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DISPLACEMENT VENTILATION

DEPLACERENDE VENTILASJON

H SKISTAD

VVS & Energi
No 10, pp 49-51, 1985

A theoretical treatment discussing what effective ventilation is, whether for heating, for cooling, or for good air quality. For the latter application displacement ventilation often has great advantages in an office environment. Air flow patterns, convection currents, thermal stratification, distribution of contaminants and temperature distribution are considered. Definitions of air exchange effectiveness, local mean age of the air, ventilation effectiveness and the ventilation index are introduced. (CWW)

In Norway "displacement ventilation" is often referred to by the very vague term "diffuse" ventilation. Over the past 10-15 years we have had very good results using displacement ventilation with a diffuse air supply in industrial conditions.

Two to three years ago we began to develop these principles for comfort applications and there are now more than 100 installations in operation in Norway using displacement ventilation in restaurants, public meeting places, offices etc. But displacement ventilation is not the answer to all ventilation problems.

My initiation to effective ventilation was the foundry industry where the use of mixing ventilation was proving inadequate. The primary purpose was to obtain sufficiently good air quality in the residence seasons, but also to have temperature control.

The solution lay in working with air flow patterns indoors and to cooperate with the forces of nature.

Figure 1 - Stratification of contaminants from a single person in a room with displacement ventilation

Höyde over gulv = Height above floor
Fraluft-kons. = Exit air conc.
Forurens.-kons = Conc. of contaminants

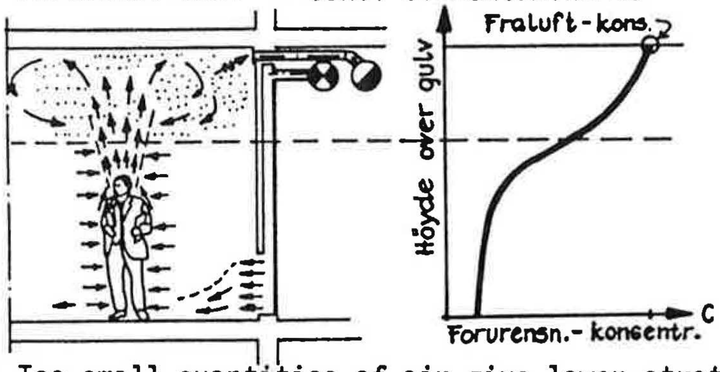


Figure 2 - Too small quantities of air give lower stratification height for the contaminants, but the air quality at head height continues to be better than with mixing ventilation and the same amount of air

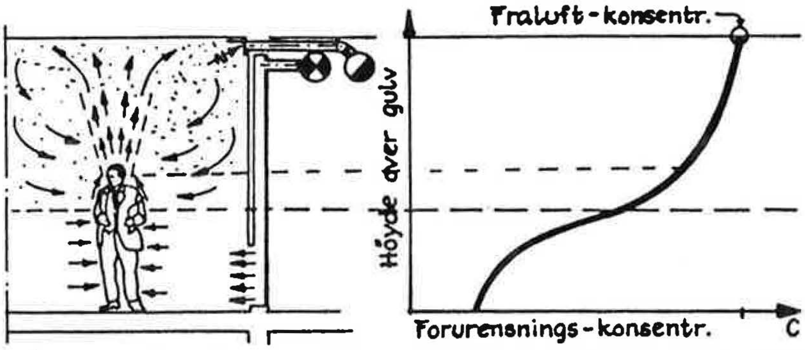
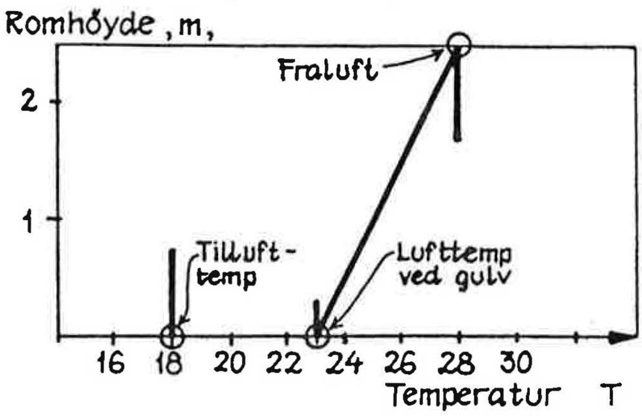


Figure 3 - Diagram for the temperature distribution in a room with diffuse air supply

Romhöyde = Room height, m
Fraluft = Exit air
Tillufttemp = Supply air temperature
Lufttemp. ved gulv = Temperature at floor level



Distribution of contaminants

When the air flow is matched to the convection currents in the room we obtain a concentration distribution as shown on the right of Fig 1. Just below the ceiling the air is at its impurest; the concentration here is the same as it would be everywhere in the room with unmixed ventilation or otherwise comparable conditions.

If the input air flow in insufficient to feed the convection stream up to heat height, we get the flow pattern shown in Fig 2. The layer where the air is purest no longer reaches up to the breathing zone for a standing person. Note however that the air the person breathes in is purer than it would have been if we had used mixing ventilation or something comparable.

Temperature distribution in the room

A typical temperature distribution in an office with displacement ventilation is sketched in Fig 3. The temperature rises fairly linearly from floor to ceiling. We do not as a rule find the stratification in temperature we get with contamination. The air temperature at floor level is higher than the supply air temperature.

The performance of the supply air equipment is of great importance. Because the supply air temperature in most cases is lower than the air temperature in the residence zone, the air will drop down towards the floor when it streams into the room. (When made visible with smoke it looks like a waterfall.)

When this happens, draught problems can easily arise on the floor in the space near the equipment. These draught problems can be avoided if we use the right supply equipment and the design is in accordance with its recorded output.

What do the various concepts say about the effectiveness of ventilation?

What use can we make of the various definitions when we wish to establish what effective ventilation is? We try to use the following definitions for the examples cited above.

Stationary effectiveness, local ventilation index, air exchange effectiveness.

Regulations

Specification regulations have proved to have little application. (By specification regulations I mean the specification of the means by which the premises have to be air-conditioned, eg on the basis of air exchange coefficient or air flow per m^2 floor area.)

Functional regulations are those that one should have as a starting point when designing an effective ventilation system. (By functional regulations I mean the statement of the environmental requirements, that is, the requirements for function of the air-conditioning plant.)

Conclusion

The aim of ventilation is in the first place to create good air quality. The aim is not air exchange per se.

No principle or system exists that is the most effective for all applications.

Displacement ventilation often has great advantages when we wish to obtain good air quality. But it does not answer all problems.

Functional regulations specify the air conditions, not the means for obtaining the desired air conditions.

At the present time I find that the concept "stationary ventilation effectiveness" (or local ventilation index) is the most appropriate when ventilation systems have to be evaluated in terms of air quality.

When we wish to measure the stationary ventilation effectiveness in practice we have to ensure that we have a stationary operational situation. In industry with processes running continuously this is generally taken care of. In some cases it may demand long periods of measurement.

The concepts of air exchange effectiveness and air exchange coefficient direct attention away from the measures for the ventilation task (air quality) and towards the means (air exchange). The concept of air exchange effectiveness in my opinion should be further developed in the direction of the effectiveness in respect of the accumulation of contaminants, and the final figure should assume another form that distinguishes better between poor and good solutions.

The new definitions in general ventilation will appear as a VVS publication

The definitions - some of them completely new - primarily for the function of general ventilation for various operating conditions proposed by the Scandinavian Ventilation Group (NVG) are listed in a separate information pamphlet that can be ordered from VVS-Tekniska Föreningen, Hantverkargatan 8, 11221 Stockholm, tel: 08-54 08 30. The text is based on an article by Mats Sandberg, SIB and Eimund Skåret, NTH.

The definitions are essentially:

- The air exchange effectiveness: This gives the rate at which the air in the room is exchanged relative to the theoretical minimum air exchange time.

- The local mean age of the air: This gives the ratio of the mean concentration in the whole room to the concentration in the exit air (agrees with the classical definition).

- The ventilation index: This gives the ratio of the local concentration to the concentration in the exit air. The index is defined as the quotient of the concentration in the exit air and that as the point in question.

There is no single ventilation system or principle that is effective for all applications and we cannot make a separation into one principle that is most effective for industrial applications and another that is most effective for comfort ventilation. We must always take as our starting point the question: why do we ventilate? We must ask ourselves "What is the problem?" and "What do we wish to achieve?".

Why do we ventilate?

There are usually one or more of the following fucntions that we wish to satisfy with air conditioning plants: heating, cooling, air quality. Often we want the ventilation plant not only to fulfil one of these tasks, but to handle for example, both air cooling and air quality. It is my experience that the best result is achieved if we try to separate the various functions in different plants, that is, ventilation to give air quality; heating plants (radiant heat, convectors etc) to produce warmth.

If we try to use the air both to give air quality and for heating, we have to indulge in compromises that diminish each separate function. As regards cooling we also reach the optimum result in terms of comfort if we isolate the cooling function in its own cooling plant, eg a cooling ceiling.

What is effective ventilation? We must first ask: Effective for what? Effective for heating? Effective for cooling? Or effective utilisation of the air for good air quality?

Effective displacement ventilation with thermal stratification

Basic principles

In Fig 1 we see a person standing in a room with displacement ventilation. Because he is warmer than the surroundings a convection stream rises up from him.

This convection stream entrains contaminants from the person. The convection stream draws with it air from the surroundings as shown in Fig 1. If we supply low-velocity air at flow level the fresh air will feed the convection stream up to the height where the air flow rate in the convection stream is equal to that of the fresh air flow.

Above this height the feed air to the convection stream is taken as return air from the air volumejust below the ceiling.

The exit air vent is placed below the ceiling so that the most contaminated air is extracted from the room.