Introduction of an Energy Efficient Ventilation System

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ABSTRACT

Differences might arise between the design and the real load of ventilation systems during operation. Consequently, the fresh air demand usually varies over a wide range. In normal usage, different types of gaseous contaminants enter the air that might be hazardous to health. The constant inhalation of contaminated indoor air might lead to discomfort or to harmful physiological effects.

The difference between the design and the real load can be diminished by augmenting the ventilation system with appropriate components and controls. The proposed additional control system tracks the actual load and supplies the necessary supplemental fresh air without disturbing the air supply to other spaces. The benefit of this system is that the required air quantity is supplied to follow the load but no energy is wasted for the heating and cooling of spaces where the system's fresh air demand is below the design load.

KEYWORDS: Indoor air quality, gas-contaminants, energy efficiency

1. PRELIMINERIES

Differences between design and load

Because of various reasons, differences might arise between the design and the real load of ventilation systems. The customer is not aware of the exact load, the number of people, and the equipment heat load in the spaces at the time of the design. The load, the number of people or the equipment heat load changes considerably during operation of the ventilation system. The layout of the space is altered resulting in changes of the volume and the air flow or the function of the space is changed.

These variations cannot be predicted, though it is not possible to mitigate the effect of the load distribution changes during operation. Thus the whole ventilation system should be developed in a way that it would be capable of furnishing sufficient fresh air according to the varying load.

Operating condition

The load, that is the fresh air demand, usually varies over a wide range during operation of the ventilation system. This resulted because of natural usage of a ventilated building where occupants' number might vary in wider scale.

In addition to the requirements on the thermodynamic properties of the circulating air, for example temperature and humidity, there are requirements on its chemical composition. During normal usage, different types of gaseous contaminants enter the air that are hazardous to health. Most common of these contaminants are carbon dioxide and carbon monoxide. Carbon monoxide, especially common where people are smoking, is a poisonous gas. Carbon dioxide that is used as the most common indicator of the indoor air quality, is not poisonous but in continued excess concentration might lead to oxygen deprivation. Moreover, the state of the art doors and windows developed in order to diminish energy demand, does not allow any false air filtration. It is important to keep these gaseous contaminants below the permitted concentration limits, especially where forced ventilation is the single source of the fresh air supply. In such systems, there is no mixing of fresh air through natural circulation. The constant inhalation of the contaminated indoor air leads to discomfort and possibly to harmful physiological effect. The increased concentration of this kind of contamination can be continuously and reliably measured and controlled by appropriate instrumentation. Since both of these contaminant gases are colorless and odorless, the occupants are not aware of their presence. Occupants are affected to varying degrees, depending on their individual susceptibility, particularly their alertness and effectiveness.

According to estimates office workers, for example, spend nearly 90% of their lives indoors. Considering ventilation, offices can be regarded as continuously operating buildings, where people sojourning usually in the same room and mostly at the same place during their working hours. It can be assumed that the individual performance depends beyond on their own capability, on their surrounding's conditions. The indoor air and its quality is not a negligible part of this surrounding. It is composed of two main aspects, the physical and the chemical one. The physical characteristics such as temperature and humidity can be measured immediately and directly. The most common contamination, the developing carbon dioxide quantity is selected in professional practice to determine the necessary fresh air volume. By measuring its quantity using reliable devices, its supplied volume can be controlled and the indoor air designed physical characteristics can be easily maintained. To the contrary, the quality of the indoor air can not be measured directly. It is worth to analyse, what kind of relation might be found between the indoor air quality and the efficiency of the occupants' performance. That is, to study, what kind of effect might have the most common physical and chemical characteristics that determine the indoor air quality, on occupants' health, capability, efficiency or productivity.

Next, there are some concerns to prove the importance of the appropriate indoor air quality. In general, office workers do complete highly responsible work; planning, contemplating, decision making, appraising, showing direction to multitude. Their activities, that is occupants' effect by all means influence decisively a lot of people. It is obvious, that the excellences of the mentioned contemplating, directives, decisions depend on occupants' actual spiritual, mental and physical state. It is more then probable, that they show the highest result in their quality of work when they are in a comfortable condition. In the contrary, their decisions might be disadvantageous, they might show false direction or unfavorable timing might marks them when for any reason their abilities diminish. This diminution does not occur at once, it is always the result of some process caused by different spiritual, mental, or the surrounding's inappropriate physical or chemical impacts. Among this latter can be mentioned the offices' indoor air quality. Depending on the component of the air, the contaminations that are generated inside the ventilated room or transported from the outside the room, affect the occupants in a varying degree. This might lead to indisposition or even to probable physiological changes. Being a work place, occupants have no possibility to leave the room to go to another place or outside for fresh air, when they do not feel comfortable because of the indoor air unsatisfactory quality.

2. OUTLINES

Proposal

The task, the objective of the study, is twofold: prevent the probable harmful effects on occupants' health in spaces with forced ventilation on the one hand, and operate the ventilating system in an energy efficient way, on the other. This can be accomplished with the proposed ventilating system. The goal of the air supply system is the maintenance of the optimal environment conditions for varying load conditions. The ventilation system's control is based on the variation of the concentration of harmful gaseous contaminants, supplying only the required fresh air volume to the space. Energy efficient operation is assured by supplying only the required fraction of the nominal air volume under part load conditions, and handling the increased air volume when the system load increases. It has to be stressed that this system is only one embodiment among numerous solutions.

The proposed ventilating system allows differentiated supply into several independent spaces at a time. The duct system supply and return should be separated by spaces or by extension of given areas. Motor driven dampers are in every supply and return branch air duct, while the necessary control devices are mounted in the main air duct and in the ventilated spaces. The main difference from traditional ventilation systems is not only the usage of supplemental equipment, but also in the selection and the sizing of the elements of the main system. The basis of the sizing is not a specific air volume any more, but a range of air volume. During sizing, both the lowest and the highest load limits need to be considered.

The proposed system will supply additional fresh air to limit the concentrations of harmful contaminants. In case of under-utilization, the energy of the heating, cooling and the transportation of the excess air can be spared.

Description

The proposed additional fresh air supply can be assured by installing supplemental equipments. These are parts of design, of mounting, of operation. The ventilating system is oversized; the main parts, the air handling unit, the main air duct, the air inlet and outlet devices are typically selected for 120% load. The supplemental equipment consists of: a return duct, air volume sensor, pressure sensor, air volume controlling device in the room's branch air duct, inlet and outlet grids supplied with controlling device, check valve in the air duct collecting and transporting the surplus air, and gas-sensors in every ventilated space. The additional control system monitors and keeps the most frequently developed gas contaminants, the quantity of carbon monoxide and carbon dioxide of the indoor air below the harmful limit. It measures the concentration of the contaminant at given time-intervals. Whenever requested, it displays the monitored quantity, and it registers the data. The gas sensor measures the contamination level, and depending on the measured value, opens or closes the room's air volume control device. This latter actuation is followed by the fresh air intake louver's and the fan's adjustments. The system gives alarm signal if the contamination level surpasses the permitted limit longer than a permitted time period. The gas sensors are mounted at a given height in every room, and the supplementary fresh air quantity depends on the measured concentrations. The suggested additional control system does not substitute the control system based on the customarily controlled temperature and humidity. The appropriate air quality in the ventilated spaces can be assured by coordinated operation of the two control systems. The layout of the ventilation system is shown in Figure 1.

The path for the additional fresh air should be assured during operation. During periods of low loads, the third duct collects and transports the excess, already handled air to the fan inlet. Thus, the fan is operating continuously with 100% air volume, working on its highest efficiency. The advantage of this system is that only the required air quantity is supplied, and no energy is wasted for the heating and cooling the air volume difference. The smaller fans indicated on Figure 1. are provided for extended periods, potentially several days, of low load conditions.

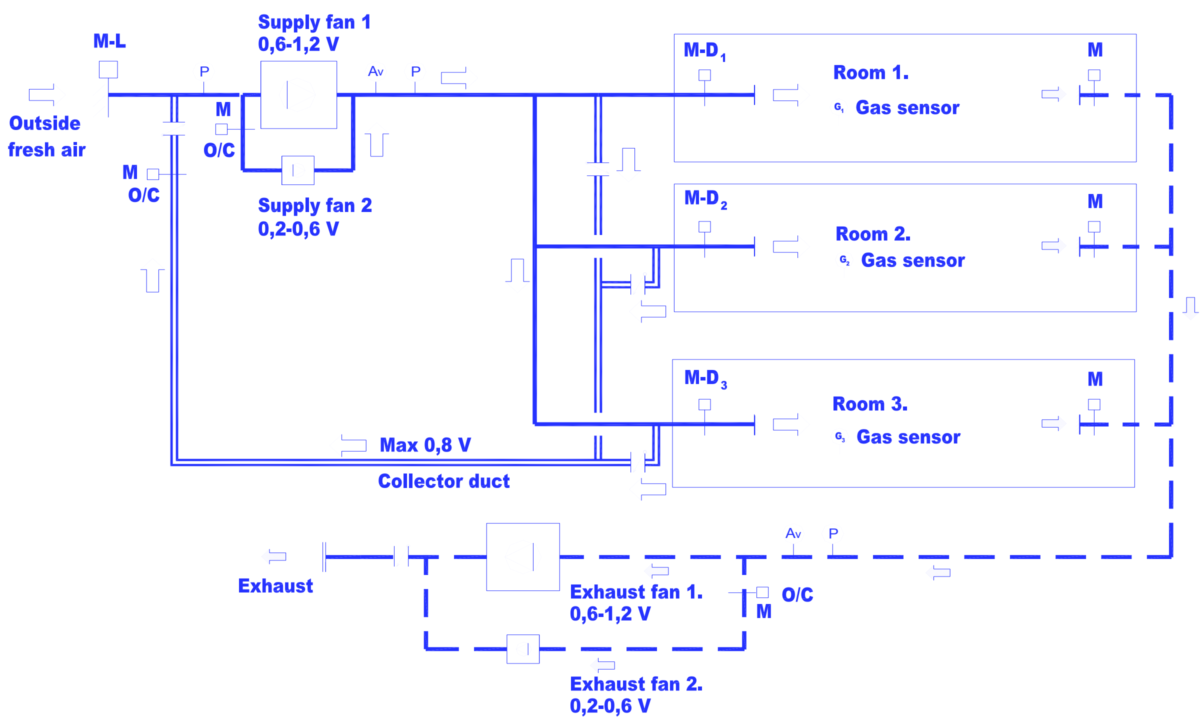

Figure 1: System Layout

By monitoring the frequency of the intervention of the auxiliary equipment, the building operator can establish whether the load in the destination room is within the ventilating system design limits.

Main asset of this method is the prevention of time-consuming evaluation of the indoor air quality based on the occupants' opinion, and avoiding any uncertainty because of the occupants' actual and probable variable dissatisfaction.

The mentioned supplemental elements are readily available on the market. It can be easily proved that these are one-time expenses that will be recovered not only in the enhanced efficiency of the people working in the ventilated spaces, but also, in energy savings. Although the proposed ventilation system is theoretically beneficial, its efficiency can only be proved by experimental testing. Therefore, it is necessary to install a prototype ventilation system with control that is based on the most typical gaseous contamination content, to monitor its performance during whole heating and cooling seasons, to analyze the results.

Operation

According to accepted practice or standard, the air quality is appropriate in a workplace if the carbon monoxide content is below 30-35 ppm during 30 minutes. Also, there are recommendations for suitable air quality below 1 000 ppm CO_2. Fresh air supply is requested if the concentration of one of the contaminants exceeds these values.

The following discussion comprises the typical situations that might occur during furnishing the fresh air due to demand. There might be normal operation, under- or over-ventilation according to the variation in actual load. These are the following:

Normal operation, the CO_2 sensors average reading including the supply air CO_2 content, remains below 1000 ppm. The room's air volume controlling devices and the fresh air inlet louver are adjusted to deliver V_{nom} air volume. The supply 1. and exhaust 1. fans are working. The additional smaller fans are off. The air valves of supply 2. fan, and exhaust 2. fan and the motor driven damper of the collector duct are closed.

When the load in the space exceeds the design conditions, there is need for supplemental air. The CO_2 sensor's average reading exceeds 1000 ppm. For the whole system's high limit of the air flow has arbitrarily been chosen at 1,2 V_{nom}. The air supply control devices and the fresh air louver are adjusted to supply up to1,2 V_{nom} air. The pressure sensor in the main air duct indicates decreased pressure. The supply 1. fan and exhaust 1.fan are working. The additional smaller fans are off. The air valves of supply 2. fan, and exhaust 2. fan and the motor driven damper of the collector duct are closed.

The load in the space is under the design conditions, only a fraction of V_{nom} is needed. The low limit of the air volume is 0,2 V_{nom}. The rooms' air volume controlling device closes, until the CO_2 sensors indicate 1000 ppm. The fresh air inlet louver is adjusted, closed accordingly. The pressure sensor in the main air duct indicates pressure elevation. Supply 1. fan and exhaust 1.fan are working, their transports are diminishing up to 0,6 V_{nom} air volume. These fans stop below 0,6 V_{nom} air volume. The return duct's damper is open. Supply 2. fan and exhaust 2. fan are working, when the request for fresh air drops below 0,6 V_{nom} up to 0,2 V_{nom}. The air valves of supply 2. fan and exhaust 2.fan, and the damper of the collector duct are now open.

3. CONCLUSION

Often lead to inadequate performance of the ventilation system, when the number of people changes for a long period in the ventilated space. Such performance anomalies can be diminished or eliminated by augmenting the ventilation system with appropriate controls. The generated invisible, odorless contaminants' high concentration might be hazardous to the health and to the performance of people there. The proposed ventilation system works reliably with any air distribution system. It continuously monitors the concentration of the gaseous contaminants, and generates alarms when necessary. The system supplies additional fresh air to the room based on the sensors' signals without disturbing the ventilation of other rooms. It can be added to existing, operating ventilation systems.

By applying this system, the required supplemental fresh air can be supplied while minimizing the energy demand of the ventilating system and, consequently, the operating costs. It has to be stressed that the energy saving can reach significant rate under part load conditions. That is, the ventilation system's energy consumption depends solely on the actual load.

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NOMENCLATURE

V	nominal fresh air demand
CO_2	carbon dioxide sensor
$M\text{-}D_1$	room air volume controlling device
M-L	fresh air intake motor driven damper
M	motor driven damper
P	pressure sensor
Av	air flow sensor
O/C	open or closed