1990). In this paper, the results of the sorption capacity measurements on silica gel are presented.

Experimental Results

The most important property of a desiccant for dehumidification and cooling applications is its ability to remove water vapor. This is usually quantified in terms of moisture capacity (kg moisture removed/kg dry desiccant) as a function of relative humidity, i.e., equilibrium isotherm. The moisture capacity of a desiccant may change upon thermal cycling and exposure to pollutants. Comparisons among the moisture capacities of virgin, thermally cycled, and contaminated samples were made to quantify degradation effects. We measured the adsorption capacities of virgin, clean, and contaminated desiccant samples at 30.5°C and at various relative humidities (14%, 29%, 44%, 58%, and 73%).

The desiccant samples removed from the DCTF were installed in the SERI heat- and mass-transfer test facility and exposed to humid air at desired conditions (temperature, humidity) for about 20 h. The samples were then removed and capped, and their moisture gain was measured with a precision microbalance. The weight of moisture gain divided by the dry weight of the desiccant provided the moisture capacity of the sample. The detailed experimental procedure of sorption capacity measurements can be found in Pesaran and Bingham (1989) and Pesaran and Dresler (1990).

Typical results of capacity measurements of virgin, clean, and contaminated samples for silica gel (lot #2, Davison Grade 40, MDF88) at 30.5°C are given in Figures 2 and 3. Data from Pesaran and Dresler (1990) show that lot 1 and lot 2 capacities were similar; deviations from lot to lot for this grade of silica gel

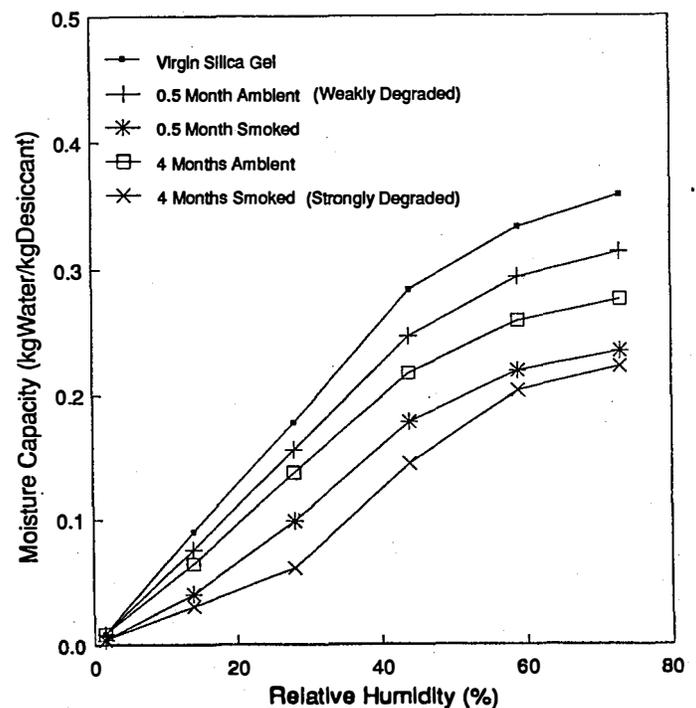


Figure 2. Moisture capacity of virgin, ambient, and smoked silica gel samples

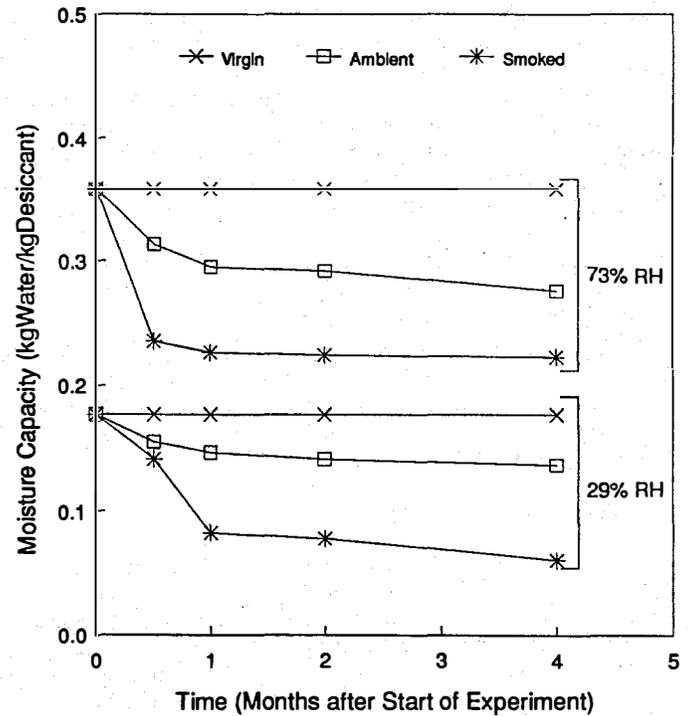
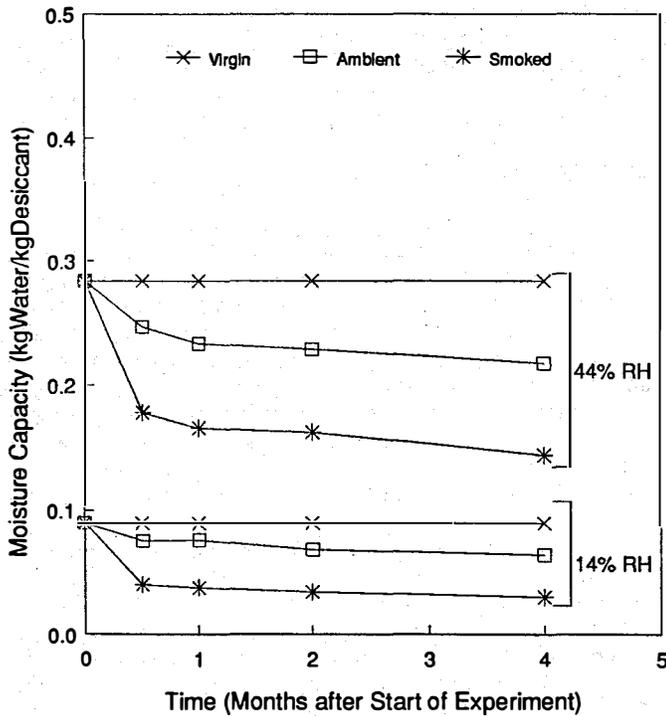


Figure 3. Moisture capacity of exposed silica gel samples as function of time

were small (less than 6%). We also observed that the capacity results were independent of the location of the sample tube in the test cells.

From the sorption measurement results, the following major observations can be made:

- Because of thermal cycling and exposure to ambient air, the sorption capacity of silica gel decreased with time. The percentage drop from the capacity of virgin samples was between 5% and 30%. Most of the capacity loss occurred in the first month of testing.
- Because of thermal cycling and exposure to cigarette smoke, the sorption capacity of silica gel decreased significantly with time. The percentage drop from the capacity of virgin samples was between 30% and 70% due to the combined effects of thermal cycling and exposure to cigarette smoke. Most of the capacity loss occurred in the first month of testing.
- The loss in capacity caused by cigarette smoke was about 20% to 50%.
- The capacity loss because of thermal cycling and exposure to smoke is more apparent at low relative humidities.

The chemical analysis of silica gel samples exposed in ambient and contaminated test cells showed the following (Pesaran and Dresler 1990). The ambient samples were contaminated with low levels of hydrocarbons and chemical agents found in cleaning agents and sealants usually found in laboratories. Low levels of these compounds and thermal cycling have caused the observed 5% to 30% loss in capacity. The chemical analysis showed that contaminated samples contained relatively high levels of hydrocarbons and nicotine from cigarette smoke.

SYSTEM ANALYSIS

This section presents the results of calculations to evaluate the impact of desiccant degradation on the performance of a ventilation desiccant cooling system under American Refrigeration Institute (ARI) design conditions. The degradation data obtained on silica gel samples were used in a system model to predict performance degradations.

Modeling

The system model used for this study was developed by Collier (1989). Collier's code simulates performances of a rotary dehumidifier, a heat exchanger, and an evaporative cooler for evaluation of the desiccant cooling system performance. The dehumidifier model in Collier's code is principally based on the combination of the pseudo-steady-state model of Barlow (1982) and the finite-difference algorithm of Maclaine-cross (1974). Table 1 summarizes the characteristics and conditions of the baseline system that was modeled. The physical dimensions of the studied dehumidifier are based on those of a dehumidifier tested at SERI (Bharathan et al., 1987). The rotational speed of the dehumidifier will be discussed later.

In addition to virgin silica gel, the silica gel exposed in the ambient test cell for 0.5 month and the silica gel exposed in the contaminated test cell for 4 months were simulated. The 0.5-month ambient sample represents a "weakly degraded" silica gel and the 4-month smoked sample represent a "strongly degraded" silica gel (see Figure 2). The experimental data for each desiccant were fit with a fifth-order polynomial for model simulations. With the degraded data, both the magnitude and the shape of the isotherm change. According to Collier (1989) and Collier et al. (1990), the isotherm shape is a more important thermophysical factor than magnitude in changing the perfor-

TABLE 1
Baseline System Parameters and Conditions

Dehumidifier	Matrix Density: 157 kg desiccant/m ³ Matrix Heat Capacity: 1960 kJ/kg K Total Frontal Area: 0.49 m ² Matrix Depth: 0.2 m Passage Hydraulic Diameter: 2.3 mm Total Transfer Area: 95 m ² Adsorption or Regeneration Air Flow Rate: 0.2 kg/s Adsorption/Regeneration: balanced flow and balanced area Number of Heat Transfer Units: 28.2 Process Lewis Number: 1
Desiccants	The experimental data of three desiccants were used: - Virgin silica gel - Silica gel exposed in ambient test cell for 0.5 month - Silica gel exposed in contaminated test cell for 4 months
Regeneration	95°C (uniform over the regeneration side; i.e., no staged regeneration)
Outdoor Conditions	ARI rating point (1 atmosphere, 35°C, and 0.014 kg moisture/kg air)
Indoor Conditions	ARI rating point (1 atmosphere, 26.7°C, and 0.011 kg moisture/kg air)
Heat Exchanger	Effectiveness of 0.93
Evaporative Coolers	Effectiveness of 0.95

mance of the dehumidifier and the system. For our simulations, we assumed that the heat of the adsorption as a function of moisture adsorbed was the same for the three desiccants. Because the heat of adsorption has second-order effects on performance results (Collier, 1989), the assumption about the heat of adsorption is expected to have minor effects on the results.

Results

Figure 4 shows the outlet air conditions from the studied dehumidifier using the three silica gels as a function of dehumidifier rotational speed. The figure shows that for the virgin silica gel, the highest dehumidification (or lowest outlet air humidity) occurs at the rotational speed of about 10 rev/hr. This may or may not be the optimum rotational speed for the best system performance because of related temperature effects. There are a number studies providing more information on the optimum rotational speed (e.g., Van den Bulck et al. 1986; Collier et al. 1990). The optimum rotational speeds for virgin silica gel found in this study agree reasonably with the speeds recommended in the literature. From Figure 4, at a rotational speed of 10 rev/hr the outlet air humidity of the dehumidifier using "weakly degraded" silica gel is 20% higher than that of the virgin dehumidifier; and for "strongly degraded" silica gel the outlet air humidity is 54% higher than for virgin silica gel. At a rotational speed of 10 rev/hr, the outlet air temperatures of the dehumidifier for each of the three desiccants are within 1°C.

The data in Figure 4 are replotted in Figure 5 to show the

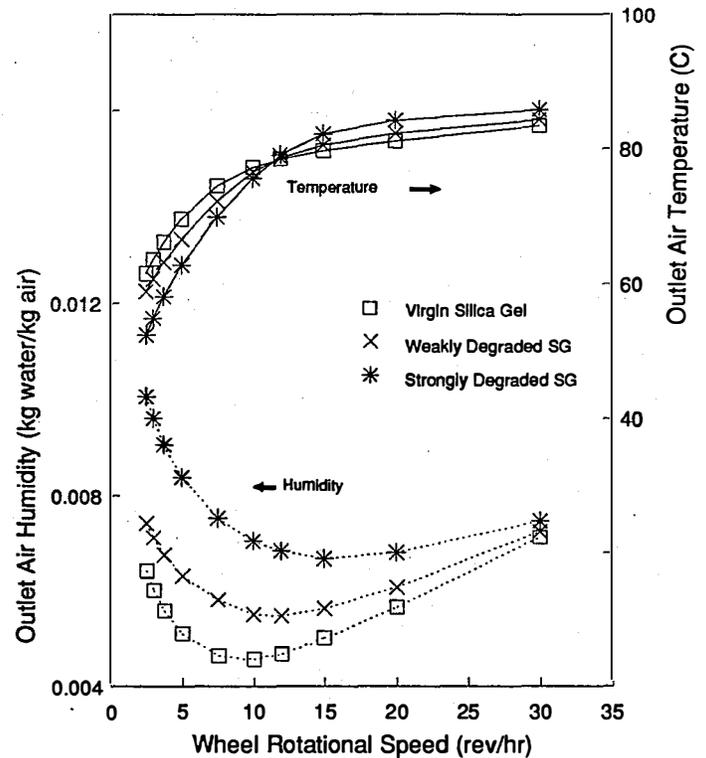


Figure 4. Impact of desiccant degradation and rotational speed on dehumidifier performance (See Table 1 for operating conditions)

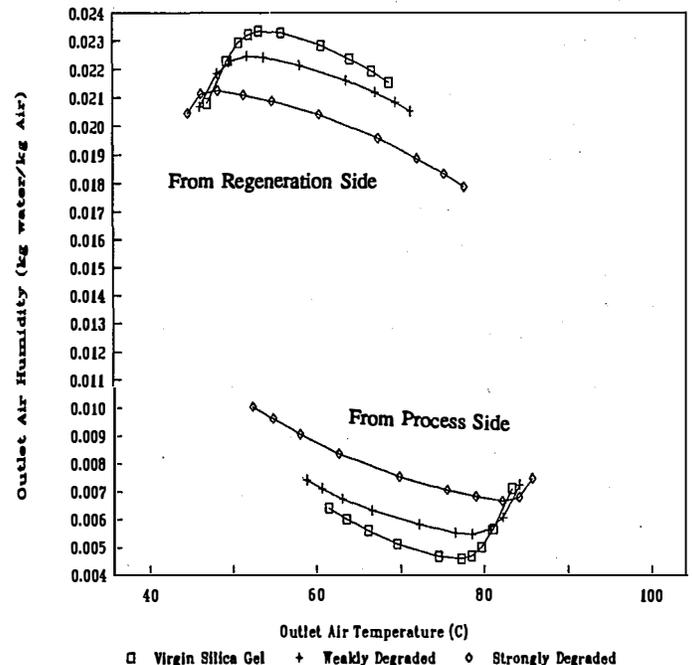


Figure 5. Impact of desiccant degradation on outlet air conditions of a dehumidifier (See Table 1 for operating conditions)

interdependence of outlet air temperature and humidity. Each point on each line of Figure 5 represents a different rotational speed. When the outlet humidity from the dehumidifier increases, it means that the dehumidification capacity of the dehumidifier is decreased and less latent load is removed by the dehumidifier. This can reduce the cooling capacity of the desiccant cooling system. The cooling capacity (CC) is defined as the amount of cooling (in terms of kJ) provided by the system divided by the amount of air passes through the system (in terms of kg). In addition, the thermal coefficient of performance (COP) of the system may decrease. The thermal COP is defined as the amount of cooling provided by the system divided by the thermal energy input for regeneration of the desiccant material.

Figure 6 compares the results of the system simulations for the virgin and degraded silica gels. The comparisons are made on a relative basis. The thermal COP and cooling capacity of the baseline system using the virgin silica gel were used for normalizing the performance parameters. For the baseline system, the COP is 0.85 and the cooling capacity is 18.8 kJ/kg at an optimum dehumidifier rotational speed of 12 rev/hr. This optimum value was obtained with the best combination of the highest COP and CC. Note that the maximum COP and maximum CC do not usually occur at the same rotational speed. Figure 6 also presents the impact of increased moisture resistance in silica gel particles due to contamination or fouling. When the outer surfaces of a desiccant are affected by a contamination layer, the rate of moisture penetration to the desiccant decreased and affected the mass exchange process in the dehumidifier. The Lewis number or Le (the ratio of moisture transfer resistance to heat transfer resistance) is expected to increase due to contamination. In our simulations, we assumed a 200% increase in moisture resistance or a Le number of 3.

From Figure 6, the following can be concluded if the rotational speed of the dehumidifier wheel is kept constant at 12 rev/hr during the operation of the system:

- 10% and 11% decrease in COP and CC, respectively, for the "weakly degraded" silica gel with Le of 1
- 19% and 16% decrease in COP and CC, respectively, for the "weakly degraded" silica gel with Le of 3
- 26% and 29% decrease in COP and CC, respectively, for the "strongly degraded" silica gel with Le of 1
- 31% and 32% decrease in COP and CC, respectively, for the "strongly degraded" silica gel with Le of 3.

As expected, the performance degradation of the cooling system with "strongly degraded" silica gel is higher than with the "weakly degraded" silica gel. An increase in moisture resistance (higher Le) degrades the performance even further.

It can be seen from Figure 6 that if the rotational speed of the dehumidifier is increased as the desiccant degrades, some of the loss in the thermal COP and cooling capacity can be recovered. This recovery is mostly in the COP. For example, if the rotational speed of the dehumidifier with "strongly degraded" silica gel is increased to 15 rev/hr, the decrease in COP from baseline will be only 13%, which is lower than the 26% with 10 rev/hr. At 15 rev/hr the decrease in CC is 28%, very close to the 29% decrease with 10 rev/hr. An increase to 20 rev/hr for the "strongly degraded" desiccant will improve the COP to only a 7% decrease from the baseline COP; however, the CC will decrease to 31% (2% higher than with 10 rev/hr). This trend can be observed for other cases: increasing rotational speed decreases the loss in the COP from the baseline COP but may slightly increase the loss in CC.

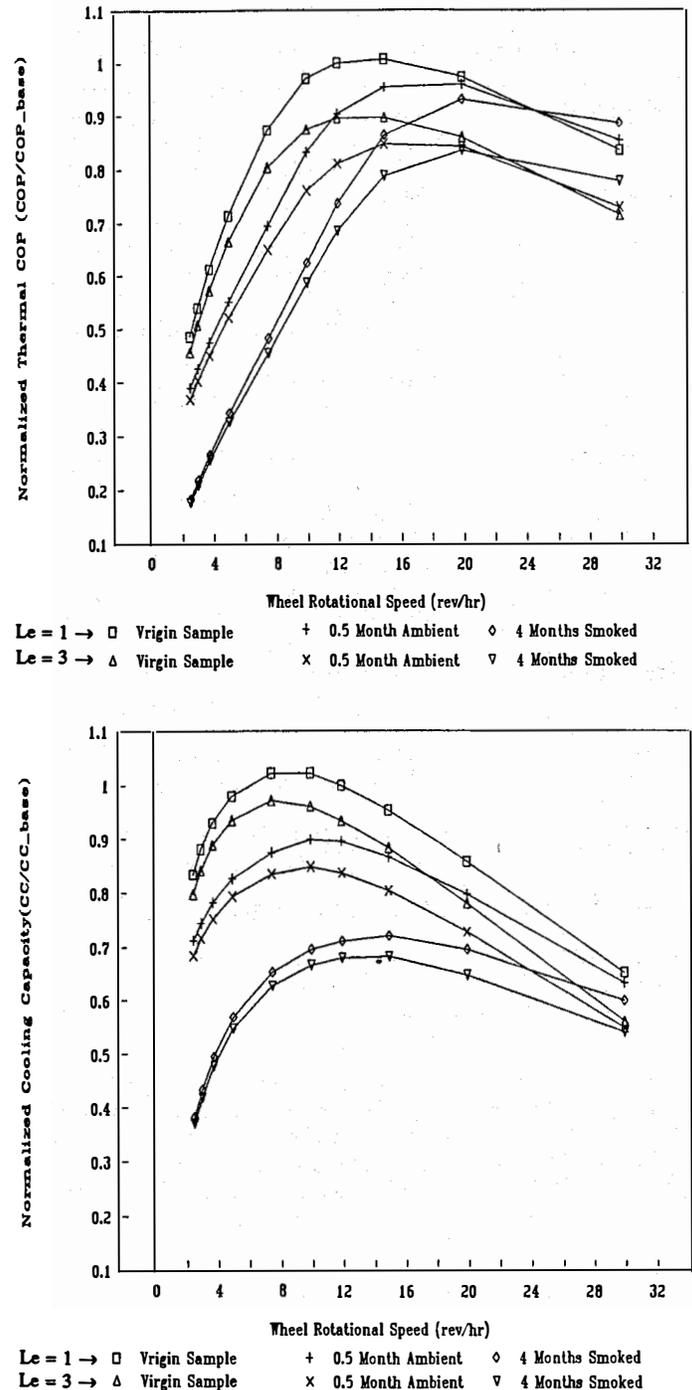


Figure 6. Impact of desiccant degradation on a ventilation desiccant cooling system (See Table 1 for operating parameters)

Other parametric runs to study the effects of desiccant degradation under different operating and design conditions have been conducted. Discussing all parametric runs is beyond the scope of this paper. In the remainder of this section, we have presented the results of some of the more interesting parametric runs. Pesaran and Penney (1991) have also presented the results of degradation studies for silica gel and Type 1 moderate desiccant with and without staged regeneration.

TABLE 2
Percent Loss of a System Using Degraded Silica Gel
from a System Using Virgin Silica Gel (Le = 1)

Parameters	Performance	Weakly Degraded SG	Strongly Degraded SG
$Ntu_h = 14.1$	Thermal COP	11%	27%
$E_{ex} = 0.93$	Cooling Capacity	12%	30%
$Ntu_h = 28.2$	Thermal COP	10%	26%
$E_{ex} = 0.93$	Cooling Capacity	11%	29%
$Ntu_h = 28.2$	Thermal COP	12%	35%
$E_{ex} = 0.87$	Cooling Capacity	13%	36%

Table 2 presents the impact of using a lower (by a factor of two) Ntu_h in the original baseline dehumidifier. The losses presented in Table 2 are based on a dehumidifier using the virgin desiccant. All parameters except the ones noted are the same for the cases compared. Because of desiccant degradation, the losses in COP and CC are slightly higher (about 1%) for the system that uses a dehumidifier with lower Ntu_h than for a system with higher Ntu_h . Table 2 also presents the results for a system that uses a heat exchanger with lower effectiveness. With a 0.87 heat exchanger effectiveness, the losses in the COP and CC are higher than for a system with a 0.93 heat exchanger effectiveness. These losses are about 2% higher for "weakly degraded" desiccant and about 7% to 10% higher for the "strongly degraded" desiccant.

CONCLUDING REMARKS

A desiccant contamination test facility was fabricated to investigate the effects of thermal cycling and contamination (cigarette smoke) on desiccant materials suitable for desiccant cooling applications. One hundred desiccant samples from six different materials were exposed to humid ambient air. Another set of similar desiccant samples was exposed to humid ambient air charged with cigarette smoke. Both sets of samples were thermally cycled between adsorption and regeneration temperatures. After exposure for a number of months their moisture capacities were measured using a gravimetric technique. Compared to the capacity of virgin samples, the capacity loss of silica gel was between 5% and 30% for the "weakly degraded" silica gel samples (which were exposed to ambient air for 0.5 month) and between 30% and 70% for the "strongly degraded" silica gel samples (which were exposed to contaminated air for 4 months). Most of these capacity losses occurred in the first month of testing. The capacity loss was found to be more apparent at low relative humidities.

Using the data obtained on silica gel, a system performance study for a ventilation cycle was performed. It was found that the loss in the thermal COP and cooling capacity was between 10% and 19% for the "weakly degraded" silica gel and between 26% and 32% for the "strongly degraded" silica gel. A 200% increase in resistance to moisture diffusion in silica gel particles (increase of Le from 1 to 3) increased performance losses between 3% and 9%. It was found that upon desiccant degradation, the performance of a system with a lower heat exchanger effectiveness degrades more than the performance of a system with a higher heat exchanger effectiveness. It was also found

that by increasing the rotational speed of the dehumidifier, the magnitude of the performance loss can be reduced. The loss in the thermal COP could be decreased significantly; however, the loss of cooling capacity could be decreased to a lesser degree.

This work has shown that desiccant degradation may occur in a desiccant cooling system, and it can reduce the system performance under "worst-case" conditions by as much as 35%. The actual loss in performance depends on the type of degradation. A design engineer has to account for losses that can occur with virgin desiccant due to thermal cycling and contamination. Adjusting rotational speed of a dehumidifier is an easy solution to alleviate performance losses caused by some types of degradations. However, the rotational speed cannot be arbitrarily adjusted because it may adversely impact the performance. In addition to adjusting rotational speed, other strategies to alleviate desiccant degradation are filtering, replacing, cleaning, and deep regeneration (occasional high-temperature burn-off). Further investigation is required before final conclusions on these strategies can be drawn.

The contamination experiment will be continued. Other contaminants and desiccants may be considered. System parametric runs are being conducted under different outside ambient conditions, regeneration temperatures (with and without staged regeneration), flow rates, dehumidifier physical characteristics (e.g., heat capacity, Ntu_h , Le), desiccants, and performance of other components in the system (e.g., heat exchanger effectiveness).

ACKNOWLEDGMENTS

This work was funded by the U.S. Department of Energy; Solar Cooling Program; John Goldsmith, Program Manager. The author wishes to thank Tom Dresler and Carl Bingham for their work on the experimental part of this study.

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