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Demand controlled ventilation systems - indoor air quality and energy conservation

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Abstract

This article reports on the indoor environment created by two different types of ventilation control systems in an eleven-storey office building. The two ventilation systems tested consisted of: a conventional system controlled by outdoor temperatures, and a demand-controlled system regulated by indoor carbon dioxide concentration. The parameters being measured are dry-bulb temperature, relative humidity, formaldehyde, VOC's, CO_2, and energy consumption.

The results show that CO_2 control alone can cause thermal comfort problems, especially during the winter. The monthly electrical consumption using the CO_2-based system was always less than that of the other system.

Introduction

Commercial buildings are ventilated with outdoor air to replace the oxygen consumed and to dilute air contaminants created by occupants and their activities. ASHRAE codes specify the minimum amount of outdoor air that is to be supplied by ventilation systems, these are based on maximum occupancy conditions. Office buildings often have transient occupancy conditions which are generally below the maximum capacity and hence energy is wasted through over-ventilation.

Recent research has shown that CO_2 is the ideal indicator for indoor air quality. A carbon dioxide sensor that measures the occupant generated carbon dioxide can be used to control the use of outdoor air in a more efficient manner. A carbon dioxide controlled ventilating system could provide outdoor air when needed, that is when the CO_2 levels in a room exceed the control point, but restrict its use when it is not needed.

The two control systems were compared in terms of energy consumption, indoor air quality, thermal comfort, and occupant subjective response. Carbon dioxide, formaldehyde, VOC's and particles were monitored for one week per month for 12 consecutive months. Temperature, relative humidity, and energy demand were monitored continuously throughout the 12 months.

Building and experimental procedure

The building tested in this study was primarily chosen because each floor is serviced by its own independent, yet identical,

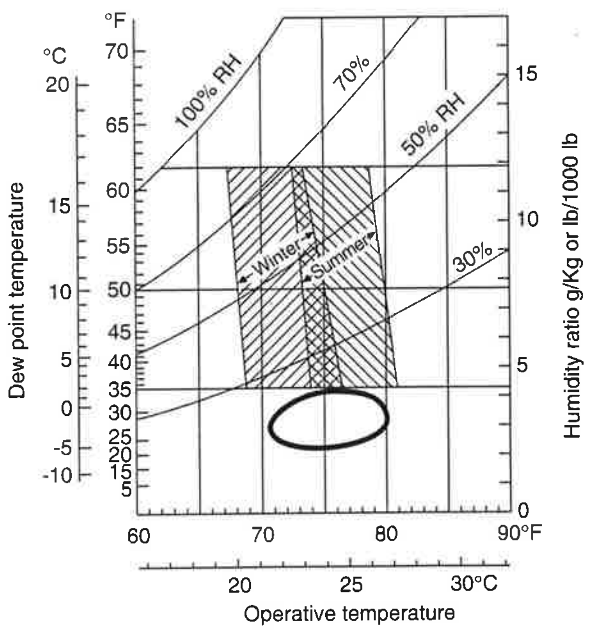


Figure 1: Measured temperature and relative humidity with respect to the standard.

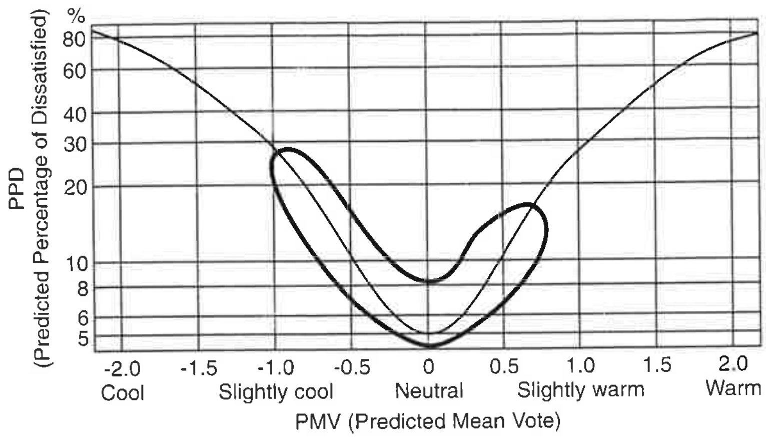


Figure 2: Predicted percentage of dissatisfied.

ventilation system. Also the occupation density of the building was highly variable.

The two floors chosen for the study were the eighth and ninth floors. These two floors had identical occupation densities, working hours, ventilation distribution, and workspace layout. The floors are divided into 60 to 80 open-area offices with four to six feet high partitions, 14 closed offices, four conference rooms, one lounge room, two public and two private washrooms, and six lifts. The building is occupied by approximately 100 white collar workers per floor, but varies since it is open to the public. The study considered only the open-area offices since the other offices are separated as to ventilation distribution.

The HVAC systems consist of two identical air handling systems per floor, which supply ventilation to all areas of the floor. A smaller system ventilates the conference room and closed offices only. The system consists of a double duct constant air volume system (CV) with the fresh air intake and exhaust on each floor, on the wall facing west. One hundred diffusers are located throughout each floor to supply the air flow to the various zones.

The conventional system functions by modulating the outdoor air dampers with respect to the temperature of the air. In the summer, if the supply temperature is high, the outdoor air dampers begin to close; if the supply temperature is low then, the outdoor air dampers begin to open. The opposite is true for the winter season.

The CO_2-based ventilation capability was added to the eighth floor air handling systems. The CO_2-based controller uses a highly sensitive infrared emission-type gas analyzer. The room air is pumped from the occupied zones to the gas analyzer through plastic tubing from the remote sensors located in the occupied space. The CO_2-based controller provides outdoor ventilation air to the space when the average space CO_2 concentration exceeds the control set point. The outdoor air dampers are opened to the minimum position when the lower limit set point is exceeded. As the CO_2 levels increase, the opening of the outdoor air dampers also increase, up to the maximum opening when the CO_2 levels reach the upper limit set point.

Ten CO_2 sampling stations were chosen in the occupied zones. A direct reading instrument was used to measure CO_2 every hour from 7:00 to 19:00 for three consecutive working days each month. Formaldehyde and VOC's were measured at six sampling stations in the occupied zones for a duration of three consecutive days each month, while the dust was collected for a period of three 10 hour working days each month.

Relative humidity and temperature measurements were taken at nine locations per floor and the total energy consumption was monitored for each floor.

Questionnaires were used to measure the subjective response of the occupants to their environment. No behavioral questions were asked. The questionnaires were distributed throughout the two floors, to all the occupants of the open-area offices, every third Wednesday morning of every month and were collected that same afternoon.

Results

The measurements indicated that the CO_2 levels remained well below the recommended limit of 1000 ppm set by ASHRAE. Throughout the course of the study the maximum CO_2 concentration attained was below 900 ppm.

The level of formaldehyde in the occupied zones was also found to be below the limits set by ASHRAE, the maximum approximately 63% below the accepted value. It was also observed that no particular work-station was more polluted than another.

The individual VOC levels were all found to be under the ASHRAE limits. The maximum stoddard solvent, toluene, and xylene levels were less than approximately 28%, 1%, and 2%, respectively of the standard.

The total dust level during the course of the study was found to be below the limit set by ASHRAE, expect for one case where the level exceeded the recommended value by 8%.

The air temperatures and relative humidity measurements showed that these parameters did not always remain within the ASHRAE comfort limits. The readings taken in the spring, summer, and autumn were almost all within the limits of the ASHRAE comfort zone. The readings taken in the winter were mostly below the comfort limits with very low relative humidities and uncomfortable conditions (see Figures 1 and 2). This is due to the fact that heating the outside air removes more moisture than the humidifier can supply to the air.

The energy demand for the floor that had the CO_2-based controller was lower than for the floor with the conventional control system. The monthly electrical consumption by the CO_2-based system was always less than that of the other system with the exception of one month (see Figure 3).

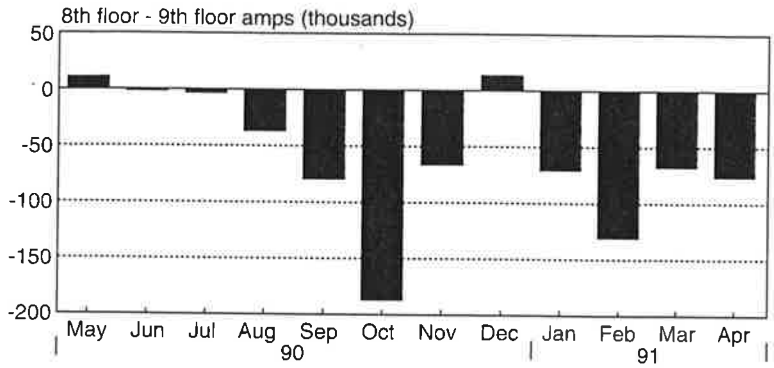
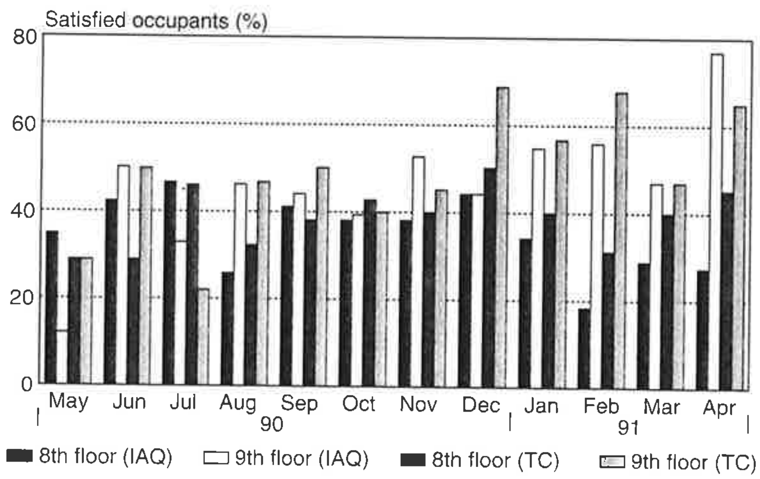


Figure 3: Monthly difference in energy demand.

The average response rates to the questionnaires for the eighth and ninth floors were 60% and 56% respectively. The results of the questionnaires showed that most of the time the occupants felt that the temperature was comfortable except for a few cases where the occupants felt cold. The majority felt the air was slightly dry to dry all of the time. The ventilation was considered to be adequate on the eighth floor at all times, except for a few cases where it was found to be drafty. It was never considered adequate by the majority of the occupants on the ninth floor. The air quality on both floors was considered satisfactory for less than half of the time by the majority of occupants, the majority of the occupants found that their physical environment had a direct impact on their productivity. Overall, less than 80% expressed satisfaction with the indoor air quality, and also less than 80% found the environment thermally acceptable for the entire testing period (see Figure 4).

Therefore, according to the ASHRAE standards, this environment is not acceptable with respect to indoor air quality and thermal comfort. This result supports earlier findings that the complaints are associated with perceived rather than measured levels of indoor environmental parameters.

Figure 4: Monthly percentage of satisfied occupants.



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