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Analysis on the Utilization of Temperature and Humidity Independent Control Air-conditioning System with Different Fresh-air Handling Methods

Xiangdong Li[a,*]

[a]*Shandong Provincial Architectural Design Institute*

Abstract

The presented research illustrates the characteristics of Temperature and Humidity Independent Control (THIC) system with different fresh-air handling methods through engineering case studies. The investigated methods include dehumidification with the application of cooling, liquid desiccant, dual cooling sources dehumidification and dehumidification wheel. By analyzing the dehumidification processes on psychrometric charts, this study summarized main design focus then conducted detailed calculation for equipment sizing. Furthermore, this study compares energy consumptions for the four methods. Results show liquid desiccant and dual cooling sources dehumidification are more suitable for general office buildings in terms of energy conservation. Dehumidification wheel method consumes too much energy therefore not applicable for comfort air conditioning systems.

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Keywords: THIC; Outdoor-air handling; Energy saving; Economic analysis;

1. Introduction

In the early 21st century, researchers in Tsinghua University first proposed the concept of temperature and Humidity Independent Control (THIC) system. Due to the advantages in high efficiency, energy saving, healthy and comfort, THIC system was widely acknowledged by the engineers in China. Official definitions, application scope and design principles for THIC systems can be found in the national standard GB 50736-2012 Design code for heating ventilation and cooling of civil buildings (Design Code in the following context).

* Corresponding author.
Email address: lxd7631@163.com

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Unlike conventional air-conditioning systems, THIC systems regulate indoor temperature and humidity separately through different approaches. THIC systems consist two subsystems, namely indoor temperature control system and humidity control system. Dry indoor terminals with high-temperature cooling water is used to control the indoor temperature and handle the sensible heating load. Independent fresh air handling system control the humidity thus handle the latent heating load. THIC systems are characterized as:

(1) Energy saving. The cooling source of THIC systems adopt high-temperature water chillers therefore, system efficiency is highly improved compared to conventional air-conditioning systems. Most of the dehumidification outdoor-air handling systems are equipped with a total heat recovery module to further reduce energy consumption. In addition, most dehumidification outdoor-air handling systems are capable to operate independently thus reduce operating time during shoulder seasons.

(2) Comfort. Indoor air temperature and humidity are controlled separately by the two subsystems without interaction between each other. Occupants could obtain indoor thermal comfort all year round.

(3) Health. Indoor terminals operate under a dry state to alleviate healthy related concerns by condensation systems.

(4) Multi-source available. Since THIC systems use high-temperature water for cooling, several low-grade sources are capable to be utilized in THIC systems together with other technologies. For example, integrate water tank to storage cold during off-peak hours when electricity price is low. It also provides opportunities to utilize natural cooling sources, e.g. earth source, water source, etc.. Furthermore, THIC systems offer possibility to use evaporative cooling technology, industrial waste heat and other types of excess heat.

With the theoretical researches and engineering applications in the recent twenty years, THIC systems has been developed different applications in terms of indoor terminal types, i.e. dry fan coil unit, radiant terminal, chilled beam, etc. The variations in indoor terminals only influence the indoor temperature handling process. However, the humidity handling process has much more impacts on air-conditioning systems which is affected by the dedicated fresh air handling process. The fresh air handling process includes liquid desiccant dehumidification, cooling dehumidification (low-temperature water cooling and dual-cooling sources) and wheel dehumidification as defined in the Design Code. When adopt different fresh air handling methods in THIC systems, system design also differs including heating/cooling source capacities, indoor terminal types and distribution system design. As consequences, system economical and energy-saving characteristics are also different. The presented research analyzes different fresh air handling methods through engineering case studies.

2. Case description

Table 1. Summer design condition

Design parameters		Unit	Value
Fresh air design condition	Dry-bulb temperature t_{Wg}	ºC	34.7
	Wet-bulb temperature t_{Ws}	ºC	26.8
	Relative humidity φ_W	%	54.5
	Moisture content d_W	g/kg.da	19.1
	Enthalph h_W	kJ/kg	83.9
Indoor air design condition	Dry-bulb temperature t_{Wg}	ºC	26
	Wet-bulb temperature t_{Ws}	ºC	20.3
	Relative humidity φ_W	%	60
	Dew-point temperature t_{Nl}	ºC	17.5
	Moisture content d_W	g/kg.da	12.63
	Enthalph h_W	kJ/kg	158.5

The presented case study locates in Jinan, Shandong Province, China. Total building area is 197932 m^2 including four office buildings (Building A, B, C and D), podiums and underground parking. Building A and Building C are 28-storey office buildings. The two buildings equipped THIC systems using dry fan coil units as indoor terminals.