Energy and Buildings 51 (2012) 1–5

Contents lists available at SciVerse ScienceDirect

Energy and Buildings

journal homepage: www.elsevier.com/locate/enbuild

Performance of desiccant dehumidification with hydronic radiant cooling system in hot humid climates

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ARTICLE INFO

Article history:
Received 21 December 2011
Received in revised form 20 January 2012
Accepted 29 January 2012

Keywords:
Desiccant dehumidifier
Chilled ceiling panels
Hydronic
Thermal comfort
Relative humidity

ABSTRACT

Experimental investigations were carried out to determine the performance of a rotating desiccant wheel with chilled ceiling panels for humid climates in Malaysia. Dehumidification capacity was in the range of 0.89–2.673 kg/h. Relative humidity reduction to 40% with high dehumidification capacity of 2.673 kg/h was achieved within 10 min with air flow rate of 243 kg/h. Chilled ceiling surface temperature between 14 and 18 °C was achieved by varying the chilled water inlet temperature from 6 °C to 10 °C at steady state. Condensation was absent on the chilled ceiling surface panels below 70% relative humidity. Thermal comfort room temperature for this investigation was 24–24.5 °C for chilled ceiling height of 2 m.

1. Introduction

Humidity is indeed a problem to be addressed in all air conditioning cases. Desiccants are materials which have an ability to absorb and/or adsorb water vapor from the surroundings. The common types of desiccants used in dehumidifier are silica gel and calcium chloride. The most common solid desiccant is silica gel for removing moisture in an enclosed area. Desiccants have been used to improve indoor air quality and reduce energy consumption. In attaining an acceptable thermal comfort, controlling indoor air quality, temperature, relative humidity and ventilation are essential. The humidity of an air-condition can be reduced by removing the moisture via desiccant dehumidification [1,2]. Desiccant dehumidifiers normally comprise of a singular desiccant, however compound desiccant have also been used [3–5]. Hot humid climates in the tropics have relative humidity in the range of about 70–80% and require significant refrigeration capacity to reduce the temperature to the dew point to remove the moisture in the air. Using desiccant dehumidification in these climatic locations will reduce the electrical power consumption.

In general the advantageous of employing desiccant have encouraged many researches to extend their investigations experimentally and numerically on the performance of the desiccant and improving indoor air quality [6,7]. More advance dehumidification system integrated with a membrane-based total heat exchanger would enhance the performance of the air conditioning system [8].

Adequate amount of fresh air into an air-conditioned space depends on the ventilation system in particular the location and either natural or forced convection [9,10]. High fresh air composition is required for example in hospitals where contaminated air is removed and also to replenish oxygen supply. However this requires a much higher refrigeration capacity to cool the higher amount of incoming hot and humid air especially for conventional air-conditional system that uses a cooling coil with an air blower. A different air conditioning system has to be considered with high fresh air composition and one of the candidates is hydronic radiant cooling [11]. Hydronic radiant cooling (HRC) system refers to the use of chilled water as a refrigerant medium via cooper tubes embedded into aluminum panels. Since its introduction in the European countries, HRC has attracted a lot of attention with displacement ventilation systems [12]. Behaviors of indoor humidity and the effect on condensation is an important consideration in hydronic chilled ceiling air conditioning [13]. Integrating chilled ceiling with dehumidified ventilated air, presents many advantageous related to thermal comfort, absence of condensation and energy saving [14–16]. In the desiccant dehumidifier, incoming humid air passes through a rotating wheel of desiccant. When the desiccant wheel is saturated with moisture, the desiccant wheel must be reactivated for continuous operating with heat energy supplied via electrical heater. Therefore to determine the required time for the desiccant to be saturated, it is necessary to control relative humidity and reduce energy consumption. Undesirable condensation on chilled ceiling panels' surfaces normally occurs in hot

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doi:10.1016/j.enbuild.2012.01.031

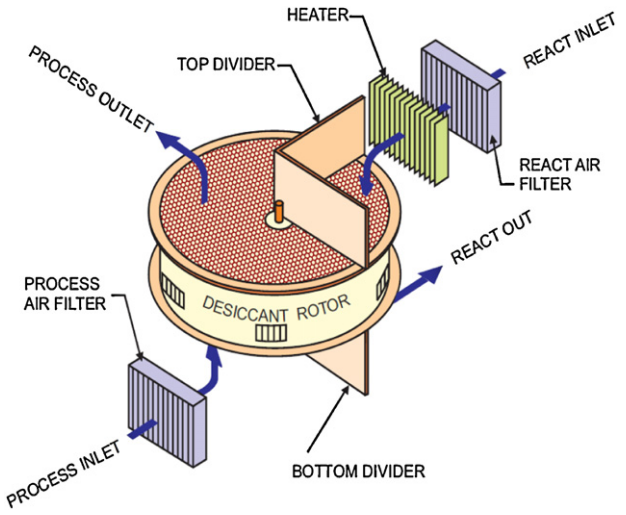

Fig. 2.1. Main process of the dehumidifier.

humid climates like Malaysia and can be prevented by controlling the chilled ceiling surface temperature and relative humidity of the incoming air or ventilated air. Investigation on controlling the desiccant operation time at various air flow rates to reduce power consumption whilst maintaining the RH and the dehumidification capacity is proposed and has never been investigated. There is no study yet on the appropriate position of the chilled ceiling panel height with respect to the chilled ceiling temperature and relative humidity.

2. Methodology

Bry-Air compact dehumidifier Fluted Flat Bed (model-FFB-600) with high performance metal silicate fluted and desiccant synthesized rotor was used in the present study. Fig. 2.1 shows the main processes of the desiccant dehumidifier, while the desiccant specification is shown in Table 1. Hydronic radiant cooling system consists of three main components: chilled ceiling panel, water circulation system and environmental chamber. Chilled ceiling panel is made from aluminum sheet and has a size of 1.70 m × 0.5 m × 0.02 m. It removes heat gain inside the chamber. Chilled water from a chiller passes through copper tubes of 0.01 m diameter embedded into the panel as shown in Fig. 2.2. There are 12 chilled ceiling panels installed below the ceiling of the environmental chamber. The environmental chamber wall thickness is 100 mm constructed with demountable clip-lock type insulated panels. The insulated panels are made of galvanized steel sheets laminated with insulation core of polyurethane with dimension of 4.25 m × 3.75 m × 3 m. An inlet into the chamber is located at the bottom right and exit at the left top directly opposite the air inlet. These air vents are of the same diameter of 11 cm. Fig. 2.3 shows the geometry of the chamber that can accommodate four occupants. The room temperature measurement (T_R) is taken 1 m above the floor. The performance of the desiccant dehumidification

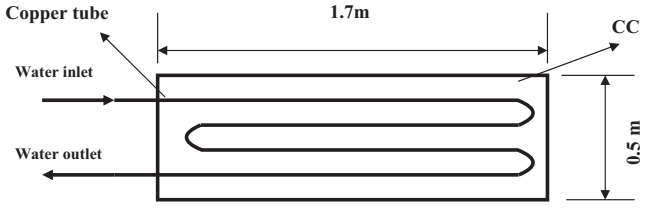

Fig. 2.2. Schematic of chilled ceiling panels with copper tubes.

Table 1
Specification of compact dehumidifier FFB-600.

Model	Unit dimension data (mm)			Process duct connection (mm)										Reactivation duct connection (mm)												Dia hose
				Inlet connection						Outlet connection (mm)				Inlet connection						Outlet connection						
	A	B	C	D	E	F	G	H	I	J	JJ	J1	K	K1	L	L1	w	O	P	Q	R	S	S1	T	T1	U	U1	x	⌀V
FFB-600	886	630	494	195	135	300	275	264	240	226	0	160	170	225	98	128	0	142	85	300	218	182	145	170	225	98	128	0	150