#4555

VENTILATION EFFICIENCY ASSESSMENT IN RESIDENTIAL BUILDINGS

D. BIENFAIT
Centre Scientifique et Technique du Bâtiment
84 avenue Jean Jaurès, BP 02
77421 MARNE LA VALLEE CEDEX 2

ABSTRACT

Ventilation efficiency may be defined as the capability of a given ventilation system to achieve the best balance between indoor air quality and energy conservation requirements :

- inside a room, ventilation efficiency is depending on air diffusion, which is mainly governed by air terminal devices and characteristics,
- in a partitionned building, ventilation efficiency is depending on air flowrates distribution, i.e. : air change values in each room as a function of time.

This second aspect is addressed in the present paper : a method based on a multizone computer model is derived ; this proposed method makes it possible to quantify the efficiency of the different ventilation systems in residential buildings.

INTRODUCTION

Ventilation of residential buildings may be achieved according a wide range of different techniques, among them natural ventilation using vertical shafts, mechanical ventilation systems and many other techniques. These systems are designed to ensure both a sufficient level of air quality and good operating conditions, which include low energy consumption. Quality assessment of these various systems is an important issue because it may ease the development of more efficient systems :

The efficiency of a ventilation system may be defined as the capability of this system to ensure an acceptable air quality level (i.e. : mean pollutant concentration in the air, condensation hazards, ...) with as low energy consumption as possible.

It is well known that for some kinds of systems, for instance passive stack ventilation or humidity controlled systems, the air change is highly varying against time : in the case of passive stack ventilation, exhaust flowrates are more important in winter, which lead to poor over the year efficiency. Actually, the best efficiency would have been achieved with systems providing low exhaust flowrates when outdoor temperature is low, which is exactly the opposite of passive stack systems. An efficiency assessment method should therefore tend to take

COMPUTER MODELS

Considering a ventilation system, the easiest way to assess the efficiency is to calculate over the heating season a mean value of pollutant concentration and condensation hazards. This may be done using a multizone computer code taking into account the phenomena which influence air movement and pollutant concentration (wind velocity, building shell air leakage, moisture transfer, ...) as well as the ventilation components (i.e. : fan, exhaust vent, ...) characteristics.

Although research work is still needed in order to improve the existing models, numerous codes have already been developped (see for instance fig. 1) and may be used in order to compute on a yearly basis the heat losses amount and the time dependent pollutants or moisture concentration in each room. The addressed problem is then, how to use these results in order to yield criteria for both air quality and heat losses level : we propose, here-after, definitions of criteria for air quality and heat losses (calculation details are in appendix 1).

DEFINITION OF HEAT LOSSES CRITERION : Qd

Heat losses amount may be expressed by a so called "deperdition flowrate", Qd :

Qd (m^3/h) is the make-up air flowrate value which, assumed to be constant during the heating season, would lead to the same heat losses amount than the value calculated using the computer code.

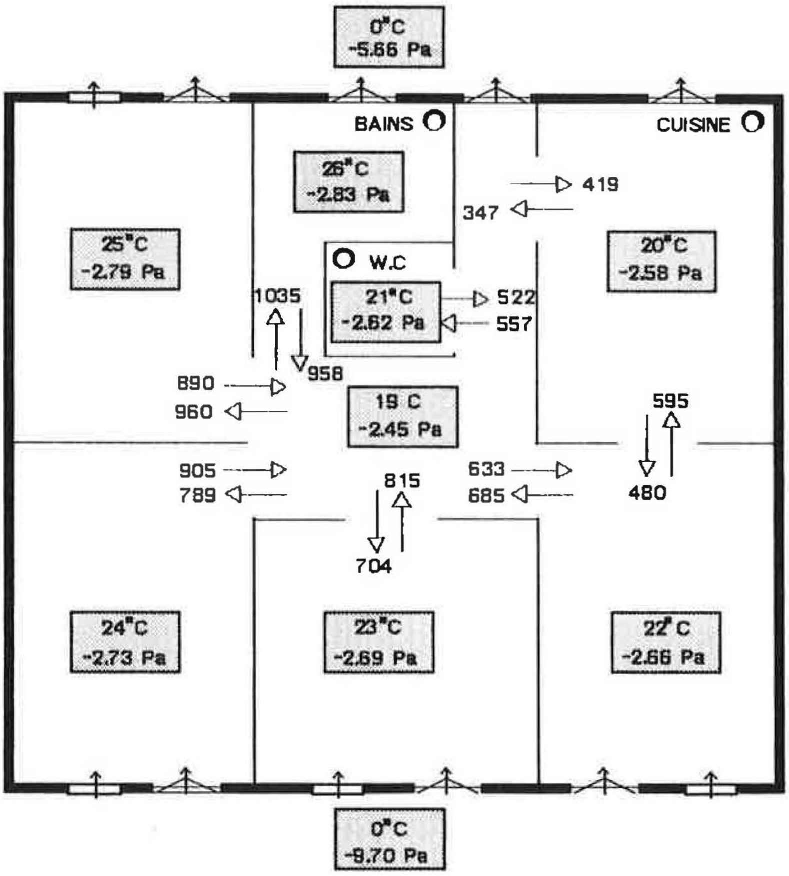

Fig. 1 : Example of multicell computer codes result (code SIREN 2)

DEFINITION OF AIR QUALITY CRITERION : Qa

General considerations

The health effect of indoor air pollutant exposure with regard to ventilation techniques assessment is almost impossible to evaluate on a deterministic basis for the following reasons :

- many pollutants are involved and there may exist some synergy between pollutants (i.e.: supposedly between radon and tobacco smoke)
- pollutant emission rates are considerably scattered according the house under consideration
- health effect of most pollutant is only known with a poor accuracy
- pollutants and furnishings may interact.

For these reasons, a practical way to account for pollutant concentration is to consider a single fictive pollutant called "virtual pollutant" which accounts for all the home air pollutants.

The criterion would then be the yearly amount of pollutant breathed by the occupants (it is consequently assumed that the relationship between exposure and health detriment is linear). This quantity may be calculated using multizone computer models, which requires some assumptions, relevant both to the occupancy schedule of each room and the "virtual pollutant" emission rate. In order to make things easier to handle it is proposed to express this in the following manner :

Air quality criterion, Qa

Qa (m^3/h) is the make-up air flowrate value which, assuming it to be constant all over the year and the air being perfectly mixed between rooms, would lead to the same amount of virtual pollutant breathed by the occupants than the value calculated using the computer code.

Ventilation efficiency, e

Usually the values of Qa and Qd are different. The ratio, e = Qa/Qd, is called the multizone ventilation efficiency.

EXAMPLES

The ventilation efficiency concept is featured by the following simple examples :

First example :

Let us consider a ventilation system (fig. 2). Whose exhaust flowrate is equal to Q1 during half of the heating season and Q2 during the other half. Under some assumptions (polllutant emission and outdoor temperature time-constant) the values of Qa, Qd and e may be derived (see appendix 1).

$$Qa = \frac{2}{1/Q1 + 1/Q2} \qquad Qd = \frac{Q1 + Q2}{2} \qquad = \frac{4.\ Q1\ .\ Q2}{(Q1 + Q2)^2}$$

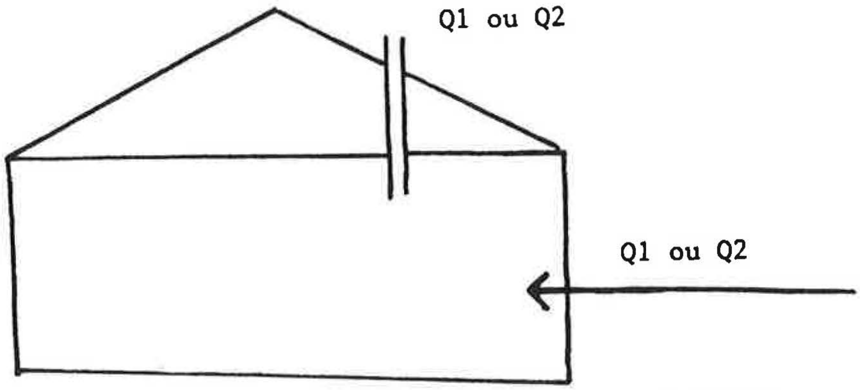

Fig. 2 : House with a single room and variable airflow

Second example :

Let us consider a ventilation system (fig. 3) whose flowrates Q_1 and Q_2 are constant. Under some assumptions (time constancy of outdoor temperature and pollutant emission ; one person staying continuously in each room), it is possible to calculate Qa, Qd and e :

$$Qa = \frac{4}{\frac{1}{Q_1} + \frac{2}{Q_1 + Q_2}} \qquad Qd = Q_1 + Q_2 \qquad e = \frac{4}{\frac{Q_1 + Q_2}{Q_1} + 2}$$

The optimum (e = 1, 3) is obtained when Q_2 is equal to zero.

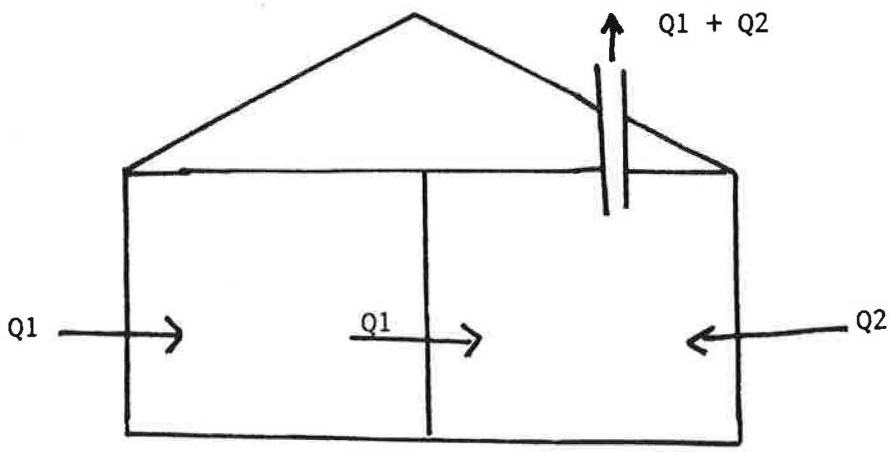

Fig. 3 : House with two rooms and constant airflow

CONCLUSIONS

The above method makes it possible using a computer code to assess the efficiency of the different ventilation systems in use in residential buildings. It may therefore be used to improve dimensioning and design of ventilation systems. However, more research work is required in order :

a/ to improve existing multizone computer models, particularly with regard to matters such as influence of wind turbulence, moisture transfer, ...

b/ to gather realistic data concerning :
- building air leakage value and distribution on each facade,
- moisture generation and pollutant emission in each room,
- meteorological data,
- moisture characteristics of furnishing
- ...

c/ to evaluate the condensation hazards, which are not addressed here

d/ to assess the validity of the assumptions that had to be taken (linearity of the exposure-health effect relationship ; no physical reaction between pollutants, uniformity of pollutant concentration in a given room, ...).

APPENDIX

Notations :

t	(h)	time
Pi(t)	(g/h)	pollutant emission rate at time t in room i
P(t)	(g/h)	ditto for the whole house
Ci(t)	(g/m^3)	pollutant concentration at time t in room i
ni(t)	(-)	number of occupants at time t in room i
n(t)	(-)	number of occupants at time t in the whole house
k	(m^3/h)	air amount breathed in one hour by an occupant
Q(t)	(m^3/h)	make up air flowrate at time t
Da	(W.h)	heat loses due to air change during heating season
Text(t)	(°C)	outdoor temperature assumed to be time constant
Ti	(°C)	indoor air temperature assumed to be time constant
Qb	(g)	quantity of pollutant breathed by the occupants alltogether during heating season
Qa	(m^3/h)	air quality flowrate
Qd	(m^3/h)	deperdition flowrate
NH	(h)	duration of heating season

Formulas

$$Qb = k \,.\, \sum_i \int Ci(t) \,.\, ni(t) \,.\, dt \qquad Da = 0{,}34 \,.\, \int Q(t) \,.\, [Ti - Text(t)] \,.\, dt$$

$$Qa = \frac{\int P(t) \,.\, n(t)\, dt}{\sum_i \int Ci(t) \,.\, ni(t) \,.\, dt}$$

$$Qd = \frac{\int Q(t) \,.\, [Ti - Text(t)] \,.\, dt}{\int (Ti - Text) \,.\, dt}$$