VENTILATION STRATEGIES AND MEASUREMENT TECHNIQUES

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PAPER 1

VENTILATION, THE BALANCE BETWEEN ENERGY AND WELL-BEING

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Synopsis

A survey is given of the sitution in The Netherlands with regard to ventilation and infiltration.

Starting from a point of generally very leaky and hardly insulated buildings now the necessity is felt on the one side to make standards for the airtightness to prevent energy wastes by too high infiltration rates and on the other hand to define minimum ventilation rates to secure safe and hygienic conditions in well insulated and airtight buildings.

This minimum ventilation rate is based on contaminants, caused by the occupants themselves, the so-called unavoidable sources.

The emission of avoidable sources, like gases from building materials, should lead to concentrations at the given minimum ventilation rate, which are not harmful. This requires adequate regulations for these contaminants.

Minimum ventilation can be obtained either by mechanical ventilation (cost aspect, especially for dwellings) or natural ventilation (requiring insight from occupants in ventilation parameters).

The research activities are related to the mentioned developments:

- ventilation/infiltration versus energy consumption
- influence of contaminants from avoidable sources (building materials etc.)
- mechanical ventilation in dwellings
- ventilation instructions for occupants.

INTRODUCTION

Ventilation of dwellings is a hot item, also in The Netherlands. Two questions are essential; firstly which ventilation rate is required to provide safe and comfortable conditions for the occupants and secondly how can this ventilation rate be obtained and maintained.

Since building design is becoming more and more energy conscious, the airtightness of new buildings is improving in the same measure. From the point of view of energy conservation existing buildings are also insulated, so that in many cases the infiltration has decreased considerably.

Dutch buildings, which have always had a bad reputation as for the degree of insulation and airtightness, now are confronted with a new situation, carrying unforeseen problems.

Where in the past infiltration was only a nuisance, causing uncomfortable conditions like draughts and low indoor temperatures, in the present situation a shortage of ventilation could result in real problems. So in 1979 the Ministry of Health asked the Health Council to report on the indoor climate and on the minimum ventilation rate in dwellings in particular (1).

This very interesting report was published in 1984. Even more important than the recommended amount of fresh air (7 dm^3/s, i.e. 25 m^3/h per person) is the motivation of it.

According to the Council the indoor climate should be of such quality that no harm is experienced by the occupants, even not on the long term. The minimum ventilation rate should be based on unavoidable sources, i.e. originated by the occupants themselves, such as body odours, carbon dioxide and moisture.

In principle all other sources of pollution are regarded as avoidable. They should be avoided or restricted to such extent, that they are harmless. For building materials and household chemicals standards should be developed such that no health risks can occur at a ventilation rate of 1,4 dm^3/s (5 m^3/h) per person, being the lower limit of infiltration quantities measured in practice. Adaption of the fresh air amount to present - possible - concentrations of avoidable pollution sources would result in big and uneconomic air quantities, as will be illustrated by the following example. In Germany pressed wood board is classified in three categories, dependent on the formaldehyde emission, according to the Uniform Technical Building Regulations (ETB-Richtlinien). The requirement of a maximum formaldehyde concentration of 0,1 ppm in the room air can be satisfied with an air change rate of 0,8 to 1 per hour, when board of the first, the least harmful, category is used. Application of material of the third category (the most unfavourable) requires an air change rate 20 times as high (2).

Even in the first case the occupant should take care that the minimum required ventilation will take place. So the two principal questions could also be formulated in this way:

- what are avoidable sources and what are their effects, based on a minimum ventilation rate.
- to what extent can the handling of the ventilation means be left to the occupant. What will be the result.

MINIMUM VENTILATION RATE

An important part of the energy spent in buildings is used for ventilation; therefore the cost aspect cannot be neglected, explaining the interest for a minimum ventilation rate. An interest, which is very lively in the present time, due to the high energy prices.

The question of minimum ventilation quantity has a long history. Already in 1861 the Barrack and Hospital Commission in the United Kingdom required 9,4 dm^3/s (34 m^3/h) per person for this type of buildings.

Although it is acknowledged that CO_2 is not the cause of a stuffy atmosphere, the CO_2-concentration is often used as measure for the aircontamination.

Over a century ago Pettenkofer introduced as limit 0,1% CO_2. For average indoor activities the production of CO_2, depending on the type of person and activity, varies between 0,0028 and 0,01 dm^3/s between (10 and 36 dm^3/h), resulting in an average of 9,2 dm^3/s (33 m^3/h) fresh air per person for not surpassing Pettenkofer's limit.

As Fitzgerald recently reported in the ASHRAE-Journal (3) the standard for ventilation, used in the USA and also in many other countries, is based on the work of Yaglou, being about 50 years old. Efforts for updating this work some 15 years ago in the U.K. were prevented by lack of funds.

Notwithstanding the high quality of the work of Yaglou new investigations certainly would have sense, since the problem is clearly influenced by time dependent factors like hygienic habits and use of building and furnishing materials. Yaglou e.g. recommends 6,7 dm^3/s (24 m^3/h) per person for well-off adults and 15,8 dm^3/s (57 m^3/h) for children of the lower social classes.

For this reason ISSO, the Dutch Institute for Study and Stimulation of Research in the field of Heating, Ventilation and Air Conditioning initiated an investigation in 1979 to determine the minimum fresh air supply per person,required in order to prevent the occurrence of inacceptable offensive odours due to stale-smelling air in offices and similar buildings.

Offensive odours, regarded in this investigation, originate from building materials, furniture and upholstery, office materials and people (cosmetics, body odours). In order to establish the degree of offensiveness and acceptibility of odours, test subjects were questioned, both occupants and visitors, according to a scale as given in fig. 1. (from (4))

ODOUR (OFFENSIVENESS) SCALE

5	repulsive, nauseating, etc.
4	objectionable, much too strong
3	no longer acceptable
2	still just acceptable
1	distinctly perceptible but not offensive
½	just perceptible
0	not perceptible

FIG.1 THE SCALE USED FOR ODOUR OFFENSIVENESS

The result of the investigation is, that the minimum fresh air supply would have to be adjusted to 9,7 dm^3/s (35 m^3/h) per person in order not to get more than 5% complaints from occupants of "odour not (no longer) acceptable". Since it is difficult to measure odours by use of instruments, this investigation worked with panels of 8 persons in a so-called "sniff-car", who where asked whether they still could distinguish odour carrying air from fresh air. The panel got samples of room air, diluted with various amounts of fresh air. The odour concentration was defined by the dilutation factor, required for the sample for which just 50% of the individuals would still perceive the odour in the diluted odour-carrying air. As indication can be given, that in moderately ventilated rooms without smoking the odour concentration is of the order of 10; when there is considerable smoking the odour concentration is of the order of 100.

The report concludes that in view of the results and the remaining uncertainties there is no justification for reducing the minimum fresh air supply in offices and comparable buildings to a considerably lower value than 9,7 dm^3/s (35 m^3/h) per person.

Ventilation rates can be given either in dm^3/s per person or in times of air changes per hour. In our conception, that the contaminants are mainly caused by the occupants, the expression in dm^3/s per person is a logic approach. For offices the value of 9,7 dm^3/s (35 m^3/h) per person equals about 1-1½ air changes per hour.

For dwellings this depends to a great extent on the size of the room and the member of occupants; only as an indication can be said that it will be about ½ - 2 air changes per hour.

EFFECT OF AVOIDABLE CONTAMINANTS

The minimum ventilation rate as mentioned before, resulting from the most recent studies, is based on the odour load of the room air, which is caused mainly by the occupants themselves.

This fresh air quantity however should also be able to keep the concentration of noxious gases, vapours or particles well below safe limits.

The number and variety of air pollutants in dwellings is big. Generally maximum allowable concentrations have not yet been determined for dwellings; for many substances even no recommendations are given. In houses these concentrations should be kept as low as possible both since special risk groups are concerned (babies, old and sick people) and as the exposure time can be permanent.

It is important, that the characteristics of the relevant materials are known, as e.g. is the case for formaldehyde from building materials.

For formaldehyde an air change rate of 0,8 - 1 h^{-1} should be sufficient; this also applies to the CO, CO_2 and NO_2 concentration, resulting from cooking with gas (2).

In - mechanically ventilated - offices the requirement of an air change rate of 1 certainly will be met during working hours. The Dutch Standard for ventilation in dwellings requires 0,001 m^3/s per m^2 floor area, which also means that an air change rate of 1 is met. However the total ventilation amount for a dwelling can be confined to 0,042 dm^3/s, which equals about an air change rate of 0,5. Here we see the contradictory interests of comfort and energy conservation.

It can be concluded, that a ventilation rate based on "freshness" generally will also be sufficient from the point of view of health. Nevertheless it is of big importance to have regulations for the maximum emission of building materials.

VENTILATION OR INFILTRATION

To satisfy the condition of freshness in a room is a matter of sufficient fresh air; it is not relevant whether the air is supplied by ventilation or infiltration.

In case of infiltration the air quantity is not constant but depends on the meteorological conditions (wind and temperature).

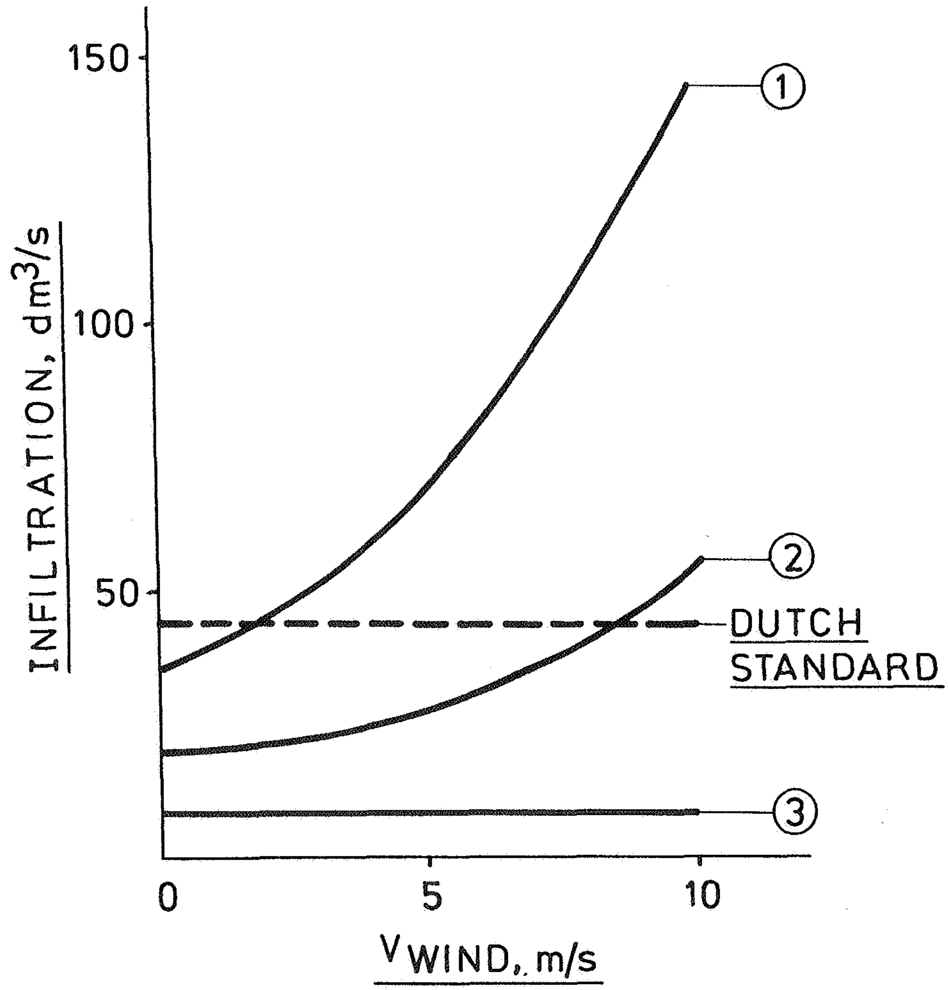
The flow through the rooms depends on the wind direction and the resistance in the dwelling. Opening of doors can make a considerable difference and the situation is even more complicated, when exhaust fans are used.

Exact calculation of infiltration and inter room air flows is only possible using a multiroom model computer programme.

It will be clear that generally the air flow will be too big, which means a waste of energy, or too small, which is undesirable for comfort reasons. In the latter case the air quantity can be increased by opening a window but here the same problem arises with regard to the adjusting of the correct quantity. Moreover for rooms at the leeside opening of a window is not a guarantee for more freshness in the room.

For the conventional type of Dutch houses the airtightness is such that the required fresh air quantity is obtained by infiltration in about 85% of the time, which means that most times the ventilation rate is (much) higher than necessary. From the energy point of view this is very uneconomical.

New houses, designed in a energy conscious way, appear to be very well airtight with hardly any infiltration. This is clearly to be seen in fig. 2. (4). For those houses the best - and only - solution is a mechanical ventilation system; i.e. both supply and exhaust in a balanced system.



(1) average dutch one family house

(2) ditto; energy-consciously designed

(3) dwelling in very well constructed apartment building

FIG. 2 INFILTRATION VS. WINDVELOCITY
(at 10m height over open country)

However mechanical ventilation, which is in all cases the best provision for a constant air renewal in all rooms, often is prohibited by the costs; this applies to houses in particular.
Therefore a study is running now in The Netherlands which conditions dwellings should meet to enable a cheap and yet effective combined air heating and ventilation system. To keep the investment costs low a simple duct system is required, ma inly restricted to a vertical duct in the core of the house with air outlets practically directly on the vertical duct.
The specification of the outlet grilles is important to obtain a uniform air and temperature distribution in the room, also at high supply air temperatures, which occur at low outside temperatures. Special problems are met during the starting period when the relatively small amounts of warm air, supplied just under the ceiling to the cold room, tend to build up a very big and uncomfortable temperature gradient.
To reduce the running costs heat recovery from the exhaust air is applied, since the Dutch standard does not allow recirculation of air from kitchen, bathroom and toilets.
For existing dwellings it is not possible to install mechanical ventilation systems; in most cases the costs will be prohibitive. For ventilation the windows or similar provisions have to be used; the correct operation is a matter of importance, to which more attention will be paid later.
For big buildings mechanical ventilation is common practice now in The Netherlands; it is felt a necessary condition to prevent cold draughts or offensive odours in wintertime. Most of these installations are provided with heat recovery systems.
Once again the choice of the type of air outlet is very important for a uniform distribution of the fresh air throughout the room. Modern air supply grilles have a high induction rate, which favours a good circulation in the room and thus a uniform air and temperature distribution.

CONTROL OF VENTILATION RATE

Natural ventilation

The most common system for air renewal is natural ventilation, the opening of windows, as is the case in most dwellings. The ventilation rate is controlled manually by the occupant. Research in The Netherlands (5) showed that all kinds of operation of windows or similar openings occur, varying from always closed to permanently open. For a good operation the ventilating means have to be well designed and dimensioned; they should be easily adjustable. But this is only the first step. Next, and very important, the occupant should know when to ventilate and to which extent; he should know e.g. that airing for half an hour during the day is sufficient for bedrooms but that a bathroom requires permanent ventilation. More difficult to instruct is the influence of all factors, which play a role in the ventilating process like airtightness of the dwelling, wind and temperature, open staircases and open kitchens. Therefore this point has to be given much attention.

A good ventilation attitude is important from the energy point of view as shown by the distribution of energy losses owing to the ventilation of a rather leaky Dutch dwelling (5):

energy required for:	percentage
- 0,5 h^{-1} air change rate	35
- The rest of the infiltration	59
- Ventilation of bedrooms; open window for 1 hour during working days.	6

Mechanical ventilation

Compared to natural ventilation the control of the air quantities is much simpler for mechanically ventilated systems. Once more the airtightness of the building is an important factor. For an reasonably airtight building and a well designed and adjusted ventilation system, the air quantity to a room is practically independent of wind and outside temperature. It is determined by the design conditions, i.e. the number of occupants in the room. Generally the design condition is the situation of maximum occupancy, which means that often less fresh air could be supplied. This applies to congressrooms, canteens and similar rooms in particular.

Automatic control of the fresh air amount, either by changing the fan capacity or by adaption of the recirculation rate, would result in more economical operation of the system. The sensor of the control system should react on changes in air quality. Since the CO_2-concentration of the room air is one of the best indicators for air quality - especially when people are concerned - equipment has been developed, based on CO_2-absorption.

Unfortunately problems arise, when tobacco smoke is involved.

Another apparatus has been developed, which uses the conductivity of a semi-conductor; this conductivity is a function of the concentration of gases and vapours, which result from human activities. As such can be mentioned ammonia, methane, tobacco smoke etc.

For our purpose it is a favourable property of the sensor, that it works cumulative, when more gases are concerned. (6)

It is evident, that these systems only can be considered for installations of some importance, otherwise the return on the investment will take too long. Up till now they are hardly met in building systems.

TRENDS OF AIR INFILTRATION RESEARCH IN THE NETHERLANDS

The research trends in The Netherlands are determined by the development as outlined before.

Essential is the point of view of the Health Council, that the minimum ventilation rate should be based on "offensive odours" and that for avoidable pollution sources standards and regulations should be developed.

There are four main topics of research.

1. Ventilation/infiltration vs. energy consumption

   More fresh are than required results in energy waste. For this topic the research can be subdivided as follows.

1.1. Regarding the present situation

- Field experiments on the air tightness of dwellings
- Investigation of the energy consequences as part of a study of reference values for energy consumption of dwellings, offices and schools.

1.2. Reduction of energy consumption.

The preparation of a standard on airtightness requirements for buildings.

2. Mechanical ventilation in dwellings.

   From the energy point of view mechanical ventilation is the most economical way to realise the required air renewal.

In big buildings this is common practice but for dwellings the costs are prohibitive.

It is studied how to develope a cheap combined air heating and ventilation system for dwellings, paying attention to the comfort as well.

3. Influence of contaminants from building materials etc.

   Since the minimum ventilation rate is based on unavoidable sources it is important to know the characteristics of avoidable contaminants, so that standards and regulations can be made to limit the emission to not harmful concentrations. This applies to dwellings in particular, in view of the special risk groups and the possibility of permanent exposure. Studies are running, also in connection with IEA Annexe IX.

4. Instructions to occupants

   Where air renewal must be obtained by natural ventilation it is important that the occupants know how to handle the ventilation means in a correct way. Before making instructions how to use them properly, it is necessary to have a good insight in the present ventilation habits of the occupants.

   Research projects on this topic are running, of which the IEA Annexe VIII can be mentioned (study of behaviour of the occupants towards ventilation).

It cannot be said that the above-mentioned trends are typical Dutch; they are rather international, having a Dutch accent now and then.
International collaboration is necessary to answer the questions and solve the problems in an efficient way. Therefore international exchange of knowledge and research results as is realised by this AIC-conference is of great importance.

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