PROGRESS AND TRENDS IN AIR INFILTRATION
AND VENTILATION RESEARCH

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METHODOLOGIES FOR THE EVALUATION OF VENTILATION RATES BY TRACER GAS COMPARISON

I.Meroni - C.Pollastro - P.Tirloni - W.Esposti

C.N.R.-I.C.I.T.E.
Consiglio Nazionale delle Ricerche
Istituto Centrale per l'Industrializzazione e la Tecnologia Edilizia
Via Lombardia,49 - 20098 - S.Giuliano Mil. - Milano - Italia

1. INTRODUCTION

Ventilation in a building enables to renew the air it contains by means of a natural exchange of air (depending on weather conditions and climate) or a forced exchange using mechanical appliances. This exchange of air must range between minimum air purity and maximum economical limit of dispersion (ventilating means cooling) without causing currents of air, unbearable for the people in the room, which would worsen thermal comfort. It is difficult to envisage the exchange because it depends on numerous variables:

- airtightness of the building;
- difference between internal and external temperature;
- speed and direction of the wind which influences the difference between internal and external pressure.

The studies for the Energy Project at the ICITE the Central Institute for Building Industrialization and Technology of the National Research Council have enabled the development of a method to measure air exchange in homes with the aid of a gas electromechanical analyzer which examines the decreasing curve, in relation to time, of the gas concentration with which the home was saturated.

In this document the authors describe the method used and the results obtained by using two different types of gas: water vapour and oxygen.

The use of oxygen has given the most interesting results which have enabled significant statistical analysis repeatable with any type of climate.

The method used resulted effective although at present there is insufficient data to define the accuracy (estimated around 10%).

Experiments were carried out on a modular prefabricated housing unit built with highly insulating material complete with forced ventilation.

2. METHODS USED

The trial methods used are based on the criteria listed in standard ASTM E 741 - 80 " STANDARD PRACTICE FOR MEASURING AIR LEAKAGE RATE BY THE TRACER DILUTION METHOD " .

This standard describes the standars technique used to measure air exchange in buildings in natural conditions using tracer gas.

A small quantity of this tracer gas is inserted into the room and mixed with the air. The exchange is determined by the decrease in gas concentration in relation to time.

It is difficult to forecast analytically the number of hourly exchanges because it varies according to the airtight level of the building, to its configuration, to the difference in internal/external temperature, to the speed and direction of the wind and to the building's construction quality.

It is, therefore, difficult to quantify the exchange since it depends upon numerous variables.

The experiment was carried out using two separate methods with different traces: water vapour and oxygen.
In this specific case the container's finishing material (fiberglass covered in polyurethane paint) enabled the researchers to disregard the hygrometrical stabilizer effect caused by the container itself.
The possibility of using the humidity content level and its variation to determine the air exchange is in fact attractive because it would make the experiment easier.

3. AIR EXCHANGE MEASUREMENT USING WATER VAPOUR: INSTRUMENTS AND MEASURING METHOD USED

Wile maintaining a constact temperature level inside the module, the related degree of umidity was increased simply by vapourizing water. Vapourizing was interrupted and the humidity conditions inside the module were monitored for various hours.
Using the formula mentioned in the quoted standard we have calculated the rate of air exchange using as a time basis a period of 4 hours, taking into consideration the difference in starting and finishing absolute humidity in the air.
To monitor the temperature and internal and external humidity, we used a data collecting system which controlled temperature and humidity feelers positioned in various points of the module.
The levels were recorded at 5 minute intervals during the whole measuring time.
The 4 hour period was chosen so as to reduce the influence of external temperature and humidity variations on the measurement.
The recordings of the measured parameters are displayed in diagram 1, where we note the following:
- the internal room temperature during the trial varied by 1°C;
- the external environmental conditions in terms of absolute humidity were maintained around 15%;
- the decrease in the level of humidity was regular during the whole measuring time.

By applying the formula mentioned in the quoted ASTM standard we obtain a value referred to volumes/hour :

$$I = \frac{1}{t} * \ln \frac{Ci - Ui}{Cf - Uf}$$

where:
- I is the number of hourly air exchanges;
- t is the period of time considered;
- Ci is the internal starting absolute humidity;
- Cf is the internal final absolute humidity;
- Ui is the external starting absolute humidity;
- Uf is the external final absolute humidity;

The results obtained are summarized in chart 1.

EXPERIMENT	n° EXCHANGES/HOUR
	WATER VAPOUR METHOD
1	0.22
2	0.12
3	0.21
4	0.27
5	0.31
6	0.19

Chart 1

4. AIR EXCHANGE MEASUREMENT USING OXIGEN: INSTRUMENTS AND MEASURING METHOD USED

The instrument used for the trials is an electromechanical analyzer which controls the oxigen concentration in a sample flow.
The analyzer, which uses a sensor cell to measure the oxygen concentration, is equipped with a three range digital detector.
The sensor is self-feeding and works on a battery. It contains an anode, an electrolyte and an air cathode. In the cathode area the oxygen is reduced to hydroxyl ions which iodize the metal anode; the oxygen is therefore used up as soon as it reaches the electrode; the sensor power, exclusively related to the oxygen concentration sampled, is therefore read and translated into oxygen %.
A collecting system memorizes the data supplied by the analyzer, these values are susequently plotted (diagram 2).
As for water vapour, air exchange evaluation is based upon the principle of decrease in the oxygen concentration level in time.
Since the atmosphere is made up of a number of gasses, the composition of which remains stable, (except the value of CO2 which is influenced by various factors) we can assume thet the oxygen percentage in the external environment is also constant.
Past experience has enabled to evaluate this concentration which at sea level is near to 20,8 % ± 0,1% and this value is pratically constant.
The atmosphere in the room where the air exchange will be measured is enriched with oxygen up to 22% by using cylinders.
Subsequently we measure the concentration decreasing time. Also in this case the number of hourly air exchange is calculated by using the formula mentioned by ASTM:

$$I = \frac{1}{t} * \ln \frac{Ci - Ce}{Cf - Ce}$$

where:
I is the number of hourly air exchanges;
t is the period of time considered;
Ci is the initial internal gas concentration (after the release of oxygen);
Ce is the external gas concentration (constant);
Cf is the final internal gas concentration (after t time).
The results obtained are summarized in chart 2.

EXPERIMENT	n° EXCHANGES/HOUR
	OXYGEN METHOD
1	0.35
2	0.37
3	0.37
4	0.38
5	0.32
6	0.36

Chart 2

5. RESULTS AND CONSIDERATIONS

From the experiments carried out, the results of which are mentioned in chart 2, we can consider the following:

- despite the original hypothesis, water vapour measurements resulted unreliable. An example of this can be found in the influence of the external related humidity variation: a fact supporting the unreliability of this method was the condensation which was noticed in various parts of the building (eg. in the intrados openable joints in the floor and on the walls) during the humidification phase. Therefore, during the measured period we passed from the condensation phase to the vapour phase which was reflected in the recorded data with a lower exchange rate;
- judging on the basis of results obtained, oxygen measurements are more repeatable; therefore, the proposed technology can be applied effectively to evaluate the air exchange in buildings.

EXPERIMENT	n° EXCHANGES/HOUR	
	WATER VAPOUR METHOD	OXYGEN METHOD
1	0.22	0.35
2	0.12	0.37
3	0.21	0.37
4	0.27	0.38
5	0.31	0.32
6	0.19	0.36

Chart 3

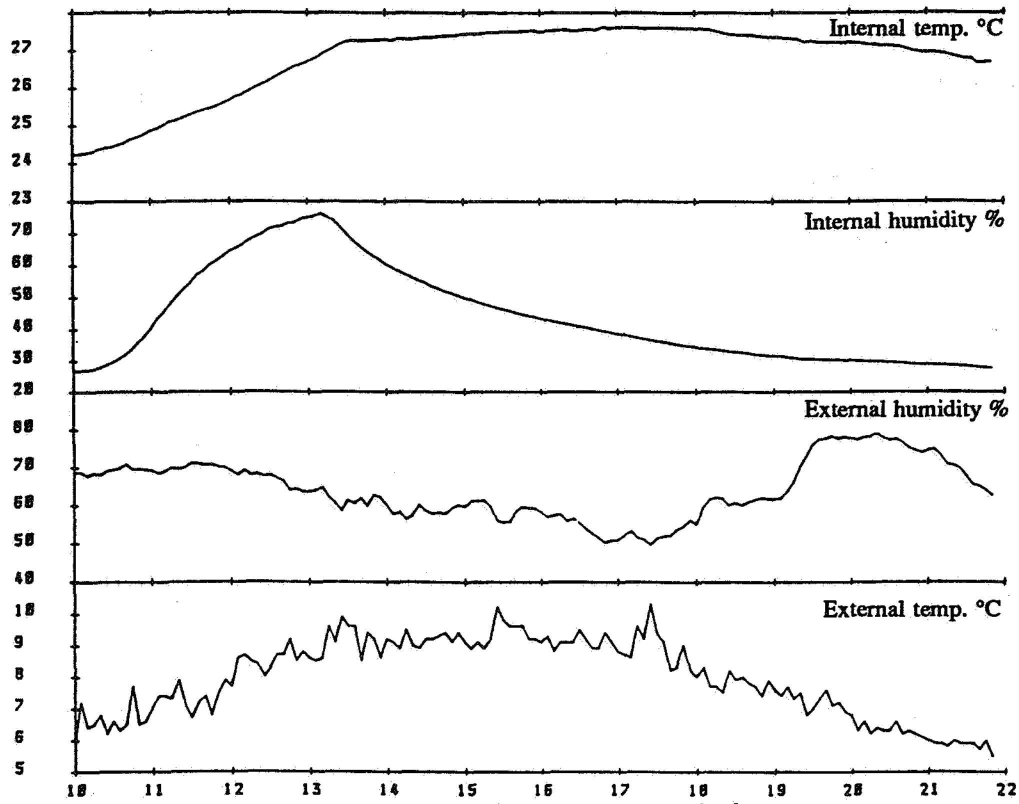

Diagram 1: Water vapour method

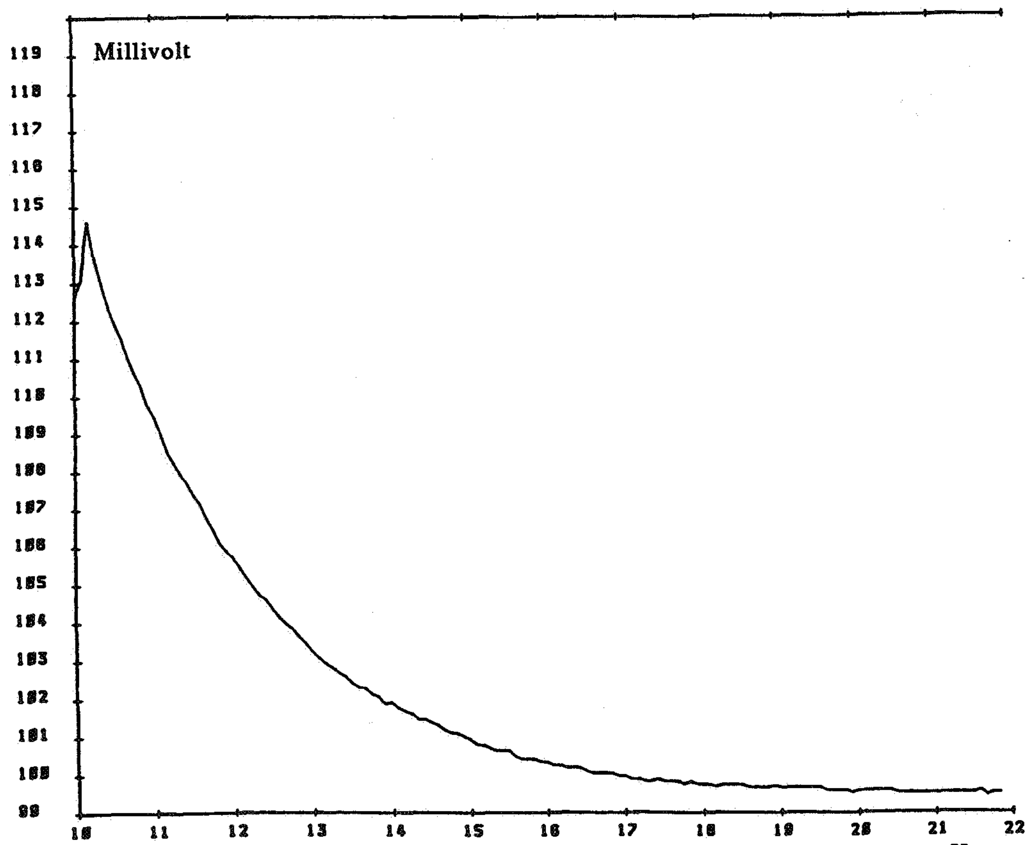

Diagram 2: Oxygen method (% shown in mv)