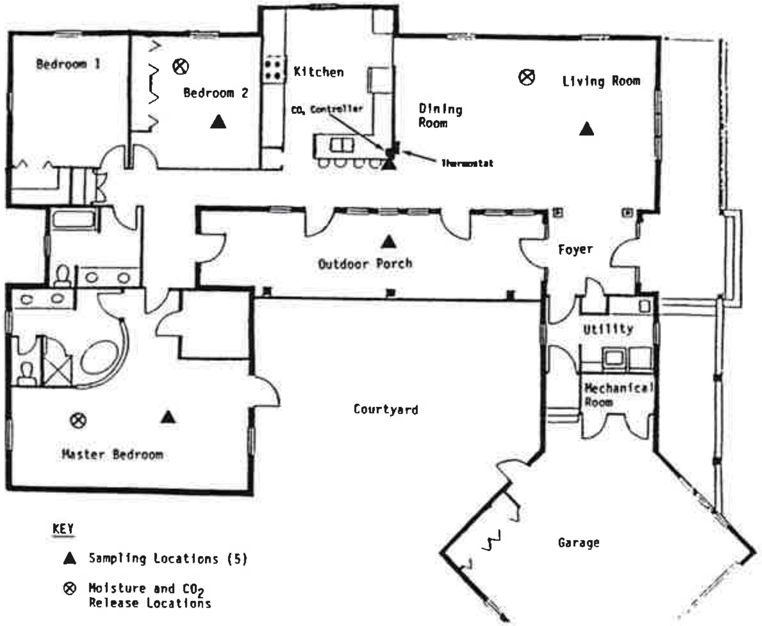

Figure 2. Sampling locations and moisture/CO_2 release locations in the energy-efficient demonstration house.

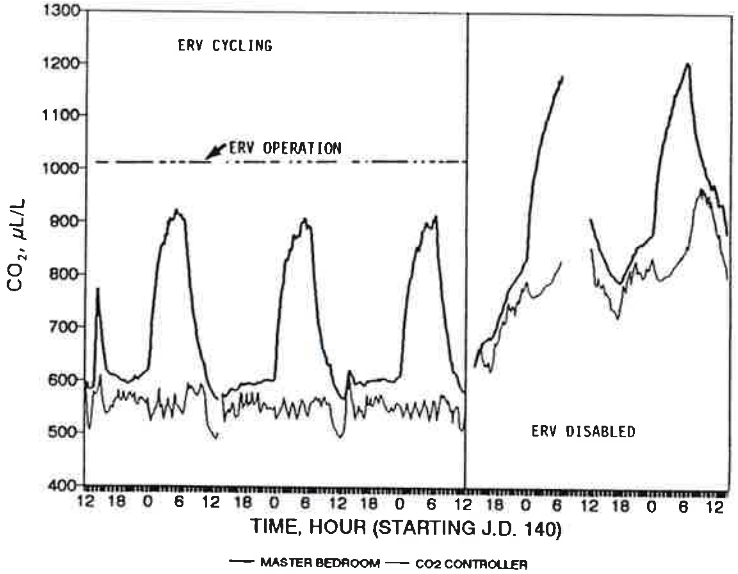

Figure 3. Time-varying CO_2 concentrations in the master bedroom and at the CO_2 controller site during periods with the ERV operating versus disabled.

EVALUATING DEMAND CONTROL STRATEGIES FOR VAV SUPPLEMENTARY BYPASS SYSTEMS

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ABSTRACT

This paper briefly summarizes the results of the carbon dioxide (CO_2) demand control ventilation (DCV) strategy, and introduces a proprietary DCV system. This system already equipped with indoor air quality (IAQ) sensors directly measures the concentration of volatile organic compounds (VOCs) in an occupied space and accordingly modulates supply air rates to provide acceptable IAQ, comfort and cost-effectiveness (especially for variable-air-volume [VAV] systems).

INTRODUCTION

Properly implemented DCV strategies can provide opportunity to maintain acceptable IAQ in accordance with ASHRAE Standard 62-1989 and offer significant energy savings. Since CO_2 is now widely recognized as a convenient surrogate for odor, and an indirect measure of adequacy of supply air (mixing outdoor and recirculated) to an occupied space, CO_2 can be used as a DCV strategy. Figure 1 shows the actual CO_2 concentrations measured by using a CO_2 sensor as a function of time in an office space occupied by four people.

An occupant-driven CO_2 algorithm incorporated into a state-of-the-art HVAC computer program was used to estimate the time-varying concentrations of CO_2 in a Los Angeles high-rise office building of 2415 m^2 (26,000 ft^2) [1][2]. Outdoor air flow rates of 7 Liters/second/person (L/s/person) [cubic feet per minute (cfm)/person] to 9.5 L/s/person to (15 to 20 cfm/person) were used as a DCV strategy to achieve a satisfactory balance between IAQ and energy consumption. As the outdoor air flow rate was increased from 7 L/s/person (15 cfm/person), the CO_2 concentration decreased, indicating that CO_2 can be used as a sensing control strategy capable of maintaining currently recommended ventilation rates in ASHRAE Standard 62-1989 [3].

The concentration of VOCs, generally used in the formulation or manufacturing of consumer products, can be reduced in an occupied space by using a DCV system already equipped with an IAQ sensor which directly measures VOC concentrations and accordingly modulates the supply air rates. This paper presents a proprietary Variable-Air-Volume/Bypass Filtration System (VAV/BPFS) and a system filter and bypass filter selection criteria for both the retrofit and new buildings.

VARIABLE AIR-VOLUME/BYPASS FILTRATION SYSTEM

Quality of comfort is a common problem in offices that have only one thermostat for several rooms. The lack of uniform responsiveness to independently varying outdoor temperatures and IAQ needs is often a major drawback of conventional single-zone

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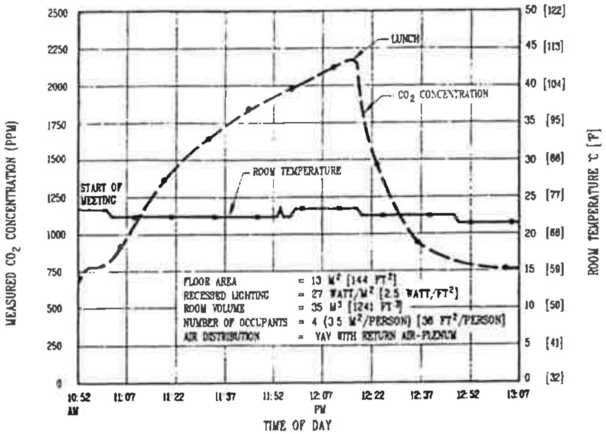

Fig 1. Measured carbon dioxide concentrations as a function of time in a conference room of an office building.

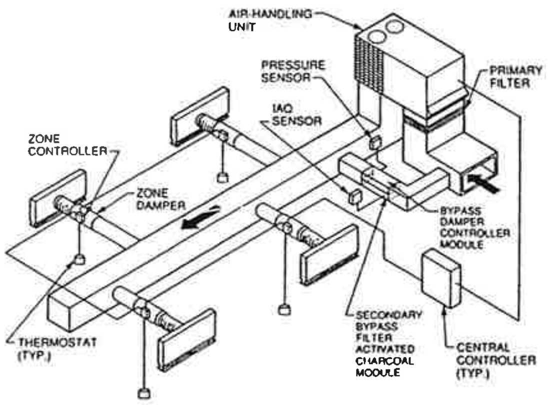

Fig. 2. Variable-air-volume/bypass filtration system.

comfort systems. The VAV/BPFS shown in Figure 2 employs an electronic control system which provides cost-effective and improved VAV comfort while simultaneously responding to varying IAQ requirements. A thermostat in each of the four zones allows the system air damper to carefully monitor and control the temperature of each zone that is most comfortable to its occupants by changing the air supply rate in response to "net-demands" for heating or cooling. Each zone damper can also communicate on a single-twisted pair of wires with the central controller which monitors each zone damper and the temperature. The central controller also automatically provides bypass control through direct air flow monitoring to allow constant fan-speed operation.

A factory-calibrated IAQ sensor, as an integral part of the VAV/BPFS, measures the concentration of VOCs in one or more zones or in a common return-air duct and independently resets the supply air temperature leaving the air-handling unit (AHU) to increase or decrease the flow through a filter/air-cleaner assembly in the bypass duct to maintain satisfactory VOC levels. Each AHU in VAV/BPFS can have one or more IAQ sensors. The IAQ sensor may be located either in the return-air duct or in the room. When it is located in the return-air duct, it senses the average contaminant concentration of all four zones combined. It may be more advantageous to locate the IAQ sensor in a "critical room," if the concentration of indoor air contaminants varies considerably in any one of the four zones.

Since VAV/BPFS is a constant-volume fan system at the AHU with colder air being delivered to all four zones, each zone thermostat will modulate its zone damper to close in order to match the increased cooling capacity of the supply air with the coincident space thermal load. Accordingly, if the AHU is in a heating cycle, then the supply air temperature will increase, and if the AHU is in a cooling cycle, the supply air temperature will decrease to reach the maximum permissible VOC concentration level. When the zone dampers modulate to close further, the bypass sensor senses the pressure build-up and automatically allows more supply air to be bypassed through the VAV/BPFS system bypass duct to the high-efficiency, filter/air-cleaner assembly.

The use of supplemental air-cleaning strategy provides energy savings because of a lower system filter pressure-drop and the lower capital cost associated with the air flow in the main HVAC system design. For an HVAC system with a VAV-bypass loop (whether a retrofit or new building), the main system filter efficiency can be determined at a maximum system flow rate instead of a minimum system flow rate [4]. Selected particulate filters must always be used in conjunction with gaseous-phase carbon adsorbers to remove VOCs [5]. Particulate filters are rated in accordance with their efficiencies on a mass mean diameter (MMD) of 0.3 micron and carbon adsorbers are based on VOC called toluene.

To illustrate the use of this filter selection criteria, let us consider both a retrofit and new building. Suppose the designer wishes to satisfy the minimum outdoor air flow rate of 9.5 L/s/person (20 cfm/person) for a retrofit office building (recommended by ASHRAE Standard 62-1989), using a reduced outdoor air flow rate of 2.4 L/s/person (5 cfm/person). Let us further assume that the building has a VAV system without a bypass loop, a supply air flow rate of 23.5 L/s/person (50 cfm/person), and ventilation effectiveness (E_v) of 65%, a typical office building.

Using Figure 3 [6][7][8], the designer locates the particulate and adsorption efficiency of 45% for a system supply air flow rate (V_s) of 23.5 L/s/person (50 cfm/person) 0.35 cfm/ft^2). The system supply air flow rate of 0.35 cfm/ft$_2$ is based on the recommended 7 people/93 m^2 (1000 ft^2) for an office occupancy in ASHRAE Standard 62-1989. Then, from Figure 4, for a MMD of 0.3 micron particulate size and the particulate and adsorption efficiency of 45%, the designer selects Filter C as the system filter.

For the same retrofit building above, let us now assume that the building has a VAV system with a bypass loop, V_s = 42.5 L/s/person (90 cfm/person), and E_v = 65%. Similarly, from Figure 3 for V_s = 42.5 L/s/person (90 cfm/person), the designer locates the corresponding particulate and adsorption efficiency of 20%. From Figure 4, for the particulate and adsorption efficiency of 20%, the designer selects Filter B as the system filter.

Most recent mathematical analyses have shown that if the required filter efficiency for the main system is relatively low, placing a high-efficiency filter in the bypass loop can improve IAQ, provided the bypass air flow rate does not exceed approximately 30% of the main system air flow rate [9]. This is shown in Figure 5 [6][7] for retrofit buildings. Referring to Figure 5, it can be seen that, if the bypass filter efficiency is less than 80%, the contaminant concentration in the occupied zone (a dimensionless ratio in Figure 5) will be greater than unity with increased bypass air flow rates and, therefore IAQ will suffer. On the other hand, if the bypass filter efficiency is greater than 80%, the contaminant concentration in the occupied zone will be approaching unity. As a result of this, IAQ will improve with reduced supply air flow rates, provided the bypass air flow rate does not exceed approximately 30% of the main system air flow rate. The effect of placing a high-efficiency filter in a bypass loop is also illustrated in Figure 6 for new buildings. For the retrofit building above, the designer selects Filter D using Figure 5 as the bypass filter with a corresponding bypass filter efficiency of 80% as shown in Figure 5.

Let us now consider a new building. Suppose the designer again wishes to satisfy the minimum outdoor air flow rate of 9.5 L/s/person (20 cfm/person) using a reduced outdoor air flow rate of 7 L/s/person (15 cfm/person). Let us further assume that the new building has a VAV system without a bypass loop, V_s = 23.5 L/s/person (50 cfm/person), and E_v = 65%. From Figure 7, the designer locates the particulate and adsorber efficiency of 30% and selects Filter C as the system filter (refer to Figure 4).

For the same new building having a VAV system with a bypass loop, V_s = 42.5 L/s/person (90 cfm/person), and E_v = 65%, the designer locates the particulate and adsorption efficiency of 10% in Figure 7 [6][7][8]. From Figure 4, the designer selects Filter A as the system filter. Similarly, using the same selection criteria for the retrofit building having a VAV system with a bypass loop, the designer selects again Filter D as the bypass filter with a corresponding bypass filter efficiency of 80% as shown in Figure 6.

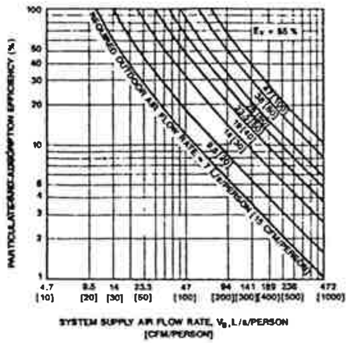

Fig. 3. Determination of system filter efficiency (retrofit buildings).

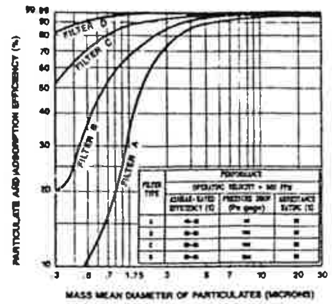

Fig. 4. A typical filter selection criteria.

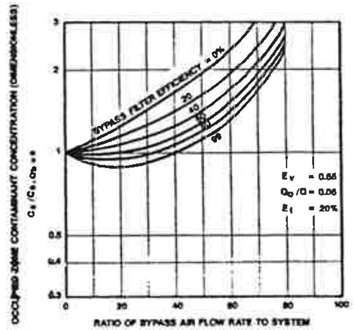

Fig. 5. Effect of VAV-bypass filter (retrofit buildings).

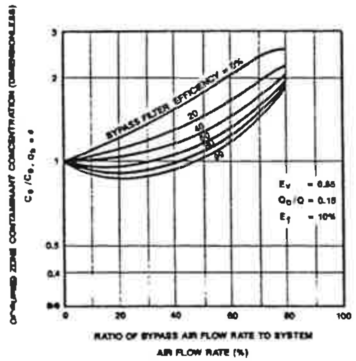

Fig. 6. Effect of VAV-bypass filter (new buildings).

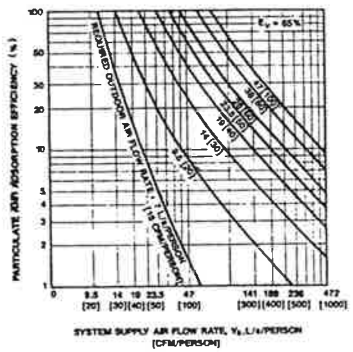

Fig. 7. Determination of system filter efficiency (new buildings).

CONCLUSIONS

The use of CO_2 DCV strategy can provide reasonable readings for full- or part-occupancies. To avoid either the falsely low or falsely high readings, instrumentation should be checked and calibrated periodically, be at or near return air grilles, and operations be at lease six ft away from instrumentation during calibration.

The reduction of supply air flow rate can adversely affect IAQ in buildings having VAV systems. Use of a supplemental high-efficiency filter assembly in the bypass loop can provide a means for offsetting reduced air supply rates without sacrificing IAQ. The temperature of each zone is carefully monitored and controlled to the level that is most comfortable to the occupants. Cleaner air is supplied to the occupied zone whenever the supply air flow rate is reduced during the VAV-mode of the system, and the VOC control can be achieved within 30% of the supply air flow rate, independent of the space temperature and humidity.

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MIXED-GAS OR CO_2 SENSORS AS A REFERENCE VARIABLE FOR DEMAND-CONTROLLED VENTILATION

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ABSTRACT

The purpose of the investigation was to gather information about the currently available types of sensor with regard to their suitability for providing a reference variable for demand-based ventilation, and to be able to estimate the associated energy-saving potenital. To this end, the air quality was measured continuously for a week in each of the following areas at the University of Zurich: the staff restaurant, a lecture hall for 300 people, and a large sports hall. The sensors used to measure indoor air quality were mixed-gas sensors [1] and CO_2 sensors. In order to evaluate the effect of temporarily switching off the ventilation system, the plant was operated manually at times.

It was found that, compared with conventional time-switch control, significant energy savings can be made by operating the plant on the basis of air quality demand, and that this does not significantly affect the comfort of users of the spaces. CO_2, released by respiration, serves as an indicator for the presence of people. Mixed-gas sensors respond to oxidisable gases and vapours. In addition to body odours, therefore, these sensors also measure the majority of other variables which affect air quality.

In a subsequent phase, the ventilation systems in the staff restaurant and sports hall will be operated on a demand basis, using mixed-gas sensors for the reference variable, so that the actual energy savings achievable can be quantified.

INTRODUCTION

In order to save energy, thereby reducing the burden on the enviroment, the majority of ventilation and air conditioning systems today are controlled by time programmes. The switch times are normally selected in such a way that the rooms are ventilated throughout the potential period of occupancy.

Experience shows that the number of occupants assumed at the design stage proves in practice to be the exception. In many rooms, moreover, the level of occupancy fluctuates widely over the day. This means that systems could be switched off at times, or at least operated at lower fan speeds, without any noticeable loss of comfort. In practice, however, this is rarely done manually. Sensors are therefore required, which will measure the ventilation demand. What is needed is a sensor which can quantify the quality of the air as registered by the human nose. Ideally, this would be a decipol sensor [2].

At present, however, there are no decipol sensors, and it is unlikely that they will ever exist in an ideal form. Experiments conducted within the framework of the "Demand-