CHANGING SICK BUILDINGS INTO HEALTHY BUILDINGS: IMPROVING THE VENTILATION SYSTEM

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Abstract

Poor design, operation, and maintenance of the Heating, Ventilation and Air Conditioning (HVAC) system of buildings can result in inadequate ventilation and an unacceptably high prevalence rate of health and comfort symptoms among the building occupants. In many "sick" buildings, relatively minor alterations to the ventilation system can result in significant improvements in air quality and change "sick buildings" into relatively "healthy buildings". Several case studies are described in which the cause of the health and comfort complaints was traced to correctable problems with the ventilation system.

Introduction

A high prevalence rate of mucous membrane irritation, eye irritation, headache, lethargy, fatigue, nausea, dizziness, and skin rash among building occupants is an indication that the building is "sick". In addition, the occupants of sick buildings often report environmental problems such as a lack of fresh air, stuffiness, inadequate temperature control and unpleasant odors. This problem, which can be defined as the "sick building syndrome", has been widely studied in both Western Europe and North America since it was first recognized in Scandinavia in the early 1970's (1).

The cause of the sick building syndrome is sometimes difficult to determine, though in many cases a suspected or probable cause has been identified. Identified causes range from inadequate ventilation, exposure to specific chemical and microbiological contaminants, work-related stress, air ions, and vibration (2,3). However, the most frequently identified factor has been "inadequate ventilation", which includes other factors, such as poor temperature control, which are related to the operation of the building's Heating, Ventilation, and Air-Conditioning (HVAC) system. Inadequate ventilation has been identified as a suspected causal factor in 50% of 356 building investigations conducted by NIOSH between 1974 and 1985 (2), and in 68% of 94 Canadian building investigations conducted by Health and Welfare Canada in 1984 (3).

Correcting Inadequate Ventilation

Some of the causes of sick building syndrome are extremely expensive to correct. For example, contamination by an allergenic microbe can require the replacement of all of the carpeting, ductwork, and furniture in a building. In contrast, correcting a problem caused by inadequate ventilation can often cost very little, although sometimes an expensive solution is required. In general, there are three types of solutions for sick building problems caused by inadequate ventilation: changing the operation of the HVAC system; changing the design of the system; or improving the system maintenance.

Several examples of each type of solution are given below. Most of the examples are drawn from building investigations in Vancouver and Victoria, British Columbia, Canada, conducted by Theodor D. Sterling and Associates, a Vancouver based company which specializes in indoor air quality research.

Changing the Operation of the HVAC System

Since the trend towards energy conservation in the mid 1970's, the design and operation of HVAC systems in North American buildings have been guided by ventilation and thermal comfort standards developed by the American Society of Heating, Refrigerating and Air Conditioning Engineers (ASHRAE). The ASHRAE ventilation standards define minimum fresh (outside) air supply rates to achieve "acceptable indoor air quality". Sick building syndrome has frequently been observed when the fresh air ventilation rate is less than the established standard. In these cases, an increase in the supply of outside air has often reduced occupant complaints. For example, an increase in the fresh air supply from 5-7 cubic feet per minute (CFM) per person to 25-32 CFM per person in a California building resulted in a decrease in the percentage of occupants reporting health symptoms from 60-73% to 25-32% (4). An increase in the amount of fresh air may cause an increase in energy costs, but may substantially improve indoor environmental conditions, and reduce occupant health and comfort complaints.

Changing the Design of the HVAC System

Poor Air Distribution. Increasing the amount of fresh air provided by the HVAC system will not change a sick building into a healthy building if poor air distribution prevents the fresh air from reaching the occupants.

Poor air distribution can be caused by "short circuiting" in which the air supplied to a space is exhausted without ever reaching the occupied zone at desk level. For example, both the supply and return air vents in an office building in Victoria were located in close proximity in the ceiling. The supply air was exhausted through the return air vent before it reached the desk level. A similar problem of poor air circulation can occur when air flow patterns are disrupted by interior partitioning. The result is a stratification of air, with no air movement at the occupant desk level.

Poor air distribution problems can sometimes be solved by very simple adjustments, such as by changing the direction of air flow from diffusers. Lifting interior partitions to leave a 10 cm gap between the floor and partition can also improve the air distribution and reduce th prevalence of occupant complaints (5). In other buildings more extensiv work is required, such as extending the ductwork in order to move the fresh air supply diffusers downwards from the ceiling.

Poor Temperature Control. Changing the placement of temperature controls can result in a decrease in the prevalence of complaints that the temperature is too hot or too cold. For example, in an office building in Victoria, a single thermostat served a large open-plan area The thermostat was located on an interior column which faced a window and was occasionally exposed to direct sunlight. The thermostat reacte to the high heat load caused by the sunlight and restricted the amount of heat, causing uncomfortably cold conditions in the interior offices. The recommended solution was to relocate the thermostat to the interior of the column and, if necessary, to use blinds during the times of direct exposure to sunlight.

In some cases, temperature control problems cannot be solved inexpensively. For example, each floor of a Vancouver building containe a single zone mechanical system and one thermostat. The third-floor office was divided into open plan and private offices and the thermosta controlling the floor was located in the supervisor's private office. The heating requirements for the total space were therefore determined by one individual's temperature preference. Other occupants complained that the supervisor kept the temperature too low. Several occupants had taken small electrical heaters into the workplace. The solution to a problem such as this is substantially more difficult than simply moving the thermostat to a more representative location. Because of the mixed office type, an appropriate design solution may be a localized control system with thermostats throughout the floor controlling heat pumps or duct mounted coils. However, such a solution would be expensive to retrofit. The potential for this type of problem should have been avoided during the design of the building.

Air Intake Placement. The placement of the fresh air intake for the HVAC system is a very important factor in the overall indoor air quality. There are a large number of documented cases in which problems were caused by placing the fresh air intake in locations where the quality of the fresh air was poor. In these cases, the air intake had been located near the air exhaust systems of other buildings or HVAC units, or close to busy streets or parking garages where they drew car and truck exhaust into the building.

For example, the occupants of an office area in a public library in Victoria complained of unpleasant odours and typical symptoms of the sick building syndrome. Inspection of the HVAC system showed that the outside air intake for the affected area was located at grade level on a busy downtown street. The problem was intensified by the proximity of the outside air intake to a commercial loading zone where trucks were often left running. The recommended solution was to relocate the outside air intake to the roof at an estimated cost of $60,000.00. This cost should have been avoided in the design phase of the building.

Inappropriate Modifications to the Building. Sick buildings are often created by modifications to the building. The HVAC system of an office buildings is frequently designed for a specific use or floor plan. Later alteration of the designated floor plan can prevent the HVAC system from functioning effectively and cause a deterioration of indoor air quality. The solution is to either return the floor plan or building use to the original design or, more frequently, to undertake further modifications.

For example, the mechanical systems of many office buildings are designed for open-plan offices. Air quality can suffer if the space is fragmented either by head height partitions or by full walls. In one Vancouver building, fresh air was supplied to the interior portion of the floor and the air was exhausted from vents at the perimeter of each floor. Heated, recirculated air was also supplied to the perimeter of each floor by fan coil conditioners in the ceiling plenum. A review of mechanical plans indicated that the system was capable of adequately ventilating an open-plan floor. However, individual offices had been constructed at a later date by a new tenant around the floor perimeter. Consequently, these enclosed, perimeter offices were supplied only with recirculated air from the fan coil conditioners. Most of the occupants of the perimeter offices kept their doors open whenever possible. However, they still reported symptoms and environmental complaints typical of sick building syndrome. The design solution was to extend some of the fresh air supply ducts to the perimeter and some of the exhaust ducts to the interior of the floor.

Altering the HVAC system itself can also cause problems, as shown in a Vancouver building which housed the offices of a social service agency. The offices consisted of a waiting room, a reception area, and several private offices. The waiting room was used by transient low-income individuals. The odor problem had been caused by a series of modifications to the original HVAC system which had affected the air flow patterns in the building. The building investigation determined that the air flowed from the waiting room into the offices and reception area, thus transporting unpleasant odors. The recommended solution was to reverse the direction of air flow by increasing the amount of air supplied to the offices and by improving the exhaust system in the waiting room.

Improving Maintenance

HVAC systems must be regularly maintained in order to effectively control indoor environmental conditions. However, HVAC systems are frequently poorly maintained. Many maintenance problems are a result of a lack of understanding by both building managers and occupants of the importance of the HVAC system and how it operates. The solution is provide the necessary information and to improve the maintenance program.

For example, the building managers of one Vancouver building were not sure who maintained the HVAC system. After several phone calls, it was determined that a service contractor visited the building annually to change the filters. Inspection of the building, which was served by six HVAC units, indicated inoperative thermostats and a general state of disrepair. Not surprisingly, the occupants had reported typical symptoms of sick building syndrome. The recommended solution was to commission an engineer to evaluate the HVAC system, design appropriate retrofit actions, and develop a regular maintenance program.

The building superintendent of another Vancouver building did not appear to understand how the system operated. The building superintendent stated that one system served the whole building even though each floor of this two-storey building was served by an independent HVAC unit on the roof. However, the HVAC system for the first floor had broken down and as a result no air was being delivered to this floor.

Clogged filters, inoperative rooftop air handling units, and broken exhaust fans in parking garages, all of which could have contributed to sick building problems, have been found in other buildings. Most of these problems could have been avoided by regular maintenance.

In some cases a sick building can be changed into a healthy building by the very simple process of explaining how the HVAC system works to the building occupants. The occupants of one Vancouver building complained about a lack of fresh air and poor air movement, particularly in the spring and fall. These occupants had unknowingly turned their office into a sick building by a failure to understand the use of the thermostatic controls. The building thermostat included a switch for either continuous fan operation or for operation only when heating or cooling was required. The fan had been set by the occupants for periodic operation and as a result no fresh air was delivered during periods of the spring and fall when no heating or cooling was required. A simple flick of the switch was all that was required to begin the process of changing this sick building into a healthy building.

Discussion

Overall, many sick buildings could have been prevented if architects and engineers had a better understanding of the health and comfort problems that can be created by poor building design and if the building managers and occupants had a better understanding of the operation and design of HVAC systems. Maintaining buildings in a healthy state means that architects and engineers must ensure that the HVAC system is capable of meeting established ventilation standards in all occupied areas of the building and the building users must ensure that the HVAC system is properly maintained and that modifications to the building do not affect the ventilation system. One of the first steps towards healthy buildings is to improve communications between design professionals such as architects and engineers and between these professionals and the building managers and occupants.

References

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