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AIR QUALITY

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Automatic control of air quality

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This paper considers the potential for energy conservation in air conditioning systems for areas with sharply varying occupancy rates.

The volume of outside air supplied to mechanically ventilated rooms with sharply varying occupancy rates, e.g. cinemas, department stores, multi-purpose rooms, lecture and conference rooms of all kinds often exceeds the actual requirement for fresh air. Air conditioning and ventilation systems with fixed minimum outside air requirements will supply too much outside air when the rooms are not fully occupied. This can result in higher energy consumption than necessary as the surplus outside air has to be distributed and, depending on the system, heated, cooled, humidified or dehumidified.

Air quality control enables the outside air volume to be controlled according to demand, thus minimising ventilation and distribution losses. The controlled variable in this application is the room air quality as measured by an air quality sensor.

Air quality

The volume of outside air that needs to be supplied to a mechanically ventilated room depends heavily on the extent to which the room air is affected by contamination and odours. Contamination and odours have numerous sources.

For example, occupants emit water vapour and carbon dioxide by perspiration and breathing. They also produce body odours. Contamination can also be caused by tobacco smoke, building materials, open fires and evaporation of liquids (e.g. alcohol in restaurants, chloride in swimming pools, household cleaning preparations etc.).

Too high a concentration of certain gases can damage health. Even low concentrations can cause discomfort and make the room air seem unpleasant. Either condition, however, can contribute to the Sick Building Syndrome. A "sick building" condition exists when more than 20 per cent of the building occupants develop health complaints that disappear outside the building environment.

Air quality is a complex concept which is determined by many factors. People judge air quality with their noses. Odours are noticed in particular when people enter a room. After they have been in the room for some time they become accustomed to the poor air quality. The sensitivity threshold to contamination is increased. Since the various gases that contaminate the air all have different effects on odour, it is not easy to measure air quality. Let us look at an example.

Recent studies tend to suggest that the levels of carbon dioxide in the air are directly related to the air quality in the room. Increases in CO_2 level correspond to a degradation in air quality. The conclusion is that by measuring CO_2 levels, building fresh air levels can be adjusted to ensure a minimum air quality is maintained. The problem with this method is that carbon dioxide does not sense bad odours, tobacco smoke and the like.

Tobacco smoke represents a very heavy room hygiene load. Consisting of more than 2,000 different components[1], tobacco smoke demonstrates the complexity of the term air quality. Similar problems occur with other sources of poor air quality such as formaldehyde which is released from some building materials. Formaldehydes can cause irritation of the eyes and respiratory tracts.

Air quality and outside air rate

In light of the situation that suitable measuring variables for air quality do not exist the minimum outside air volume required for hygienic reasons has been fixed in most ventilation standards as the outside air rate (m^3/h per person).

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The outside air rate varies according to the room type and is considerably higher if smoking is permitted. The outside air volume, therefore, depends on the size of the hygienic load, i.e. on the room type, purpose of the room and the occupancy rate.

The outside air rate is a useful design variable for rooms and buildings where occupancy rate and hygienic load are known and fairly constant. There are, however, many rooms where this does not apply e.g. multi-purpose rooms, cinemas, conference rooms, restaurants, etc. in which it is not only the occupancy rate which varies sharply but also the room air quality because of smoke and odours from meals, cigarettes, occupants, etc. If the design outside air volume for rooms of this type is based upon satisfactory air quality when there is a maximum load, then

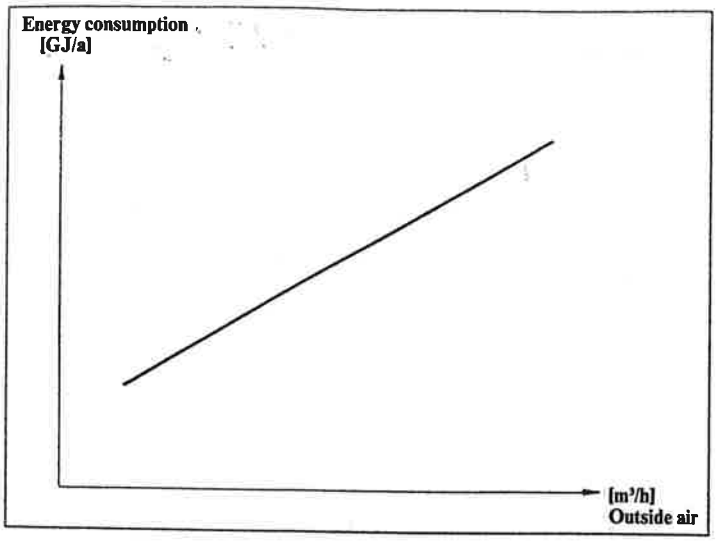


Fig 1: Correlation of energy consumption and outside air volume.

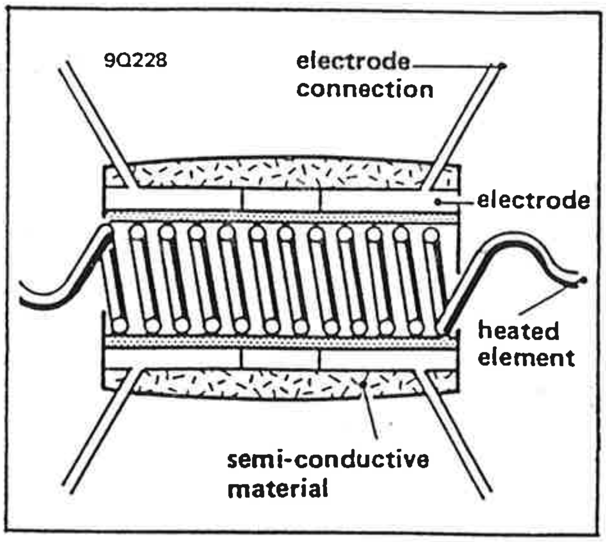


Fig 2: Air quality sensor (schematic)

there will be a surplus of outside air when the room is not fully occupied. This surplus, i.e. the outside air which is not required, still has to be handled, consuming in the process almost the same amount of energy as that needed for fully occupied rooms.

Outside air is expensive. The energy consumption of a HVAC system is determined to a large extent by the outside air volume (see Fig. 1),[4].

Heating, cooling, humidifying, dehumidifying, can consume more than 50 per cent of the annual energy costs of a HVAC plant[2]. Consequently, the need to reduce outside air rates is one of economic importance. Significant outside air reductions, however, are almost impossible because even with the implementation of economy or energy recovery cycles, or the like, to minimise outside air rates to those permitted by various design standards (ASHRAE, DIN, etc.) still will not guarantee good air quality.

One logical solution is to make the supply of outside air dependent on the actual hygienic load in the room.

Manual air quality control

One step in this direction, even if only a compromise, is to use step switches for manually controlling the supply air volume in intermittently occupied rooms. Experience has shown, however, that this manual control is often used incorrectly, i.e. either there is insufficient outside air supply which causes the air quality to drop or there is a surplus of outside air which negates the energy saving effect of the system.

Incorrect use of manual control is partly due to the fact that the human sense of smell becomes accustomed to sustained odours. A fairly objective judgment of the room air quality by, for example, the manager of a restaurant is almost impossible after a time.

Automatic air quality control

With an air quality sensor it is possible to measure the room air quality continuously and to adjust the outside air volume automatically to the room air load, thus minimising ventilation losses. The air quality sensor uses the odours in the room air as a measure of the hygienic load. An air quality sensor is so sensitive it will even detect odours of low intensity, thus ensuring that the room air is virtually odour free. This method will also ensure that the carbon dioxide content in the room air remains within a small range.

The operating principle of the air quality sensor is based on the findings that a decrease in air quality is accompanied by an increase in combustible (non-oxidised) gases in the room air. These gases are caused by human perspiration (ammonium hydroxide, methane, fatty acids), cigarette smoke, kitchen vapours, etc.

The sensor itself works on the Taguchi principle[6]. It consists basically of a heated element inside a semiconductive tube (zinc dioxide) (see Fig. 2),[5].

The semi-conductive material is porous with a large surface area that is able to adsorb oxidisable gases. During this adsorption process electrons are released, which increases the conductivity of the semi-conductor. This process is reversible. If the gas concentration decreases, the gases are diffused from the semi-conductor. The sensor responds very quickly, within a few seconds. It is not subject to wear, which means it will operate reliably for years. Above all, however, is one significant feature and that is the sensor is not selective, i.e. it measures the total gas concentration even if several gases occur simultaneously. It responds with varying degrees of sensitivity to many different gases such as hydrogen, carbon monoxide, hydrocarbons, alcohols, esters, benzene etc. Table 1 illustrates some of the broad categories to which the air quality sensor is responsible. In this respect the sensor corresponds very closely with the human sense of smell.

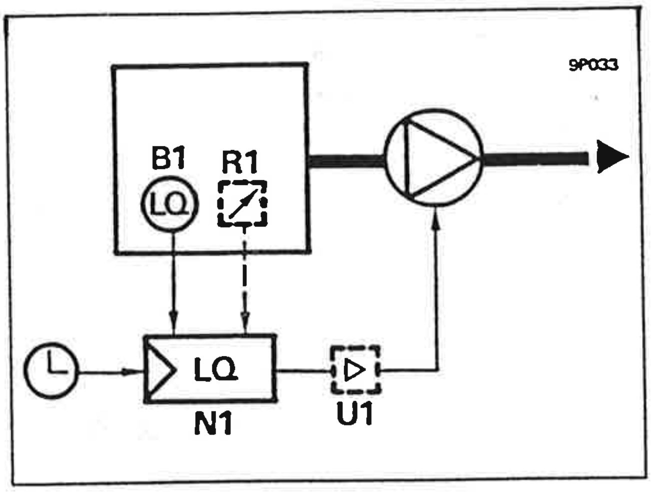
The sensor used in conjuction with a suitable controller (analogue or DDC) can be used to effectively control outside air volume being supplied to a conditioned space. The controller will compare the air quality measured by the sensor with a preset response value (setpoint). According to the deviation from the setpoint it increases or decreases in sequence the outside air volume via an associated control device (air damper). The controlled variable can be a proportional signal and a voltage free change over contact (SPDT), thus making not only modulating control of the outside air dampers or the fan speed possible but also step control of the fan speed.

System examples for air quality control

The following system examples are all taken from actual cases and illustrate three typical applications for air quality control. As shown in the examples air quality control can be used as a self contained system in simple extract air systems (toilets, kitchens, etc.) or as a part of a more complex control system

Hydrogen Sulphide	Freon-22	Trichloroethylene
Vinyl Chloride	Ammonia	Acetone
Methyl Ethyl Ketone	Freon-12	Ethanol
Hydrogen	Propane	Nitrogen Peroxide
Methanol	Methane	Chlorine
Gasoline	Methyl Chloride	Carbon Dioxide
Formaldehyde	Carbon Monoxide	

Table 1: A Portion of the Gases to which the Air Quality Sensor is responsive.



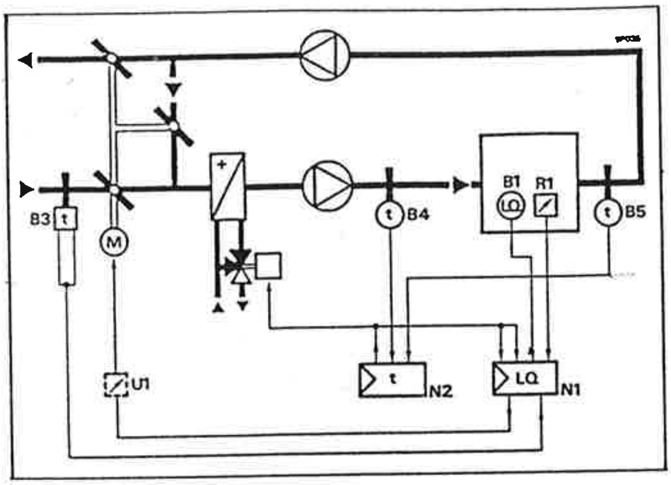


Fig 3 (left): Air quality control in an exhaust air system.

Fig 4 (right): Air quality control combined with temperature and damper control.

in central air conditioning plant.

Exhaust Air System (Fig. 3):

Operation:

The room air quality sensor (B1) measures the value of the air quality which is then compared in the controller (N1) with the setpoint pre-set on the controller (N1) or on the remote setpoint potentiometer (R1). According to the deviation from the setpoint the controller (N1) switches the fan on or off.

Alternatively, modulating control of the fan speed can be achieved using the speed controller (U1).

The time clock can override the air quality controller at pre-set times (e.g. during the night).

Return Air with Heating (Fig. 4):

Operation:

The air quality controller (N1) compares the measured air quality value in the room (sensor B1) with the pre-set setpoint. It subsequently adjusts the proportion of outside air in the supply air volume via the dampers, according to the deviation from the setpoint.

The temperature control acts on the air dampers and the hot water heating valve and is additionally fitted with a low limit control for the supply air temperature. The damper signal of the temperature controller (N2) is transmitted via the air quality controller where it is interconnected such that the signal with the highest demand for outside air has priority. The 'free cooling' function is thus not inhibited by the air quality control (as an alternative, a minimum proportion of outside air can be set on the potentiometer U1).

The output signal of U1 is, at the same time, transmitted to the interlocking input of the air quality controller, thus locking out the air quality sensor during the warm up period (valve fully open).

In extreme outside air temperatures the proportion of outside air may be set

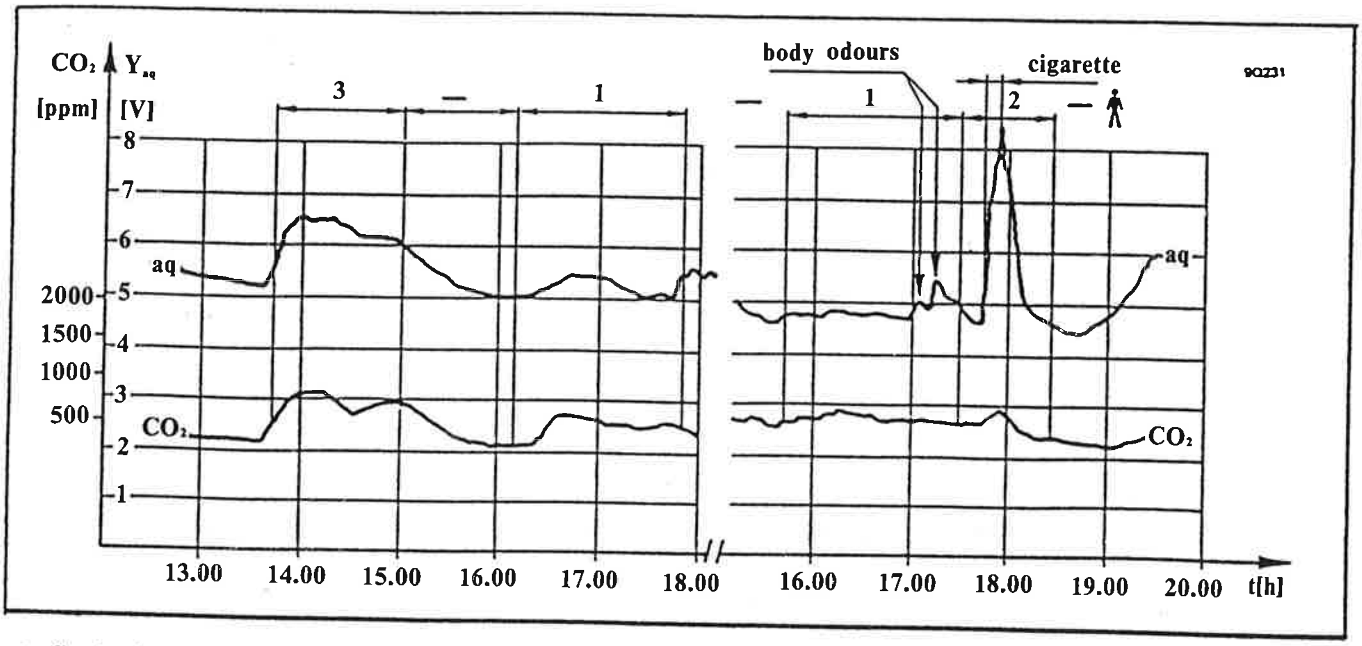


Fig 6: Comparative measurement between CO_2 content and air quality sensor in an office.

at a fixed value. The high limit control is adjustable on the air quality controller and can be activated with a dual thermostat (B3).

Air Conditioning System with Enthalpy Based Return Air Mixing (Fig. 5):

Operation:

An enthalpy controller controls the air dampers according to the enthalpy demand in the room (the output signals of the temperature and humidity controller N1/N2) and the supply of enthalpy from the return air and outside air duct (measured with the sensors B1 and B2).

When the room air quality declines the air quality controller (N4) switches in the damper control, proportionally increasing the outside air volume. For this purpose the damper signal of the controller N3 is transmitted via the air quality controller where it is interconnected to its output signal. The higher demand for outside air has priority in each case.

Practical experience with air quality control

Use of an air quality sensor based on the Taguchi principle has been used and tested in many applications. Some results and findings include:

1. The principle used for detecting odours has proved successful. It has been possible to reduce the annual average outside air volume (and therefore the energy costs) substantially in all systems, without any complaints of unpleasant odours or discomfort.
2. The energy savings achieved vary according to the system and the use of the room. However, the greater the fluctuations in occupancy and the purpose for which the room is used, the larger the percentage energy savings which can be expected (approximately 10 to 40 per cent).
3. Fine adjustments of the controller can only be made on an empirical basis and are best carried out by the user of the system.
4. The sensor is very sensitive to tobacco smoke (an absent feature of other surrogate measurements of air quality) as shown in Figure 6[5] which illustrates a comparative test between an air quality sensor and a CO_2 sensor.

The air quality sensor responds very quickly and sharply to cigarette smoke in the room. The CO_2 content, however, increased by only a negligible amount in the smoky atmosphere.

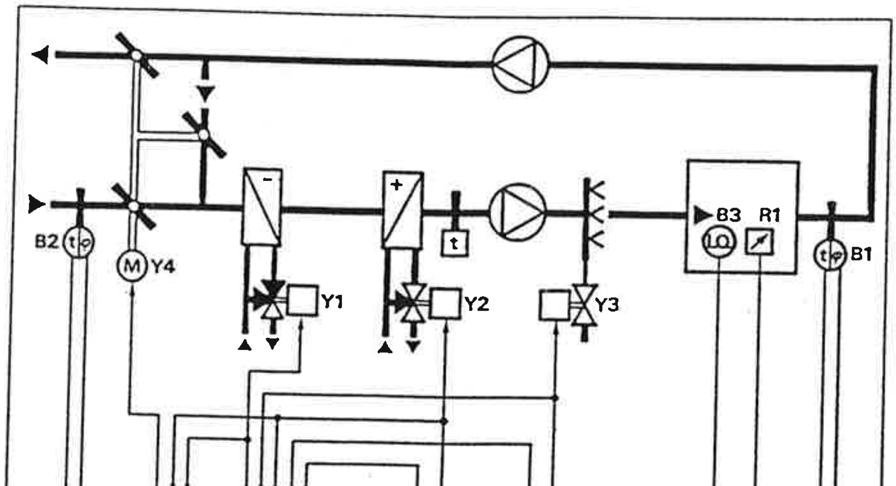


Fig 5: Air quality control combined with enthalpy control.

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