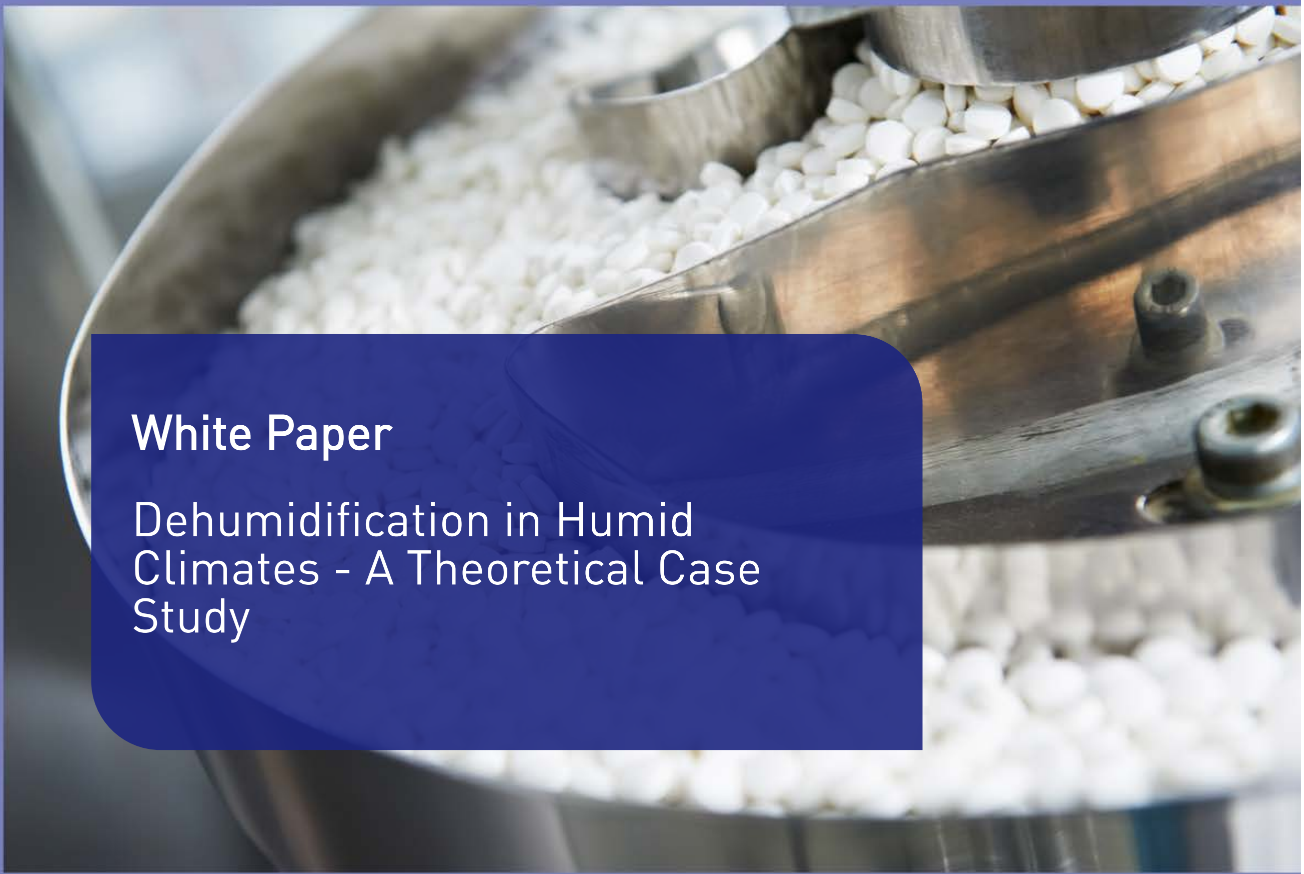

White Paper

Dehumidification in Humid Climates - A Theoretical Case Study

This white paper provides details of a theoretical comparison of operating costs associated with mechanical dehumidification systems and liquid desiccant dehumidification systems when applied to humid climates. The case study also provides a comparison of the different dehumidification processes for both single pass HVAC systems and recirculating HVAC systems.

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Executive Summary

Dehumidification for internal climate control is typically provided via mechanical means (cooling the air beyond its dew point temperature) or via the use of desiccant systems (using a hydroscopic medium to adsorb moisture from the air). An understanding of the effectiveness and operating costs of dehumidification systems is essential to the design of air conditioning systems in humid climates.

A desktop investigation was undertaken to compare the annual energy costs of typical air handling systems utilising mechanical dehumidification, and that of similar systems utilising liquid desiccant dehumidification. This investigation was based around an imaginary clean room of nominally 100m², located in Hong Kong. Comparative energy consumption costs were estimated for both single pass and recirculating ventilation systems.

The annual energy costs for single pass air handling systems incorporating mechanical dehumidification and liquid desiccant dehumidification were estimated at $308,998 and $250,916 respectively. This is a 19% reduction in energy costs for the desiccant system.

The annual energy costs for recirculating air handling systems incorporating mechanical dehumidification and liquid desiccant dehumidification were estimated at $80,698 and $68,933 respectively. This is a 15% reduction in energy costs for the desiccant system.

When designing dehumidification systems, consideration also needs to be given to the factors affecting whole-of-life costs such as capital expenditure, maintenance and economical life expectancy of plant equipment.

In addition to the financial benefits of desiccant dehumidification systems, they are less likely than mechanical dehumidification systems to provide in-duct conditions that promote the growth of bacterial / mould.

Introduction

Dehumidification in heating, ventilation and air conditioning (HVAC) systems is typically provided either mechanically or via the use of desiccants. Mechanical dehumidification works by cooling air beyond its dew point forcing moisture vapour to condense and drop out of the air stream. Desiccant dehumidification works by introducing a hydroscopic medium into the process air stream which adsorbs moisture from the air; the medium is reactivated by introducing it into a separate air stream at a higher temperature that allows the moisture to be released.

For facilities in locations that are not susceptible to high humidity, dehumidification for internal comfort conditions is easily provided by virtue of the air handling system cooling coils. For similar facilities in areas of high humidity, the ability of the air handling systems to provide the required dehumidification, and the associated costs, demand more consideration in regards to facility design.

The decision to use one technique over the other depends on a number of factors such as climatic conditions, spatial constraints, control tolerance, capital cost, operating cost and contamination control, to name a few. This case study focuses on the operating costs for a humid climate, specifically that in Hong Kong, with some consideration of the practical implications.

Desktop Analysis

Heat load calculations were performed for each hour of the year taking into consideration internal loads for people, lighting and equipment, and external loads associated with outdoor air conditioning. External fabric loads were ignored for reasons described later in this section.

To provide a reasonably accurate estimate of the energy consumed by the mechanical dehumidification process, a basic cooling coil model was developed to determine the coil sensible heat ratio (SHR) based on entering dry-bulb temperature and humidity. The performance of the desiccant dehumidifier was based on information available for a proprietary liquid desiccant system as described later.

When modelling the single pass ventilation systems, each timestep calculation was considered independent of those preceding it; that is, the temperature and humidity of the air entering the air handling unit was determined solely from the respective outdoor air conditions. In contrast to this, each timestep calculation for the recirculating systems was dependent on the room conditions from the preceding timestep as well as the outdoor air conditions corresponding with the timestep for which the calculation was based.

To provide a fair comparison between mechanical and desiccant dehumidification systems, the mechanical HVAC systems were based on current high efficiency technology commonly applied to new installations. Where different systems incorporated common equipment, the same efficiency and performance was applied to that common equipment.

The following sub-sections provide details of the input information used to estimate the annual energy consumption and subsequent operating costs for each HVAC system option.

The Facility

The following data describes the facility parameters that applied to this case study.

HVAC System	Single-Pass	Recirculating
Floor Area, m^2	100	100
Ceiling Height, m	3	3
Volume, m^3	300	300
Air Change Rate, h^{-1}	20	20
Supply Air Rate, L/s	1670	1670
Outdoor Air Rate, L/s	1670	100
Return Air Rate, L/s	0	1570
Temperature Setpoint, °C	20	20
Humidity Setpoint, %RH	50	50
Daily Hours of Operation	24	24
Annual Days of Operation	365	365

Table 1. Facility Parameters

The facility described was considered to incorporate a building fabric of high thermal performance, such as sandwich panel, and located within a greater air conditioned building thereby eliminating the external heat loads associated with solar gain and thermal conduction.

The following internal heat loads were applied to each model.

No of People	10
Sensible Load per Person, W	115
Latent Load per Person, W	105
Lighting Load, W/m^2	15
Equipment Load, W/m^2	50

Table 2. Internal Heat Loads

Weather Data

The weather data used for this case study was based on the EnergyPlus weather data for Hong Kong which is derived from data developed by the City University of Hong Kong and available on the EnergyPlus website [1].

Coil Performance

The software package SPC2000 by S&P Coil Products Ltd [2] was used to provide a reasonably accurate model for the cooling coil performance with respect to the SHR. By selecting a particular coil to meet the peak design conditions, the SHR for different on-coil conditions was determined and tabulated.

Desiccant Dehumidifier Performance

The performance of the liquid desiccant dehumidifier was based on literature provided by Advantix which is available on their website [3], and also through direct discussion. The specific model used in this case study was the DT-RT/15 rooftop packaged unit; for simplicity the relationship between process air temperature reduction and inlet moisture content was approximated as directly proportional.

Central Plant Performance

The cooling / heating for the AHU was based on the use of central chilled water and heating hot water systems.

The chilled water (CHW) system consisted of a high efficiency air-cooled chiller with an Integrated Part Load Value (IPLV) Coefficient of Performance (COP) of 6 and associated pumps operating at an efficiency of 70%; these figures were used irrespective of load.

The heating hot water (HHW) system consisted of a condensing boiler with an efficiency of 95% and associated pumps operating at an efficiency of 70%; as similar to the chilled water system, these figures were used irrespective of load.

Air Handling Unit Performance

The AHU model used in the calculations was based on an AHU consisting of a fan operating at an efficiency of 40%, cooling and heating coils, a roughing filter, a general filter, a HEPA pre-filter and a HEPA filter (whether centrally mounted or terminally mounted is irrelevant to this analysis). The pressure drop across each filter was based on the average pressure drop associated with the clean and dirty conditions for each respective filter. The pressure drops associated with each coil, filter and the ductwork system are summarized in the table below.

AHU Component	Pressure Drop, Pa
Roughing Filter (G4)	150
General Filter (F5)	150
Cooling Coil	100
Heating Coil	50
HEPA Pre-filter (F7)	150
HEPA Filter (H13)	425
Ductwork and Fittings	200

Table 3. AHU Component Pressure Drops

The figures in the table above relate specifically to the options which consist solely of an AHU. Where systems incorporate an AHU and a pre-conditioner, adjustments to the number of filters used and cooling coil pressure drops were adjusted accordingly as described in the following sub-section.

Air Handling Configuration - Single-Pass Option

Mechanical Dehumidification

The air handling system for this scenario consisted simply of a single AHU.

Desiccant Dehumidification

The air handling system for this scenario consisted of a packaged liquid desiccant dehumidifier to pre-treat the incoming air and an AHU. The pressure drop through the AHU was reduced from that used in the Mechanical Dehumidification scenario to account for the reduced cooling coil size.

Air Handling Configuration - Recirculating Option

Mechanical Dehumidification

Two scenarios were considered for Mechanical Dehumidification as follows:

1. The first scenario involves an air handling system consisting simply of a single AHU. The dehumidification process was applied to the mixed return and outdoor air.
2. The second scenario involves an air handling system consisting of an AHU and a pre-conditioner. The AHU incorporates the same filters as the first scenario, less the roughing filter; the pre-conditioner incorporates basic filters. The pressure drop through the AHU was reduced from that used in the first scenario to account for the reduced cooling coil size. The dehumidification process was applied to the outdoor air only as it passed through the pre-conditioner. The AHU conditioned the mixed return and outdoor air.

Desiccant Dehumidification

The air handling system for this scenario consisted of a packaged liquid desiccant dehumidifier to pre-treat the outdoor air component and an AHU to condition the mixed return and outdoor air. The pressure drop through the AHU was reduced from that used in the Mechanical Dehumidification scenario to account for the reduced cooling coil size.

Energy Tariffs

The energy tariffs for electricity and gas were based on the rates provided by HK Electric and Towngas respectively, as published on their websites in October 2014. Both of these companies provide varying rates based on total annual consumption; for simplicity, a single figure for each fuel tariff was used and determined by averaging the respective tariffs.

The tariffs used for electricity and gas were 140.83 c/kWh and 22.44 c/MJ respectively.

Results

The tables below summarise the results of this theoretical case study.

Single Pass Option	AHU Only		Desiccant System	
Annual Energy Consumption	Elec, kWh	Gas, MJ	Elec, kWh	Gas, MJ
Dehumidifier	0	0	136066	0
Chiller	94692	0	8460	0
Boiler	0	458476	0	29511
AHU Fan	44802	0	28344	0
CHW Pump	6462	0	577	0
HHW Pump	413	0	27	0
Total	146369	458476	173474	29511
Annual Cost per Fuel Type	$206,124	$102,874	$244,295	$6,622
Total Annual Cost	$308,998		$250,916	

Table 4. Annual energy consumption and costs for the Single Pass option.

Recirculating Option	AHU Only		Desiccant System		AHU with Precon.	
Annual Energy Consumption	Elec, kWh	Gas, MJ	Elec, kWh	Gas, MJ	Elec, kWh	Gas, MJ
Dehumidifier	0	0	8138	0	1402	0
Chiller	33673	0	11671	0	17238	0
Boiler	0	393098	0	0	0	0
AHU Fan	44802	0	28344	0	37487	0
CHW Pump	2298	0	796	0	1176	0
HHW Pump	354	0	0	0	0	0
Total	81127	393098	48949	0	57304	0
Annual Cost per Fuel Type	$114,247	$88,204	$68,933	$0	$80,698	$0
Total Annual Cost	$202,451		$68,933		$80,698	

Table 5. Annual energy consumption and costs for the Recirculating option.

Discussion

It can be seen from a quick review of the results that there are significant cost savings to be achieved by the application of desiccant dehumidification. It can also be seen that for recirculating systems that pre-conditioning outdoor air is fundamental in reducing costs associated with energy consumption.

In terms of cost, the use of desiccant dehumidification in lieu of mechanical dehumidification provided a reduction of 19% for the single pass option and 15% for the recirculating option (assuming both systems incorporate pre-conditioners).

One of the key factors that contributes to the reduction in energy consumption of desiccant dehumidification systems is the extent to which additional cooling (beyond that required to meet temperature set points) is provided. For a single pass system, the entire supply air volume must be cooled and then reheated accordingly, and as such the savings are substantial. In recirculating systems the savings are less substantial as only the outdoor air component requires cooling beyond the dew point. As such there is no need to provide reheating as the cooling provided by the pre-conditioner supplements the cooling (required to meet temperature set points) provided by the AHU.

In determining the SHR for the cooling coils, it was observed that moisture carryover was likely for the more humid periods of the year. Moisture carryover can result in re-humidification of the air resulting in the inability to meet design humidity set points within tolerance, or more detrimentally to the build-up of moisture within the AHU / duct work which can promote the growth of bacteria / mould. Ineffective dehumidification is more likely in single pass systems where there is only one cooling coil that can be used for dehumidification; the potential for moisture build-up within the ducted system is common to both single pass and recirculating systems. Moisture carryover is not a problem associated with desiccant systems. Alternative coil selections and reduced chilled water temperatures could be used to eliminate the occurrence of moisture carryover, however further cost penalties would apply.

This case study was limited to the estimation of costs associated with energy consumption and did not consider the costs associated with capital expenditure, maintenance or economical life expectancy of plant equipment.

Conclusion

When designing climate control systems for facilities in humid climates, serious consideration needs to be given to the method of providing dehumidification. For both single pass and recirculating systems, significant energy cost savings can be achieved by using desiccant dehumidification systems as opposed to mechanical dehumidification systems.

For recirculating systems, the use of pre-conditioners for dehumidifying the outdoor air component is essential from an economical point of view. The final design for the dehumidification system should also consider the costs associated with capital expenditure, maintenance or economical life expectancy of plant equipment.

In addition to the financial benefits of desiccant dehumidification systems, they are less likely than mechanical dehumidification systems to provide in-duct conditions that promote the growth of bacterial / mould.

References

[1] http://apps1.eere.energy.gov/buildings/energyplus

[2] SPC2000 Version 6.3, S&P Coil Products Ltd, http://www.spcoils.co.uk

[3] http://www.advantixsystems.com

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