OPTIMUM VENTILATION AND AIR FLOW CONTROL IN BUILDINGS

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(Title) FULL-SCALE MEASURMENTS OF INDOOR AIR FLOW

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SUMMARY

Full scale measurements of air flow velocities, temperature, intensity of turbulence and air exchange rate are carried out on two rooms with different type of ventilation located in the department of architecture at Chalmers University of Technology. The measurements have shown that *mixed* ventilation gives variable mean flow velocities with a high risk of draught as compared to the room provided with displacement ventilation. Air exchange rate for the room with *displacement* ventilation is obtained from tracer gas monitor by employing *decay* and *constant emission* methods. The measurements give similar results for both the methods.

1. INTRODUCTION

For probabilistic modelling of air quality in a room, access to full-scale data is a pre-requisite condition for describing the distribution of air flow velocities, intensity of turbulence, draught and temperature. With this in mind, the work described in this paper deals with full-scale measurements for two different types of ventilation systems .The first test object is provided with *mixed* ventilation and the second test room consists of *displacement* ventilation. Full-scale measurements of air flow velocities, intensity of turbulence, draught and temperature are carried out at 24 locations and five different heights. Measurement of air exchange rate is only carried out for test *room B*. The note presents measuremnts at two levels only, namely, 0.6 m and 1.4m height. Details of measurements at other levels are given in reference 1.

2. INSTRUMENTATION

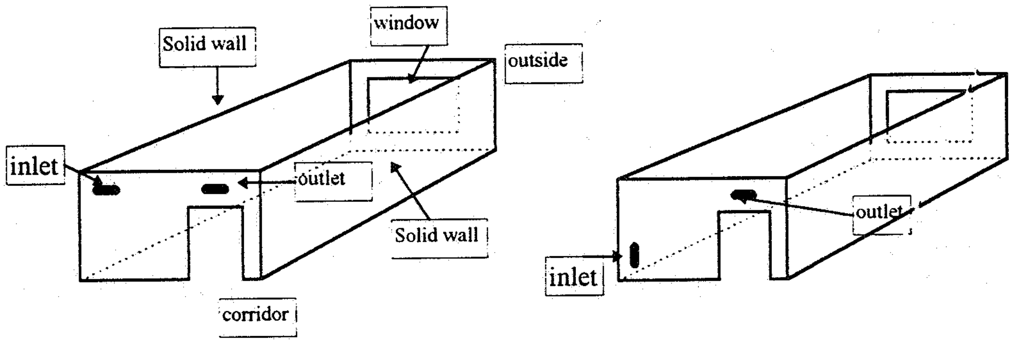
Air flow velocities and temperatures are measured with constant temperature instrument developed by *SWEMA*. The instrument is designed for measurement of low velocities with high sensitivity and is based on the principle of measurement of convective flow caused by temperature difference.A total number of nine *SWEMA 300* anemometers are acquired and out of which eight are omni-directional and one is uni-directional.

The air exchange rate is measured with multigas monitor instrument developed by *Brüel & Kjaer (B&K)*. The instrument consists of a multipoint doser and a sampler which is operated from a desk top computer. The measuring system can be operated either by recording the decay of tracer gas over a length of period or as a continuous measuring device by providing extra supply of the gas to keep a constant level. Although the system is slow in time response, yet it is one of the most reliable measuring system available at the present time.

3. DESCRIPTION OF TEST ROOMS

Full-scale measurements of air flow velocities and temperature have been carried out for two rooms with identical construction but with different ventilating systems.The first object *room A* is ventilated with old type system of *mixed* ventilation, while the second object *room B* is recently fitted with ventilation based on the principle of *displaced* flow. Figure 1 shows the two rooms with locations of air inlets and outlets together with their dimensions and volume. It should be observed that the construction properties of the two rooms are identical and any differences in the air flow are due to functioning of the ventilating systems.

Location of the measuremnt points is shown in figure 2.



Room *A Mxed* Ventilation **Room B** *Displacement* Ventilation

Figure 1 Test rooms with *Displacement* and *Mixed* \ entilation Systems

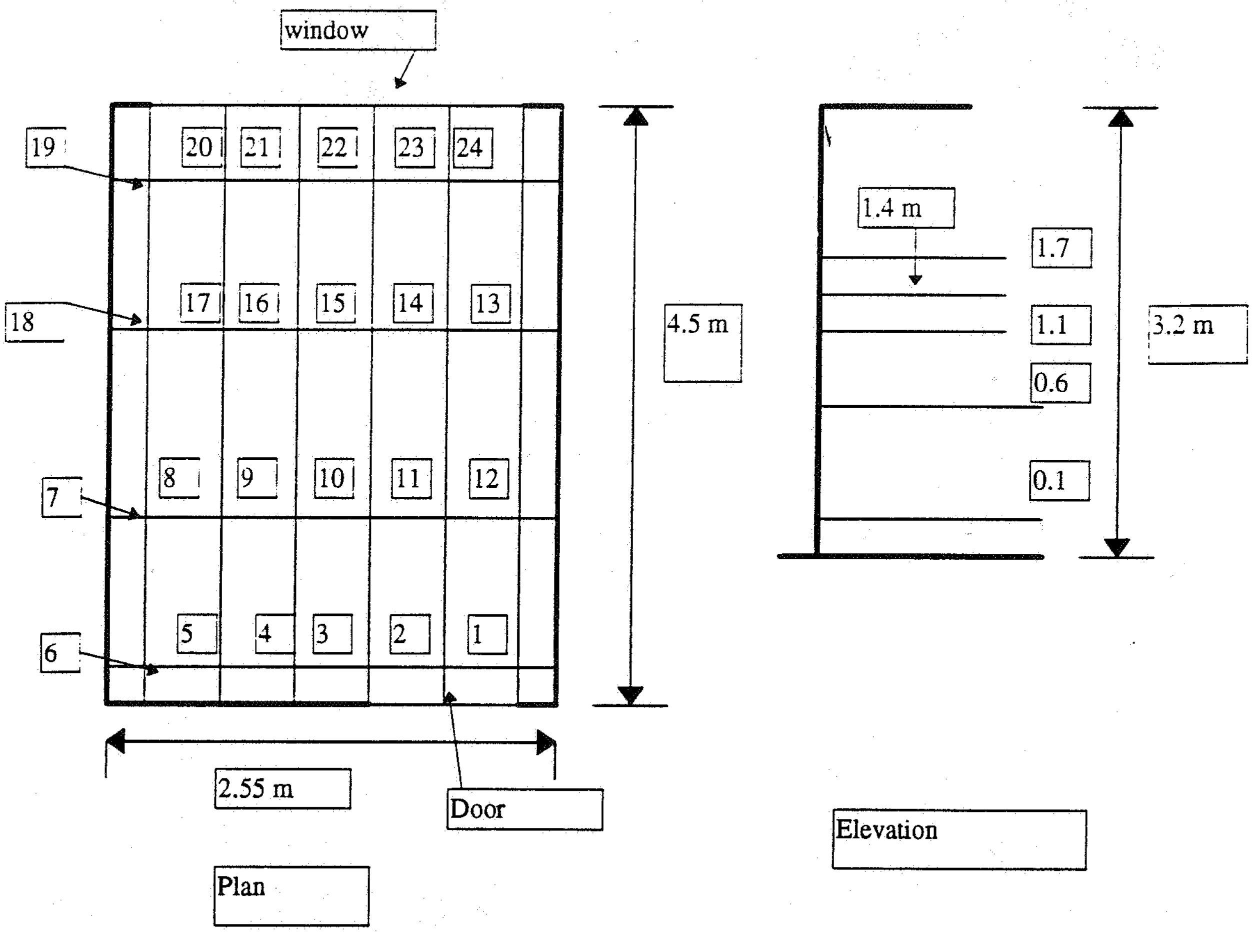


Figure 2 Location of measurement points at different levels

4. MEASUREMENTS OF AIR FLOW VELOCITIES, INTENSITY OF TURBULENCE, AND DRAUGHT

4.1 Distribution of Air Flow

Ventilation in test *room A* is of mixed type with the inlet and outlet located near the ceiling as shown in figure. A three-dimensional view of the flow for levels 0.4m and 1.6 m is shown in figure 3. The plot shows that the air flow velocities are generally higher near the window which is further away from the ventilation inlet and low near the entrance.The measurements have shown that the mean air flow varies considerably from location to location and lies between 5 and 15 cm/s. The range for minimum and maximum velocities was from 0 to 30 cm/s for all levels.

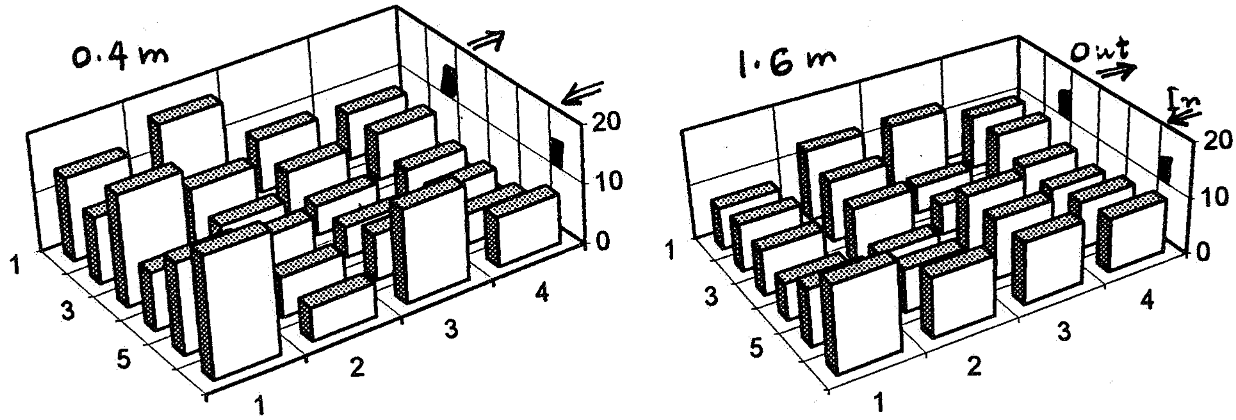


Figure 3: Three-dimensional View of Flow for *Mixed* Ventilation *(Room A)*

Ventilation in *room B* is of *displacement* type with inlet located near the floor and the outlet at the top corner at a distance of 10 cm from the ceiling. The details are shown in figure 2. In both test rooms, all the measurement points have been selected with due consideration given to their similarity in position.

Three-dimensional plots of the flow velocities are shown in figure 4. A general impression from these figures is that the flow is not varying as opposed to the case for *room A*..

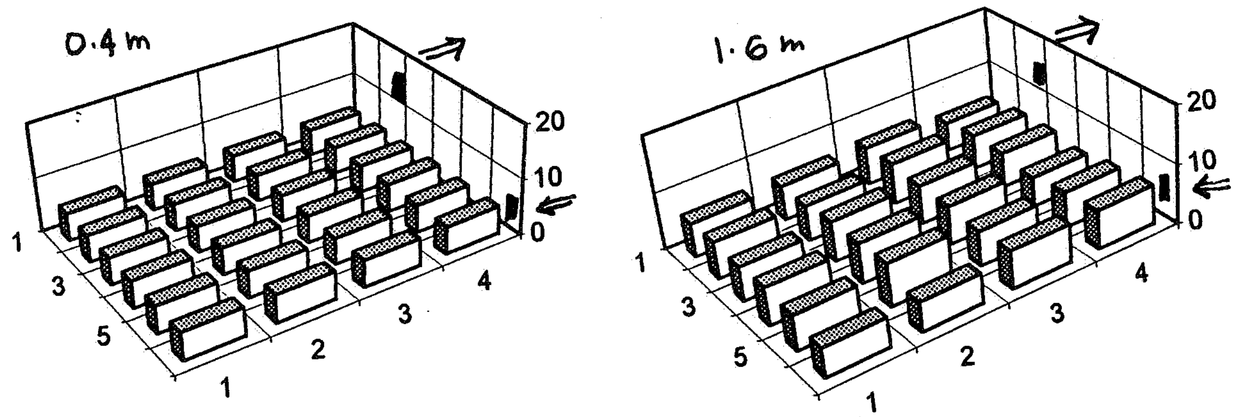


Figure 4: Three -dimensional View of Flow for *Displacement* ventilation *(Room B)*

4.2 Intensity of Turbulence

The air flow in room fluctuates randomly and is generally expressed as a ratio of standard deviation σ and mean flow velocity v. Larger the intensity of turbulence, greater is risk of draught. For the case of measurements of intensity of turbulence for *mixed* ventilation systems, I_V is approximately 20% as shown in figure 5. This is valid for all levels except at certain locations where it can be about 40%.

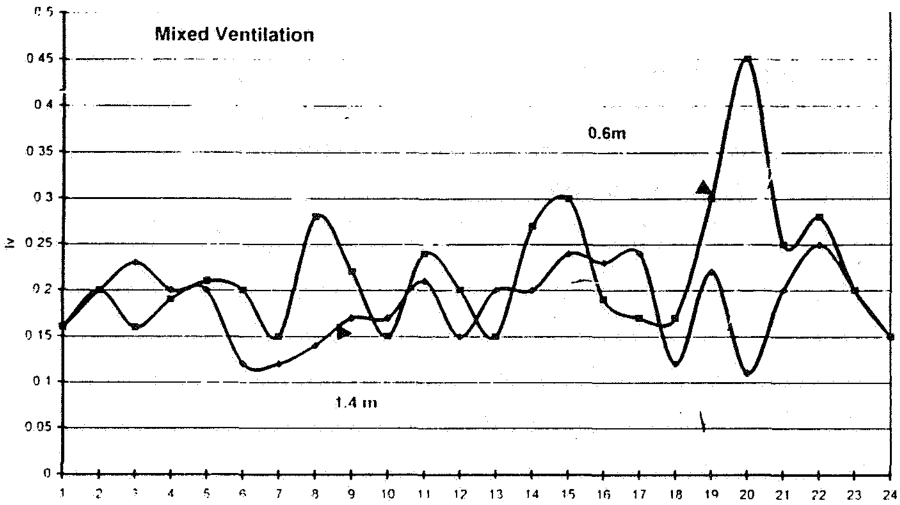


Figure 5: Intensity of Turbulence for *Mixed* Ventilation *(Room A)*

For the case of *displacement* ventilation,the intensity of turbulence I_V varies considerably from point to point in the room as shown in figure 6. It lies between 20–40% depending on the height of the measuring point.

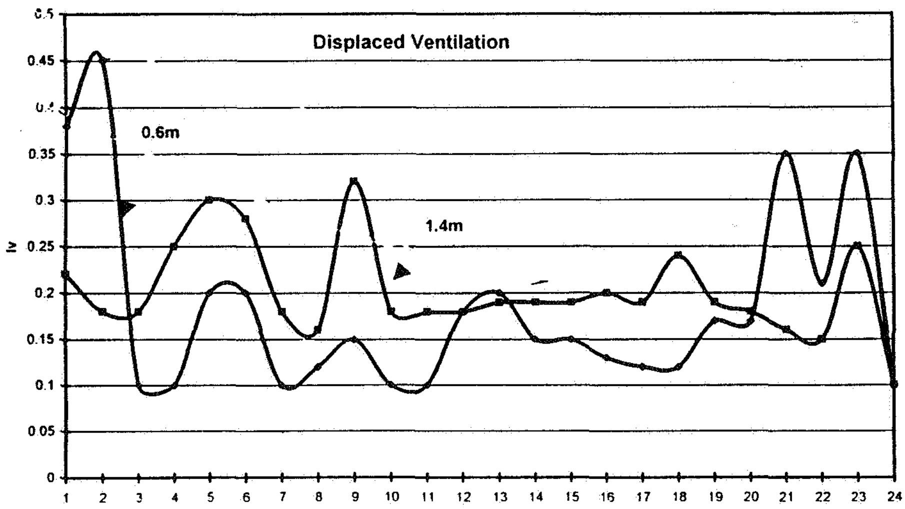


Figure 6: Intensity of Turbulence for *Displacement* Ventilation *(Room B)*

4.4 Risk of Draught

Sensation of draught is dependent not only on the mean flow velocity and temperature but also on the intensity of turbulence. Reference 2 gives an expression for calculating the percentage of dissatisfied inhabitants which can be written as:

$$PD = \{34 - t_a\}\ \{0.01\ v - 0.05\}^{0.623}\ \{0.00369\ \sigma + 3.143\}$$

where $v \geq 5$ cm/s

t_a - temperature inside the room in °C

v - mean flow velocity cm/s

σ - standard deviation of velocity

It can be noted that the risk of draught PD increases with increase in the mean flow velocity and intensity of turbulence. Figure 7 shows the risk of draught as a percentage of dis-satisfied people for all the measured points at different levels. It is approximately 8% and in some cases it approaches to 15% in *mixed* ventilation

For the case of *displacement* ventilation,the intensity of turbulence I_V varies considerably from point to point in the room as shown in figure 5. It lies between 20–40% depending on the height of the measuring point. However, these variations have insignificant effect on the risk of draught as the mean flow velocity is rather low (approximately 5 cm/s).

It should be mentioned that the sensation of draught is subjective and varies from person to person and also the above formula is approximativ

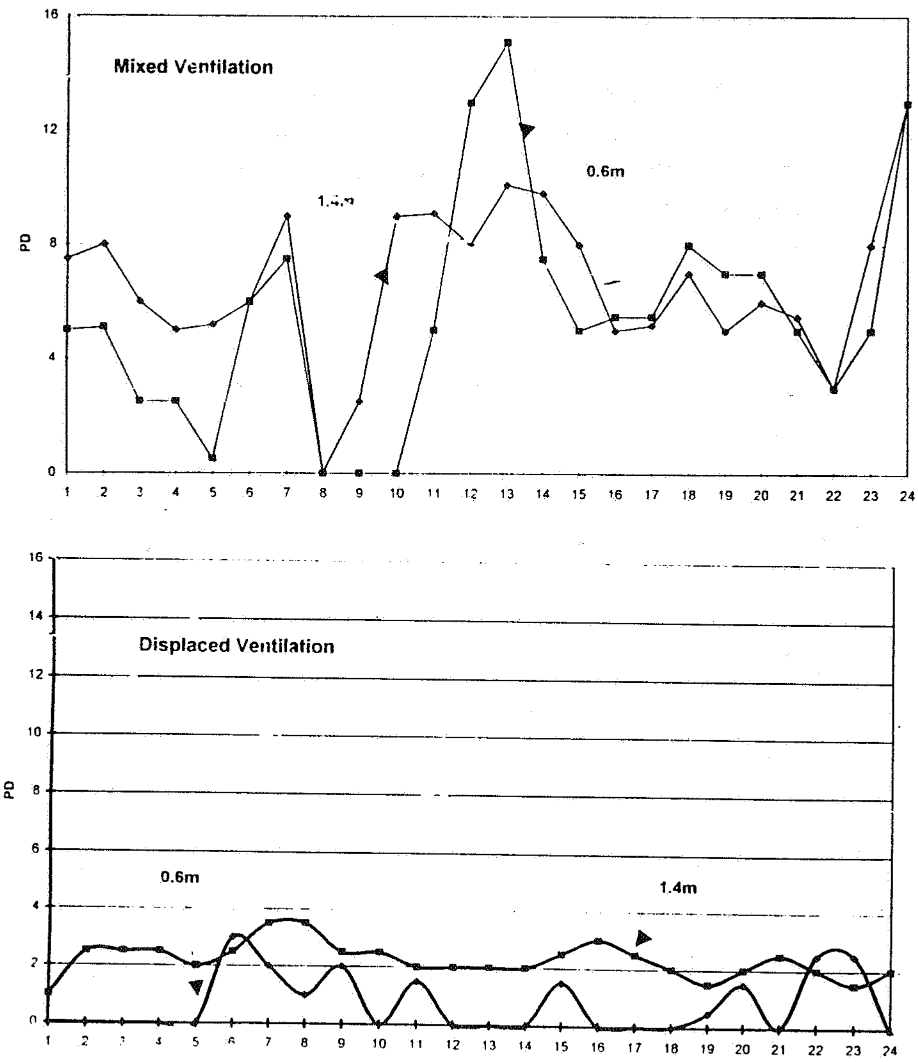
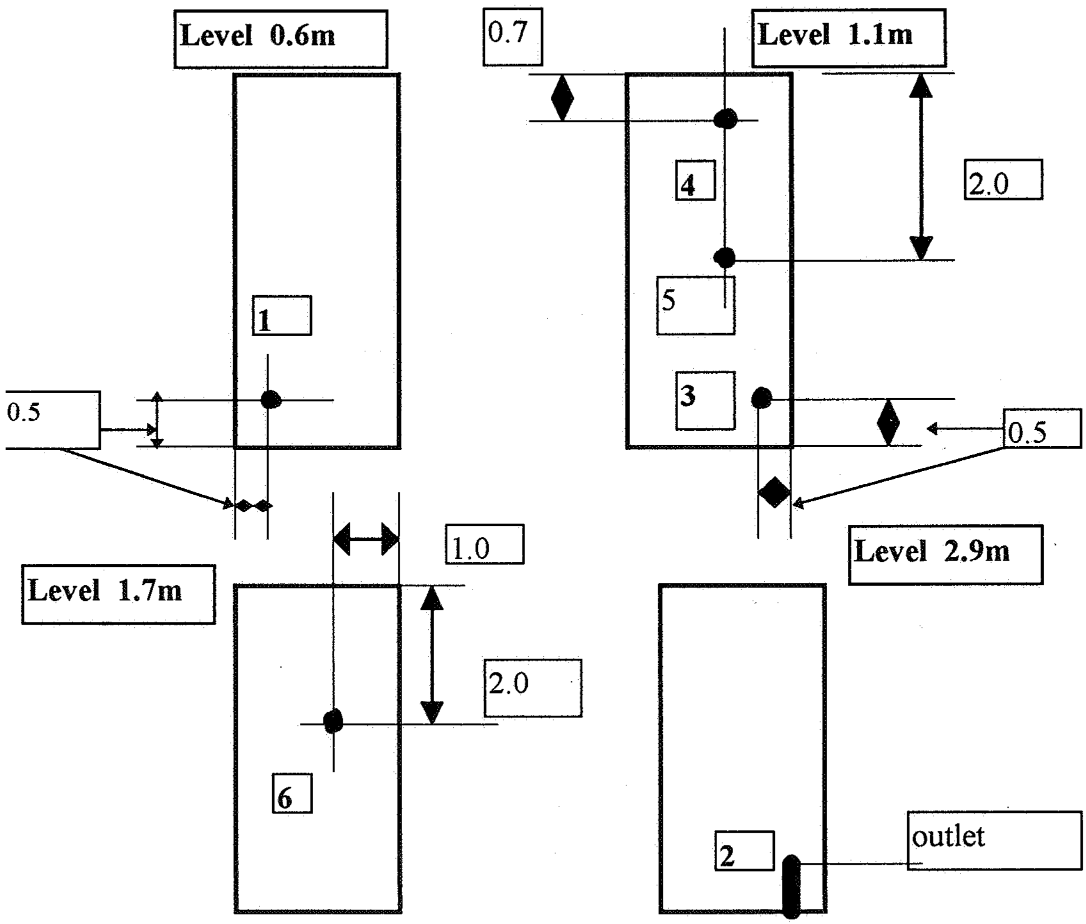


Figure 7: Draught in *Room A* and *Room B*

5. MEASUREMENT OF AIR EXCHANGE RATE FOR ROOM "B"

Air exchange rate for test *room B* is measured at six locations and four different levels as shown in figure 8. Locations 1 and 2 are situated near the inlet and outlet respectively. The other measuring points are related to the flow in the middle and near the window



Level 2.9

Figure 8: Location of Measuring Points

Two different methods are employed for studying the air exchange rate in the room. The first method is based on the principle of decay of the concentration of the injected gas. Figure 9 shows the curves for the decay of the tracer gas for various locations.

An average value of 1.8 change/hour is obtained for all the points. Minimum value needed to fulfil the hygienic criteria given in the Swedish Standard amounts to 0.7 change/hour based on the volume of the room. It implies that the criteria for hygienic conditions is satisfactorily fulfilled by the displacement ventilation.

The second method for measuring the air exchange and air flow rate is to use constant emission method. In this method, the tracer gas is emitted at a constant rate for the duration of the measurement period. Figure 10 shows the results of measurements for all locations and it can be noted that all points have the same amount of concentration of gas after an initial period of one hour. Values of air exchange rate are automatically calculated by the *Brüel & Kjaer* (B&K) measuring system and amounts to 1.9 change/hour.

Age-of-air and air-exchange efficiency are obtained from measurements with the decay and the constant emission method. Table 1 presents the results based on the calculations performed by (B&K) computer programme on the measured data. It can be noted that both methods give similar results for air exchange efficiency, local and room average age-of-air. However, constant emission method shows larger variation in air exchange efficiency between measurement points 1 and 4 as compared to decay method. The measurements show that the efficiency of the ventilation is over 50%.

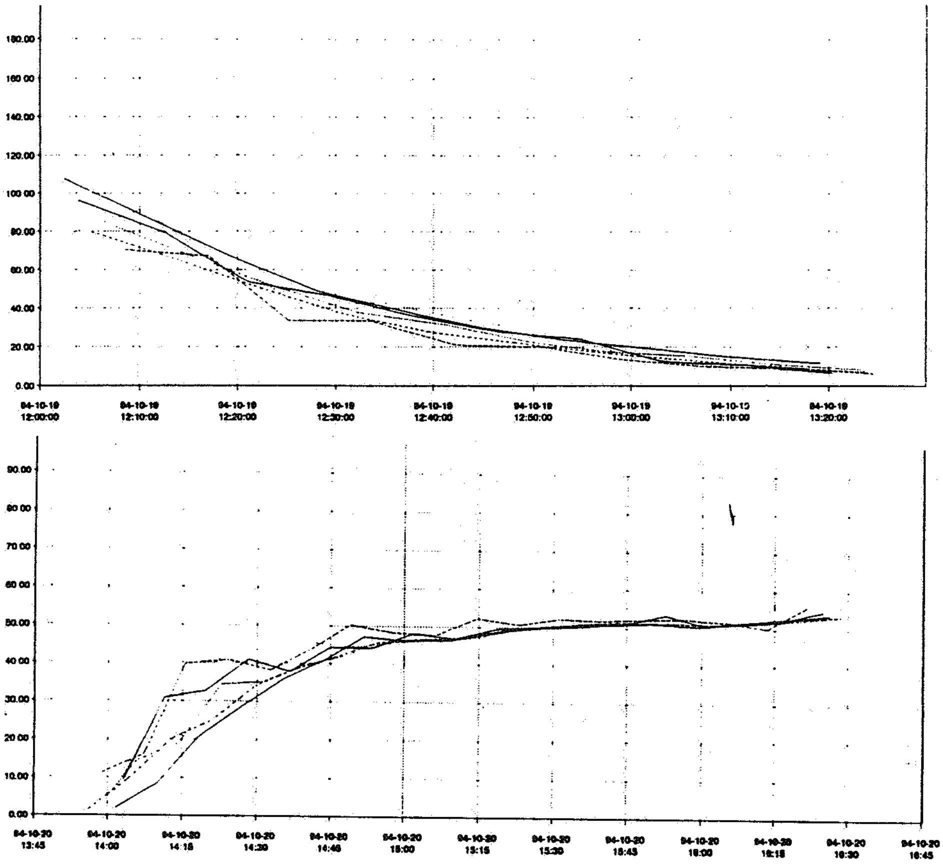


Figure 10: *ACH* based on *Decay* and *Constant* tracer gas methods

LOCATION	HEIGHT ABOVE THE FLOOR (m)	AIR EXCHANGE EFFICIENCY %		LOCAL AGE OF AIR (MINUTES)		ROOM AVERAGE AGE OF AIR (MINUTES)	
		Decay	Constant Emission	Decay	Constant Emission	Decay	Constant Emission
1	0.6	63	68	42.8	38.8	33.9	28.2
2	2.9	60	64	42.0	46.6	35.1	36.3
3	1.1	60	68	43.0	41.7	35.7	32.0
4	1.1	58	52	38.7	32.4	33.0	31.0
5	1.1	60	58	40.5	32.4	33.7	27.5
6	1.7	57	67	43.3	42.8	38.0	32.2

Table 1: Air Exchange Efficiency at different Locations

6. DISCUSSION OF RESULTS

Air flow velocity, intensity of turbulence and risk of draught are measured in two different rooms, identical in construction but with different ventilation systems.

The mean air flow is approximately 5 cm/s for the *displacement* ventilation and the air flow is evenly distributed over all levels and the risk of draught is minimal due to low flow velocities. In the case of *mixed* ventilation, the flow velocities over the whole room behave in an erratic manner. The flow velocities vary considerably from point to point and are much larger near the window and in the direction of the outlet. The risk of draught for the user is much higher for the mixed ventilation system as compared to displacement ventilation.
A comparison of results for two test rooms in figure 11 shows that the *displacement* ventilation provides air flow with low velocities and subsequently low risk of draught.

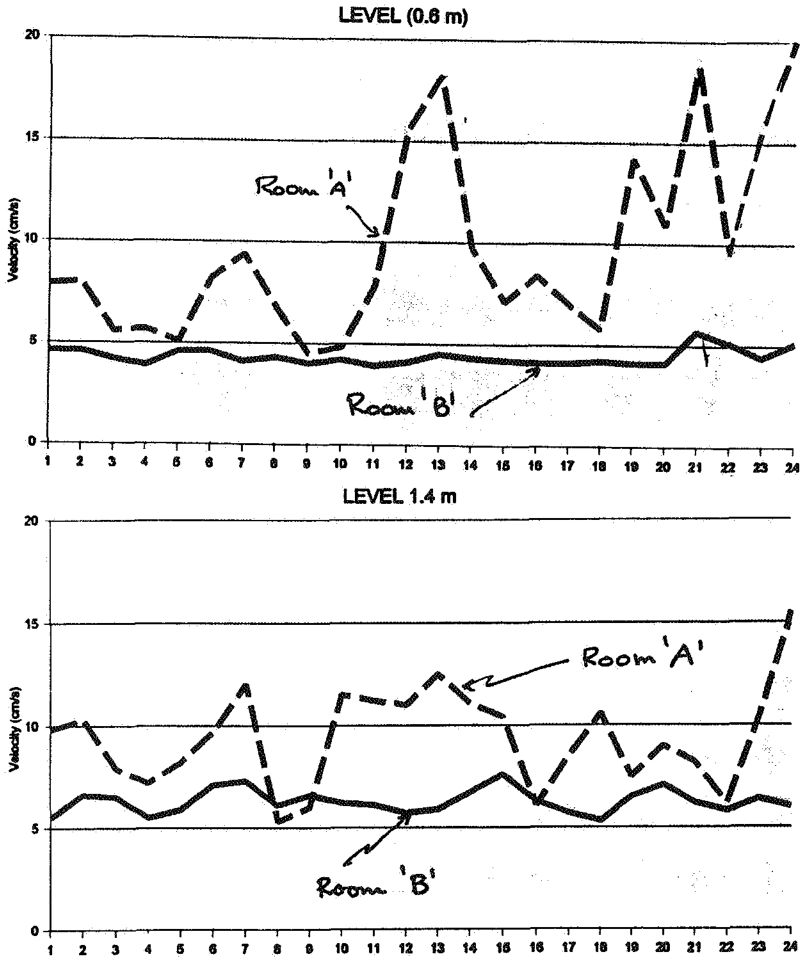


Figure 11: Comparison of Air Flow Velocities in *Room A* and *Room B*

Measurements of air exchange rate are carried out with the help of tracer gas monitor manufactured by *Brüel & Kjaer (B&K)*. Two different methods, namely, decay and constant emission are used in measuring the air exchange rate. It is found that the two techniques give similar results. Age of air and ventilation efficiency are also obtained from the measurements.

7. ACKNOWLEGEMENT

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8. REFERENCES

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