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Using a chain recooling system on buildings in hot and humid climates

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ABSTRACT

In hot and humid climates, warm outside air with rich moisture content impacts several aspects of building operation. To meet the ventilation requirement while maintaining indoor relative humidity (RH) at the desired level, dehumidification is usually required. This is typically done by cooling the air to 55 °F (12.8 °C). However, if the zone cooling load is low, then inefficient reheat may be necessary to maintain the indoor temperature set-point. To achieve better system efficiency, a new HVAC system concept called the "Chain Recooling System" is proposed. In this paper, it is shown that compared to a conventional Single Duct Variable Air Volume (SDVAV) system, the proposed system has the potential to provide better indoor air quality, eliminate the reheat requirement, and reduce fan energy consumption. To demonstrate the advantages of the proposed system, a building on the Texas A&M University campus in College Station, TX, is selected as a case study. It is projected that the HVAC system related energy consumption would be reduced by 15.2% and the average contaminant level would be reduced by 27% if the SDVAV system were replaced by the CRS without sacrificing comfort in the individual zones.

1. Introduction

Single Duct Variable Air Volume systems with terminal reheat are widely used in large-scale buildings in the USA. The advantages and disadvantages of these centralized all-air system are well-documented [1].

One of the two major deficiencies of a SDVAV system is the reheat requirement. Due to the asynchronous demand behavior of building zones and the terminal box minimum flow rate setting to ensure proper ventilation, research has demonstrated that the in-zone temperature cannot be correctly controlled without reheat [2]. Since the minimum flow rate set-point is a key factor influencing need for reheat, numerous authors have focused on optimizing this setpoint to reduce the energy consumption [3–11]. On the other hand, others [12–15] have focused on alternative ways to achieve the same reheat reduction goal, such as using cooling coil temperature reset. The other major deficiency of a SDVAV system is its over-ventilation of many zones. Since the system delivers the same air mixture to each zone, proper ventilation to the critical zone (the zone requiring the highest OA fraction) will generally result in over-ventilation for other zones [16,17], and it has been demonstrated that increased ventilation (OA intake) usually results in higher energy use [18,19].

All of these deficiencies have the same origin: In a SDVAV system, the cooling, ventilation, and dehumidification functions are coupled; thus compromised operation is necessary if these three demands are not perfectly matched – which seldom occurs. To address this issue, decoupling these functions, such as using a dedicated outdoor air system (DOAS), seems to be a legitimate answer. Numerous authors have reported [17,20–22] different levels of savings from using a DOAS instead of SDVAV with reheat. While the DOAS has demonstrated greater energy efficiency than the SDVAV system, it is hard to upgrade a SDVAV to a DOAS because the design schemes are different. That is, the DOAS application is generally limited to new buildings and is difficult to add in building retrofit projects. However, in any city in the world, the number of existing buildings will dominate the building stock for many years, so the potential benefit is greatly increased for technologies that can be retrofit in buildings. Even the DOAS system does not eliminate over-ventilation in some zones.

2. Objective of the study

The objective of this study is to propose a new HVAC system – the Chain Recooling System (CRS). The proposed system has several advantages compared to the SDVAV system with reheat even if it includes a DOAS - including total elimination of the reheat requirement and over-ventilation. It can also be implemented in a building retrofit project relatively easily because many components are common to the SDVAV system. The CRS may also be used to replace a SDCAV system. CRS utilizes a series of boost fans to deliver the air to multiple zones in series, where a zone is defined as an area served by a single terminal

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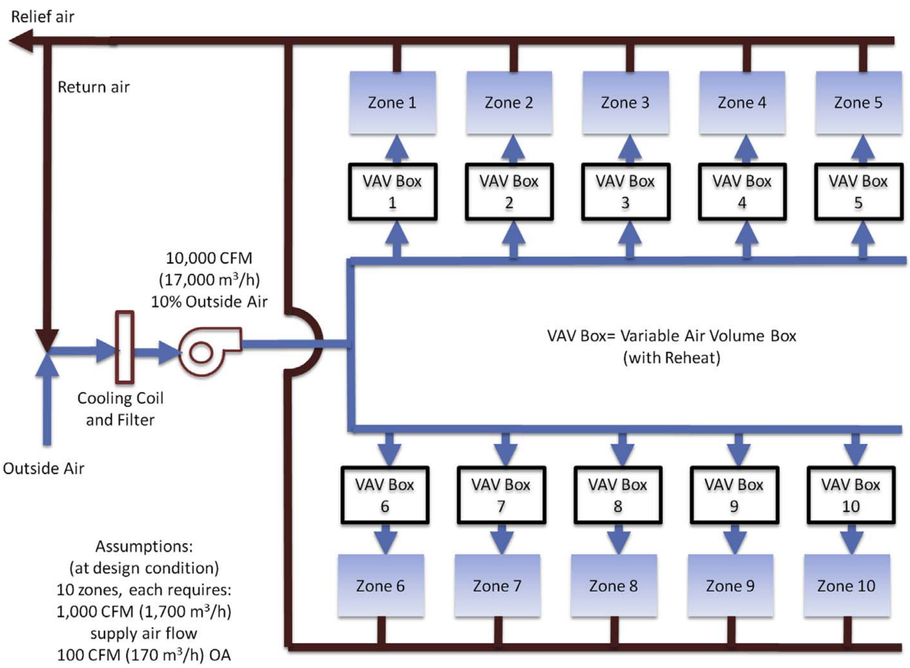

Fig. 1. SDVAV system diagram (10 zones served in parallel).

box. The amount of the air to be delivered as the base flow is the sum of the ventilation requirement of all zones linked in one chain, and this amount is equal to 50% of the design supply airflow rate of one terminal box. As a result, fans in the CRS only have to overcome the flow resistance between two adjacent zones, while the fan in a SDVAV system is typically designed to compensate the friction loss of the longest flow path in the whole system, thus the fan energy consumption is essentially lowered in a CRS system.

To illustrate the system, assume an office building has 10 identical zones, where each requires 1000 CFM (cubic feet per minute) (1700 m^3/h) supply air flow for the design cooling condition and 100 CFM (170 m^3/h) outside air (OA) flow for ventilation per ASHRAE 62.1 [23]. As shown in Fig. 1, a SDVAV system provides the same amount of airflow to each of the 10 zones in parallel, so the air handler unit (AHU) fan must be capable of handling 10,000 CFM (17,000 m^3/h) air flow. However, in CRS operation as shown in Fig. 2, the 10 zones will be served by two parallel “recooling chains.” 1000 CFM (1700 m^3/h) of 100% OA flow passes through the preheat coil, which will be activated only when the OA temperature is colder than the required supply air temperature of the first zones of the recooling chains (zone 1 and zone 6 in this case). Half of the OA flow then goes into terminal box 1 as primary flow to mix with zone return air and the total air flow is supplied to the first zone after additional cooling if needed to meet the zone load. In the fan powered terminal box diagram shown in Fig. 3, the supplementary airflow damper position and the fan speed are interlocked to ensure a constant base flow pulled from the previous zone. In this case the maximum supply airflow rate is 1000 CFM (1700 m^3/h) when an additional 500 CFM (850 m^3/h) supplementary air is pulled in and the minimum is 500 CFM (850 m^3/h) with the supplementary airflow damper fully closed. The control logic of the terminal boxes in

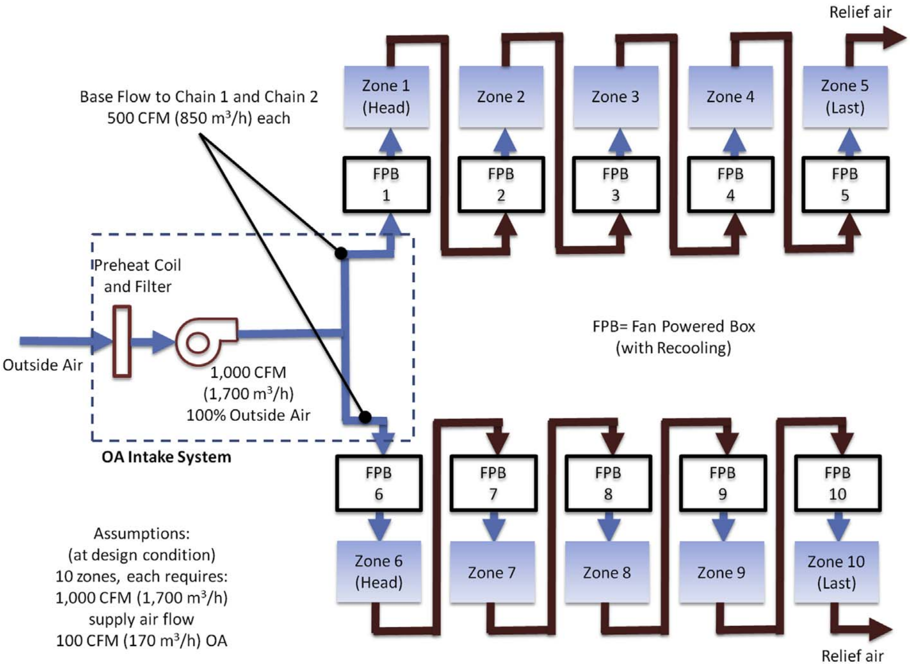

Fig. 2. Chain Recooling System Diagram (Zone 1–5 Served by One “Recooling Chain” and Zone 6–10 Served by the other).