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Measurement of ventilation routes on dwelling

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Abstract

To check the designed ventilation routes, the authors have developed a method for measurement of ventilation rate and routes in the spaces using multi-tracergases. We verified this method in a test chamber with three rooms and in a test house that is designed ventilation routes.

In this measurement, different kinds of tracergase were generated at the same time in each room and sample gas was inhalted constantly in each room and obtaining the concentrations of three kinds in each room by using the flame ionization detector. In this way, integrated concentration value or mean concentration of each gas are obtaining by one sampling in each room. As for the standard flow rates, calibrated values were obtained by the measurement of air velocities in connecting ducts. The results from the tracergas method are almost the same as the standard air flow.

And also we verified this method in a latest test house to confirm the ventilation routes. Consequently, a measuring method of ventilation between multi spaces is useful to know the actual condition of ventilation with its routes.

1.Introduction

Though the airtightness of general houses in Hokkaido is going to be higher, the occurrence of air pollution and vapour condensation are more anxiously concerned. There needs the necessity of design of ventilation system and its routes for to get a solution of these problems. However there needs also the way of test if that system goes well.
To check the designed ventilation routes, the authors have developed a method for measurement of ventilation rate and routes in the multi-spaces using multi-tracergases.

2.Principle of measurement

The basic principle of measurement is by a tracer gas method. Suppose the spaces with three rooms that are connecting by the controlled constant air flow like as fig.1. When the different kind of tracer gases generates in each space, the balance equation of concentration of each tracer gas can get as follows;

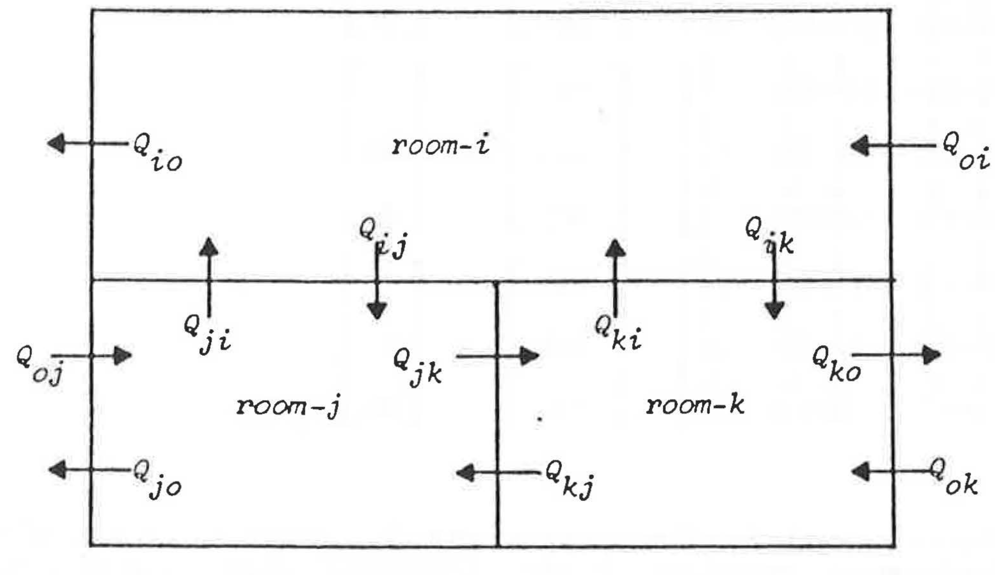


Fig.1 Model with three rooms

$$\begin{aligned} M_i + C_j^i Q_{ji} + C_k^i Q_{ki} &= C_i^i (Q_{ji}+Q_{ki}+Q_{oi}) \\ C_i^i Q_{ij} + C_k^i Q_{kj} &= C_j^i (Q_{ij}+Q_{kj}+Q_{oj}) \\ C_i^i Q_{ik} + C_j^i Q_{jk} &= C_k^i (Q_{ik}+Q_{jk}+Q_{ok}) \end{aligned} \qquad (1)$$

$$\begin{aligned} C_j^j Q_{ji} + C_k^j Q_{ki} &= C_i^j (Q_{ji}+Q_{ki}+Q_{oi}) \\ C_i^j Q_{ij} + M_j + C_k^j Q_{kj} &= C_j^j (Q_{ij}+Q_{kj}+Q_{oj}) \\ C_i^j Q_{ik} + C_j^j Q_{jk} &= C_k^j (Q_{ik}+Q_{jk}+Q_{ok}) \end{aligned} \qquad (2)$$

$$\begin{aligned} C_j^k Q_{ji} + C_k^k Q_{ki} &= C_i^k (Q_{ji}+Q_{ki}+Q_{oi}) \\ C_i^k Q_{ij} + C_k^k Q_{kj} &= C_j^k (Q_{ij}+Q_{kj}+Q_{oj}) \\ C_i^k Q_{ik} + C_j^k Q_{jk} + M_k &= C_k^k (Q_{ik}+Q_{jk}+Q_{ok}) \end{aligned} \qquad (3)$$

Since the equations (1)-(3) are realized simultaneously, these can rewrite at every ventilation routes as follows;

$$\begin{bmatrix} (C_i^i-C_j^i) & (C_i^i-C_k^i) & C_i^i \\ (C_i^j-C_j^j) & (C_i^j-C_k^j) & C_i^j \\ (C_i^k-C_j^k) & (C_i^k-C_k^k) & C_i^k \end{bmatrix} \begin{bmatrix} Q_{ji} \\ Q_{ki} \\ Q_{oi} \end{bmatrix} = \begin{bmatrix} M_i \\ 0 \\ 0 \end{bmatrix}$$

$$\begin{bmatrix} (C_j^i-C_i^i) & (C_j^i-C_k^i) & C_j^i \\ (C_j^j-C_i^j) & (C_j^j-C_k^j) & C_j^j \\ (C_j^k-C_i^k) & (C_j^k-C_k^k) & C_j^k \end{bmatrix} \begin{bmatrix} Q_{ij} \\ Q_{kj} \\ Q_{oj} \end{bmatrix} = \begin{bmatrix} 0 \\ M_j \\ 0 \end{bmatrix}$$

$$\begin{bmatrix} (C_k^i-C_i^i) & (C_k^i-C_j^i) & C_k^i \\ (C_k^j-C_i^j) & (C_k^j-C_j^j) & C_k^j \\ (C_k^k-C_i^k) & (C_k^k-C_j^k) & C_k^k \end{bmatrix} \begin{bmatrix} Q_{ik} \\ Q_{jk} \\ Q_{ok} \end{bmatrix} = \begin{bmatrix} 0 \\ 0 \\ M_k \end{bmatrix}$$

So we can get ventilation rate on each routes by using these simultaneous equations if the generating flow rate of tracer gases are known. However if the generating of tracer gas is pulsive, the integration value of concentration of response in other space except generating tracer gases will be equal to the constant value of concentration of constant generating, i.e.

$$C_i^i(t)=\int_0^t \psi_i(\tau)\Delta M_i(t-\tau)d\tau \quad \text{where,} \quad C_i^i=1/\Delta t\int_0^\infty C_i^i(t)dt$$

$$C_j^i(t)=\int_0^t \psi_j(\tau)\ C_i^i(t-\tau)d\tau \qquad C_j^i=1/\Delta t\int_0^\infty C_j^i(t)dt$$

$$C_k^i(t)=\int_0^t \psi_k(\tau)\ C_i^i(t-\tau)d\tau \qquad C_k^i=1/\Delta t\int_0^\infty C_k^i(t)dt$$

In the same manner,

$$C_i^j=1/\Delta t\int_0^\infty C_i^j(t)dt \qquad C_i^k=1/\Delta t\int_0^\infty C_i^k(t)dt \qquad M_i=\Delta M_i/\Delta t$$

$$C_j^j=1/\Delta t\int_0^\infty C_j^j(t)dt \qquad C_j^k=1/\Delta t\int_0^\infty C_j^k(t)dt \qquad M_j=\Delta M_j/\Delta t$$

$$C_k^j=1/\Delta t\int_0^\infty C_k^j(t)dt \qquad C_k^k=1/\Delta t\int_0^\infty C_k^k(t)dt \qquad M_k=\Delta M_k/\Delta t$$

where,

C_i^i :response of concentration at room-i due to the tracer gas generation in the same room-i (ppm)

C_i^j :response of concentration at room-i due to the tracer gas generation in another room-j (ppm)

Mi :steady generation rate of tracergas in room-i (ml/h)

Qij: ventilation rate from room-i to room-j (ml/h)

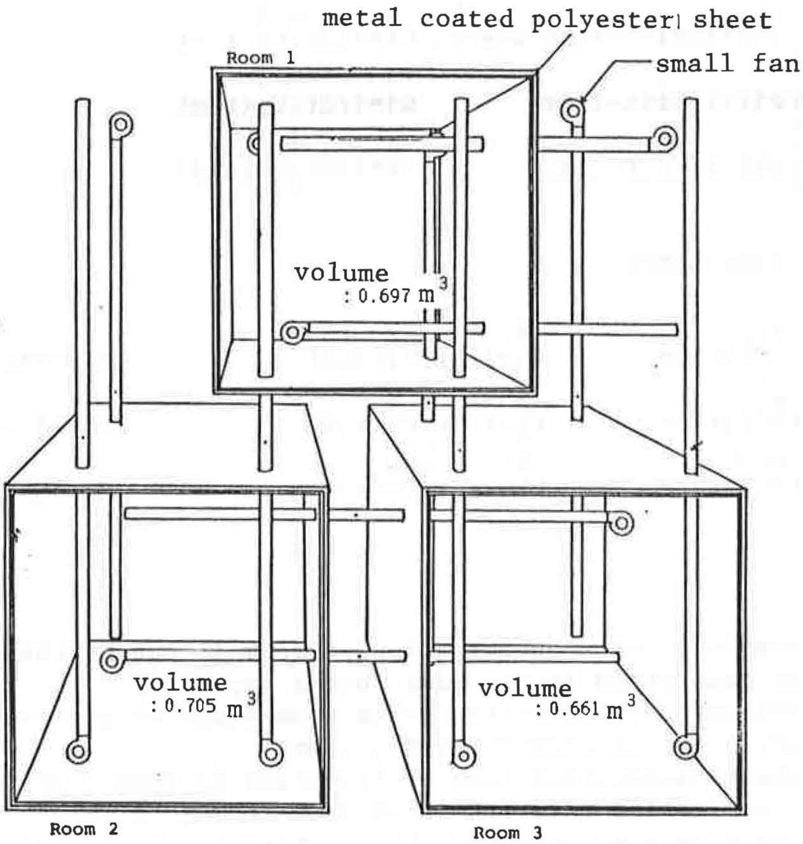
ψi : unit pulsive response of concentration in room-i (ppm/h)

Therefore when the generation of tracer gas is pulsive, we can get the ventilation rates on each space by using of pulsive generating time dt and the integration value of concentration.

3.Test results in the test chamber

Figure 2 shows the test chamber with three spaces. Three spaces are connected by circular ducts and the standard air flow in each duct were controlled by the small sized electric fans. Each standard air flow rates are calculated by the hot wire anemometer that measures air velocity in the circular ducts.

And to avoid loss of tracer other than by ventilation, the material of wall surface of test chamber used a metal coated polyester sheet.



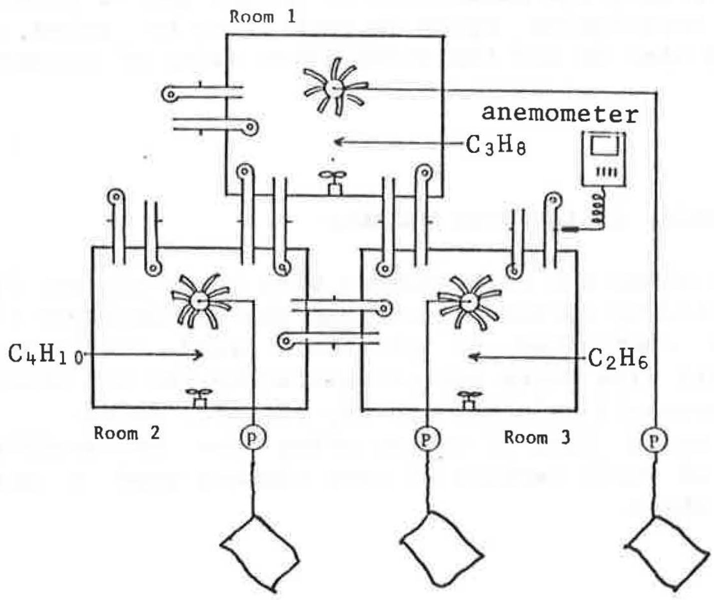


Fig.2 Test chamber and an outline of experiment

The tracer gases that we used are three kinds(C_2H_6,C_3H_8,C_4H_{10}). The integrated value of concentration of tracer gas were sampled into gas bug constantly used of small pump. By this way, the integrated value of concentration of tracer gases are able to get instantly and with high accuracy without other treatment way for integration. And the sampled tracer gas are analyzed by the flame ionization detector (FID).

Figure 3 shows the results of experiments in test chambers with three kinds tracer gases. The tracer gases in each space were generated 0.8 litter and the sampling time were 30 minutes which is not influenced on the integration value. The parenthesized values mean the standard air flow rates. As compared this with measured value by the tracer gas, each values are almost the same. But there remain some issues to be examined for the measurement of concentration such as purity of gas or unevenness of mixing.

From this results, practical use of this measuremental method is confirmed.

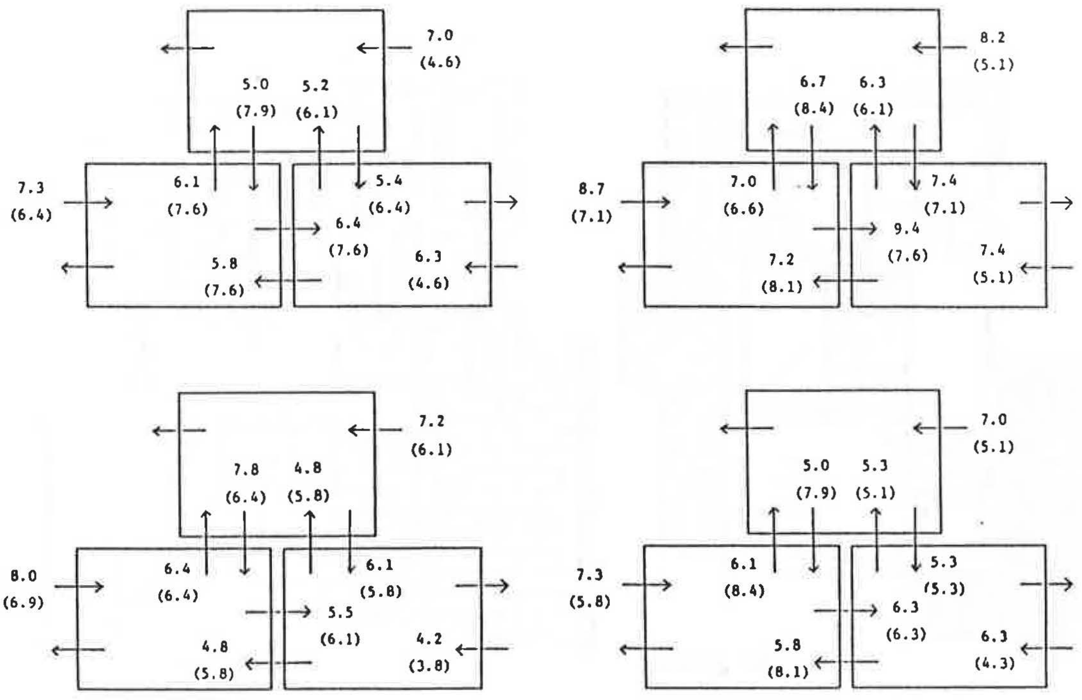


Fig.3 Test results

4.Measurement results in a test house

The verification of this method are done in the latest test house as shown fig.4.

This test house is formed iron steel flames covered outside with wooden air barrier, and made for the purpose of designed ventilation and heating system. The airtightness of this test house is 1.2 cm^2/m^2 as equivalent leakage area per total floor area.

Figure 5 shows the degree of airtightness of several kind constructive methods. Comparing with the degree of general wooden house by the traditional constructive method called 'Jikugumi' (9.0 cm^2/m^2), degree of this test house is able to say in high level(1.2cm^2/m^2) in Hokkaido at present.

The ideal ventilation system and its routes of this house is designed as fig.6. The attic space is used as the supply ducts. The fresh air is supplied to the attic space first from heat recovery ventilation equipment. The polluted air is exhausted through ducts from bathroom, toilet and kitchen where the air pollution occurs mainly.

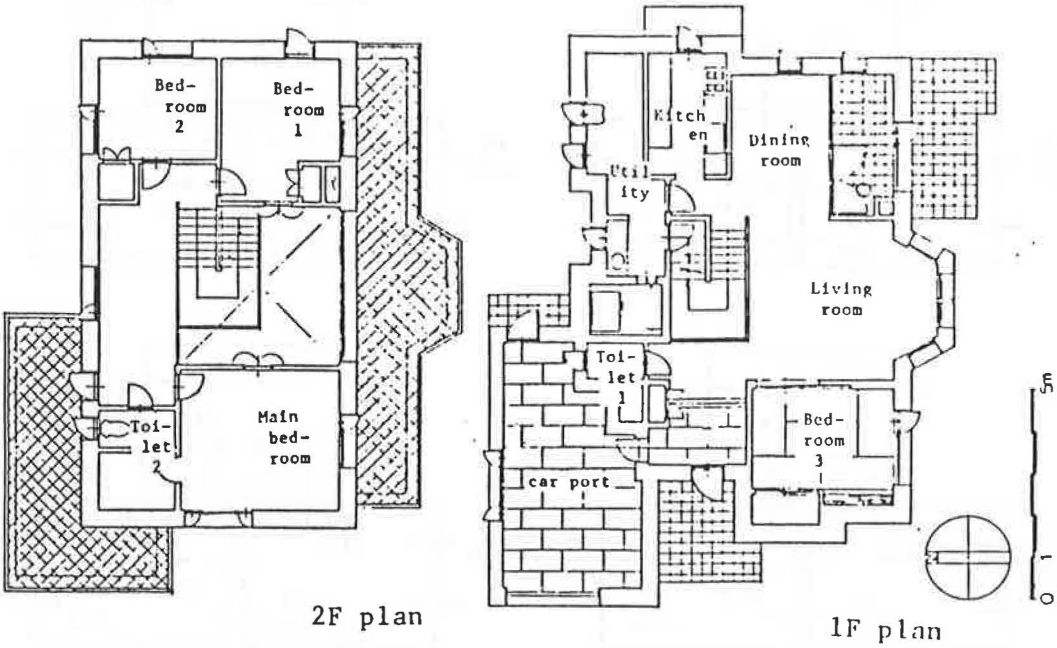


Fig.4 Test house

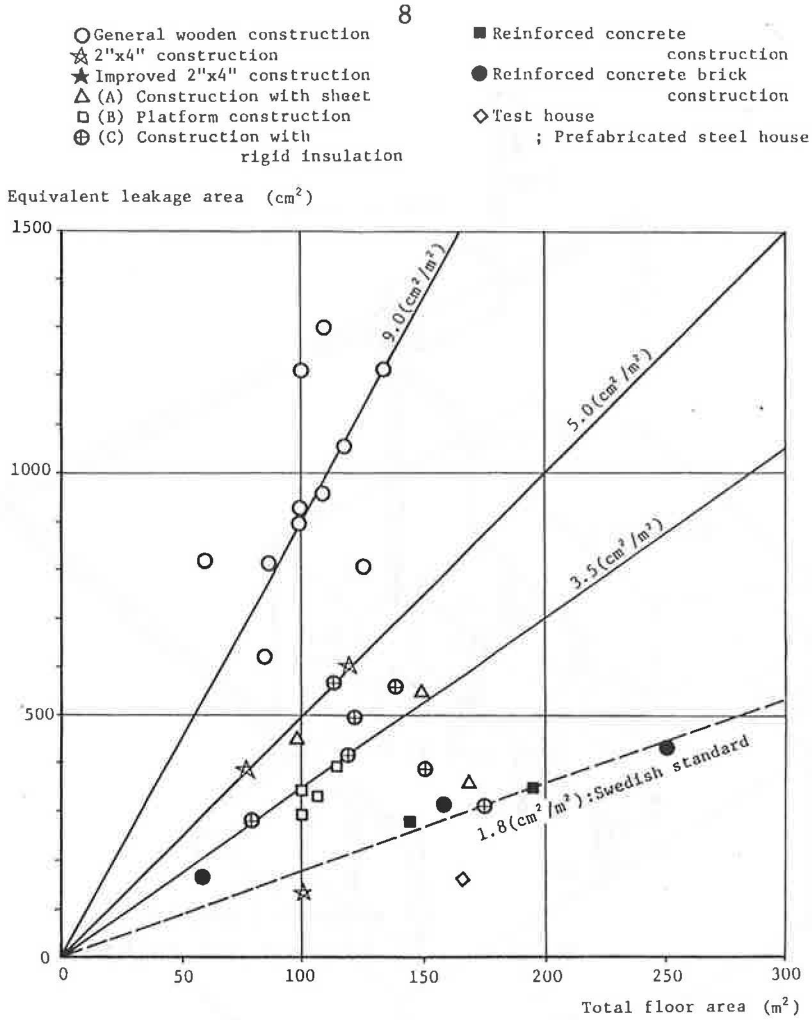


Fig.5 Equivalent leakage area of several constructions in Hokkaido

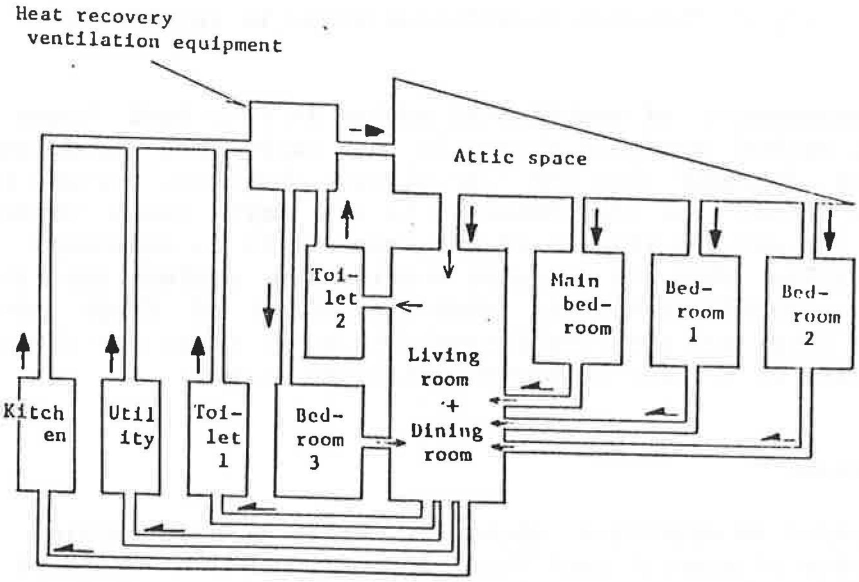


Fig.6 Ventilation routes in the test house

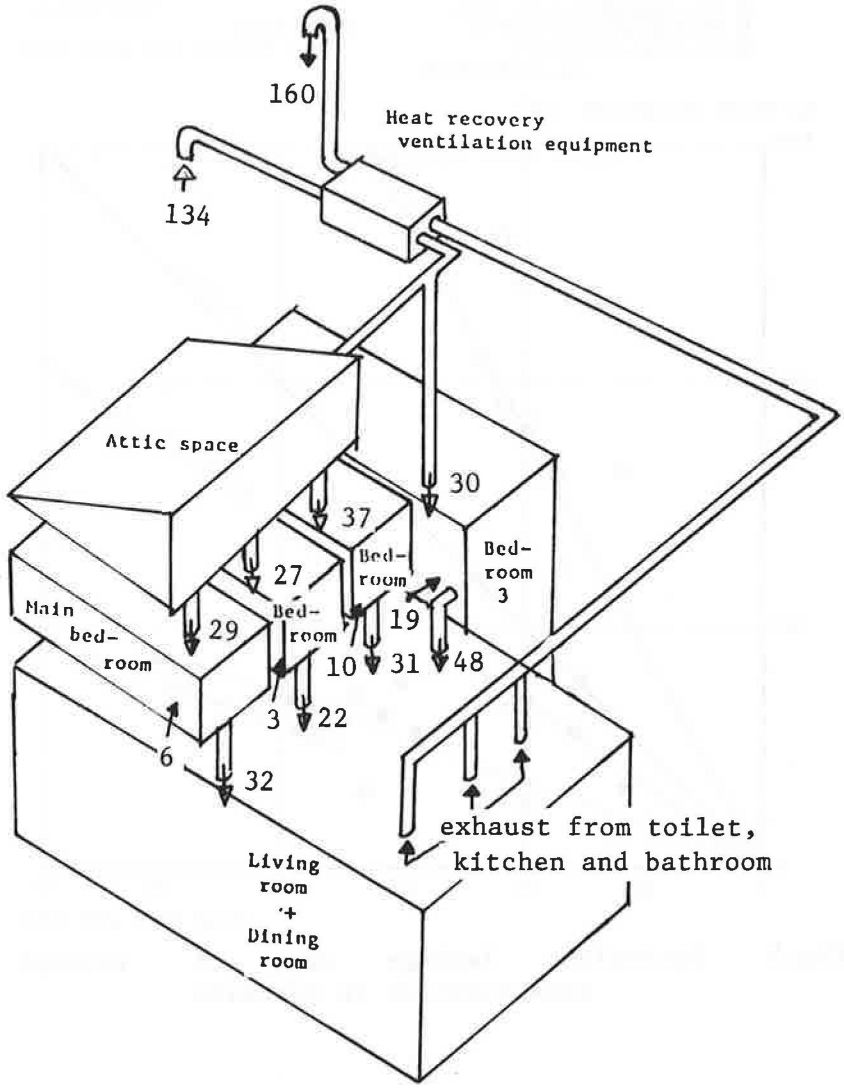


Fig.7 Measured ventilation rates in test house

The measurement of ventilation routes in this test house are done by method mentioned above. In this case, the simultaneous equations decrease than the case of test chambers. Because there are few rooms that are connected to the next rooms directly. Figure 7 shows the results of measurement. It is obviously from this results that the designed ventilation routes are nearly realized. Ventilation are taken from inlet of fresh air of supplied room, and air flow through the other rooms are exhausted from outlet of toilet, bathroom or kitchen finally.

5.Conclusion

This paper is described about the method of ventilation rate and routes of general dwellings. The method which we showed has some different characters from other measuring method by the tracer gas;

a) The supplying of tracer gas is pulsive (not continuously).
b) Responses of concentration in several space are able to get as integration value of concentration automatically.

So the results of measurement can take as constant generation method of tracer gas. As showed the results of several investigations, we confirmed the usefulness of this method in practical measurement of ventilation routes.

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