Energy and Buildings 41 (2009) 229–233

Contents lists available at ScienceDirect

Energy and Buildings

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

Optimization of cooling coil performance during operation stages for improved humidity control

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ARTICLE INFO

Article history:
Received 9 July 2008
Accepted 16 September 2008

Keywords:
Cooling coil
Dehumidifying performance
Design and operation
Thermal comfort and IAQ
Hot humid climates

ABSTRACT

In hot and humid climates, indoor humidity levels are usually high and this is a matter of concern from Thermal Comfort and IAQ perspectives. This phenomenon can be attributed to the inadequate dehumidifying performance of the cooling coil. Amongst other factors, poor dehumidifying coil performance results from the selection and installation of an oversized coil and the conventional strategy of modulating the chilled water flow rate as the only available control method. It is not uncommon to find that operating conditions demand a reduced chilled water flow rate not just during part load conditions but even during the actual peak load condition. Based on a simulation method that involves selection of coils for different conditions, this paper presents the findings of the performance evaluation of an oversized coil at different conditions during the operation stage. The findings show that the dehumidifying performance of the oversized coil at reduced loads during normal operation can be significantly enhanced by changing the effective surface area of the coil through a simple manipulation of the effective number of rows of coil operation.

1. Introduction

In designing and selecting the type of cooling coil for any use in buildings, a clear understanding on the anticipated condition and usage of the building needs to be established. A typical heating, ventilating and air-conditioning (HVAC) design process would involve calculation of peak cooling loads, specification of system and equipment configuration, calculation of annual performance and calculation of cost [1]. In hot and humid climates, the performance of the cooling and dehumidifying coil has a strong bearing on the eventual indoor environmental conditions, which in turn, has a tremendous impact on the indoor air quality. It is important to recognize that the primary function of the cooling coil is not just cooling but the ability to cool and dehumidify in the correct proportion of sensible and latent loads in which they occur in a dynamically changing operation stage [2]. Thus, the room sensible heat ratio (RSHR) and the sensible heat ratio (SHR) of the coil are key design considerations. Notwithstanding the design of the coil, its operation is typically controlled by attempting to match the actual cooling load in operation with the required coil capacity. The only way to achieve this is by modulating the chilled water flow rate. Some control strategies include the use of air-bypass around the coils or temperature reset [3]. Studies have also been conducted to compare different control strategies for indoor humidity levels [4].

Often, the cooling coils are oversized due to an over estimation of the anticipated cooling loads and this would have a detrimental effect on the cooling and dehumidifying performance at part load operating conditions. Inevitably, conventional HVAC control strategies would inhibit the ability of the coil to dehumidify exactly when the opposite is desired. In order to overcome the consequential elevated humidity levels in the occupied zones, overcooling is routinely employed which leads to an increase in energy consumption. This paper deals with the issues associated with overdesigning, commonly prevalent in typical design practice, and recommends a solution that can result in improving the cooling and dehumidifying performance of the oversized coils in a dynamically fluctuating operation stage. The proposed solution will also lead to an overall reduction in cooling coil energy consumption due to the enhanced dehumidifying performance being achieved. It is important to note that solutions to improve the dehumidifying performance must be energy efficient in today's context of sustainable design. Several studies have focused on HVAC system optimization for energy management and some have also included hot and humid climates [5–8].

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doi:10.1016/j.enbuild.2008.09.005

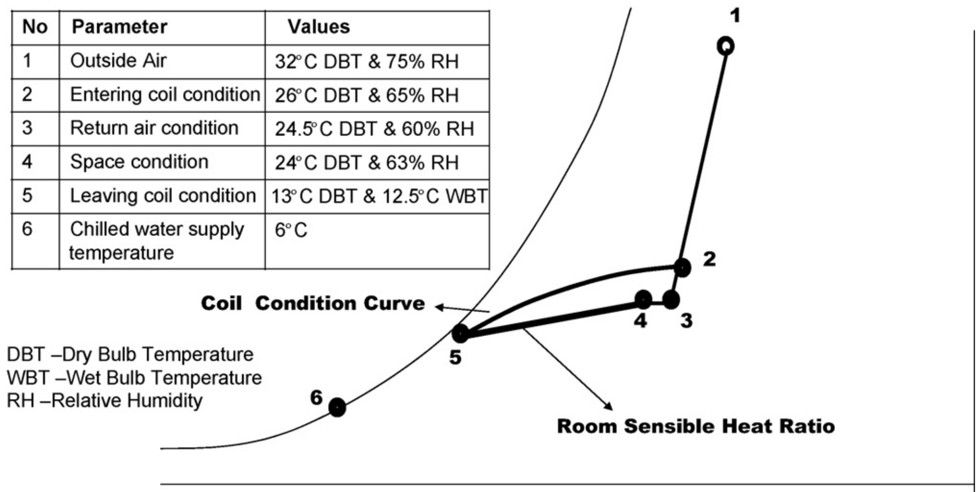

Fig. 1. Psychrometric state points for the base-case simulation of the oversized coil.

2. Methods

A simulation approach is adopted in this study that involves an evaluation of the coil performance for various operating conditions and through the use of various coil geometries. A standard coil selection program, freely downloadable from the internet, is used in performing the simulations [9]. A hypothetical building with an actual maximum cooling load of 100 kW supplied with a 200 kW design capacity (oversized) cooling coil is considered. The required indoor air-condition for the entire simulation is set at 24.5 °C with an expected relative humidity of 60%, resulting in the upstream coil conditions of 26 °C DBT and 65% RH. The psychrometric state points, associated with the design conditions of 200 kW, are shown in Fig. 1. The simulations at other anticipated operating conditions are then performed and this process involves the use of the oversized coil as well as coils with other geometries that are customized to the prevailing cooling loads. Based on the evaluation of the various simulation results, a solution is recommended that could result in an improved performance of the oversized coil during the normal operation stage.

3. Results and discussion

3.1. Coil selected for design capacity—Operating at design capacity

Since the simulation exercise aims at comparing between the various cooling coil operating conditions, the first step is to simulate the coil at design capacity (also known as base-case). Both Tables 1 and 2 show the configuration of the cooling coil at its design capacity (base-case). Table 1 shows the conditions that are required to remain constant throughout the entire simulation while Table 2 shows the required conditions, with some having the ability to be manipulated to simulate the effectiveness of the various operating conditions. The different simulated conditions can then be used to determine the difference in coil performance as compared to the base condition. Two different scenarios are further considered in this analysis—Constant Air Volume (CAV) system and Variable Air Volume (VAV) system.

3.2. Oversized coil in a CAV system—Operating at actual maximum peak load

While the coil design capacity is 200 kW, the actual maximum peak load is only 100 kW and thus, the coil is now oversized. Series A1 simulates the oversized coil operating at actual peak load condition. To understand the effectiveness of operating the design capacity coil operating at half its design load, a comparison between base condition (Design load) and Series A1 (Actual Peak load) is shown in Table 3.

The basic performance criterion for any typical cooling coil is often judged by its cooling capacity (sensible) and its dehumidification (latent) capability, which is measured in terms of SHR. As seen in Table 3, operating a coil at half its design capacity (from 200 to 100 kW) increases the SHR by 10%. A recent study elaborated that “coils with higher SHR may reduce temperature too quickly for adequate moisture removal to occur, while coils with low SHR may dry out the air too much and indoor air may become too dry” [10]. This 10% increase in SHR could affect the air quality that is produced as the efficiency of the dehumidification process is reduced, i.e., the coil is able to achieve the required temperature

Table 1
Fixed configuration of the cooling coil at design capacity.

Air side data	Air on DB temp.	26 °C
	RH (%)	65%
	Standard air	Yes
Fluid side data	Fluid on temp.	6 °C
	Max pressure drop	50 kPa
Physical data	Fin material/type	Aluminium 0.15 rippled
	Coil type	Water
	Tube diameter	16 mm
	Tubes high	30
	Finned height	1218 mm
	Finned length	2100 mm
	No. of sections	1
	Surface margins	1

Table 2
Adjustable configuration of the cooling coil at design capacity.

Air side data	Airflow (m^3/s)	6.45
	Face velocity	2.52
	Air off DB	13
	Air off WB	12.5
	Capacity (kW)	200
	SHR (%)	52%
Physical data	Rows	6
	Fin density	9
	Circuit type (F - Full Circuiting)	F
Fluid side data	Fluid on temp	6
	Fluid off temp	12
	Fluid flow rate (l/s)	7.96
	Actual PD	56.5