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AIR INFILTRATION AND VENTILATION SYSTEMS

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ABSTRACT

It is often assumed that dwellings with balanced ventilation systems are more affected by the outdoor climate than those depressurized with exhaust ventilation systems and therefore need to be more airtight to avoid excessively high airchange rates. However, very little data exists to verify and quantify this effect.

Measurements of airchange rates has been performed with the constant concentration tracer gas method in three apartments in buildings with different ventilation strategies. The buildings are included in the Stockholm project. Simultaneous measurements of wind speeds and temperatures as well as wind directions from a nearby climate station are used

The measurement results show that the total airchange rate in the three apartments are very constant and close to the fan-controlled air flows, although the driving forces for stack and wind effects were big. This show that the mechanical air flows are dominating in airtight buildings, which is desired. The standard deviation in total airchange rates was found to be between 4 and 6 % of the averages and weakly correlated to wind speed and wind direction. The smallest variation in total airchange rates and the least correlation to wind was found in the most airtight apartment with exhaust ventilation system. Although the variation in total airchange rate is small, individual rooms could show significant changes in supply air flow because of wind effects.

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BACKGROUND

New Swedish houses are made airtight with continuously operating mechanical ventilation systems. These are either exhaust fan systems (E) or exhaust and supply fans systems (ES). According to standard practice, the so called "balanced" ventilation systems (ES) should be adjusted to a slight negative pressure compared to the outside. This is done by setting the supply fan airflow to 80-90 % of the exhaust air flow. The reason for this is to avoid internal overpressure which in connection with air leaks could cause condensation problems in attics and in building structures in cold climates. For the exhaust fan system, inlets for supply air are provided in the building envelope with more or less sophisticated devices.

The size of the negative pressure is determined by the relation between the fan-controlled air flows and the airtightness of the building envelope during operating conditions (including intentional openings). Typically, the negative pressure for the ES system is in the order of 1-3 Pa and for the E system 5-15 Pa. Even higher pressure differences have been measured in apartments with E system and too few supply air openings.

As the exhaust only system normally creates a greater negative pressure inside than the ES system, it should be less sensitive to wind fluctuations. It could then be assumed that these houses have lower unintentional air infiltration levels, although very few attempts have been made to quantify this effect.

Attempting to document these effects, measurements of total airchange rate by the constant concentration tracer gas method were performed together with wind and temperature measurements in three unoccupied apartments with different ventilation systems.

The apartment buildings used for the tracer gas measurements are included in the so called Stockholm project and very well documented. The Stockholm project includes six new experimentally built energy efficient apartment buildings. Hourly data on energy use, energy supply, temperatures, outdoor climate, equipment performance etc. are taken and analyzed in many different aspects[1].

DESCRIPTION OF THE HOUSES

Skogsalmen (ES)

The Skogsalmen block of apartments consists of many buildings in two to four storeys. The floor plan and location of the measured apartment is shown in Figure 1. Each apartment is individually ventilated by an exhaust and supply mechanical ventilation system with heat recovery. The pressure difference to the outside during operating conditions (caused by the fan forces) is almost zero. The air leakage at 50 Pa for the apartment is 0.9 airchanges/hour (ach), which is better than the Swedish building code requirement, 1.0 ach. As all the blower door tests were performed, the leakage could be to the outside or to adjacent units. The apartment is exposed to winds from the south, east and north. On the south side, a glazed balcony covers the exterior wall. To the east, the apartment is exposed to the wind as one wall in a walkway "tunnel" through the building.

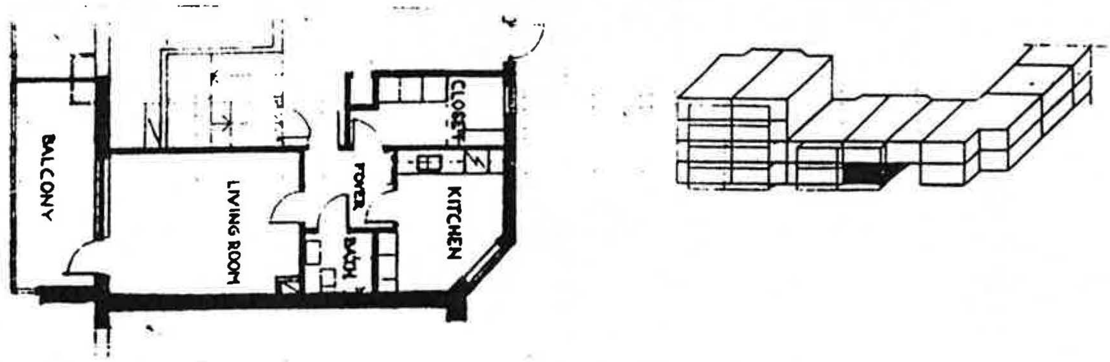

Figure 1. The measured bottom corner apartment in the Skogsalmen building (floor area 39 m^2, volume 94 m^3).

Sjukskoterskan (ES)

The Sjukskoterskan apartment building is equipped with a central unit for supply and exhaust air with heat recovery. The apartment location and floor plan is shown in Figure 2. Pressure difference to the outside is small. This apartment is less airtight than the previous, about 1.0 ach at 50 Pa, which is the size of the Swedish building code value. The apartment is exposed to winds from the north, west and south directions.

Konsolen (E)

The Konsolen building has a central exhaust ventilation system. Supply air enters the apartments through slot openings under the windows behind radiators in bedrooms and living rooms. The apartment where measurements were performed is shown in Figure 3. The negative pressure difference is about 15 Pa, owing to the good airtightness, 0.8 ach at 50 Pa. The big negative pressure is in this case necessary to overcome the pressure drop in the used special air inlets. The apartment is exposed to winds from the north and south directions and partly from the east.

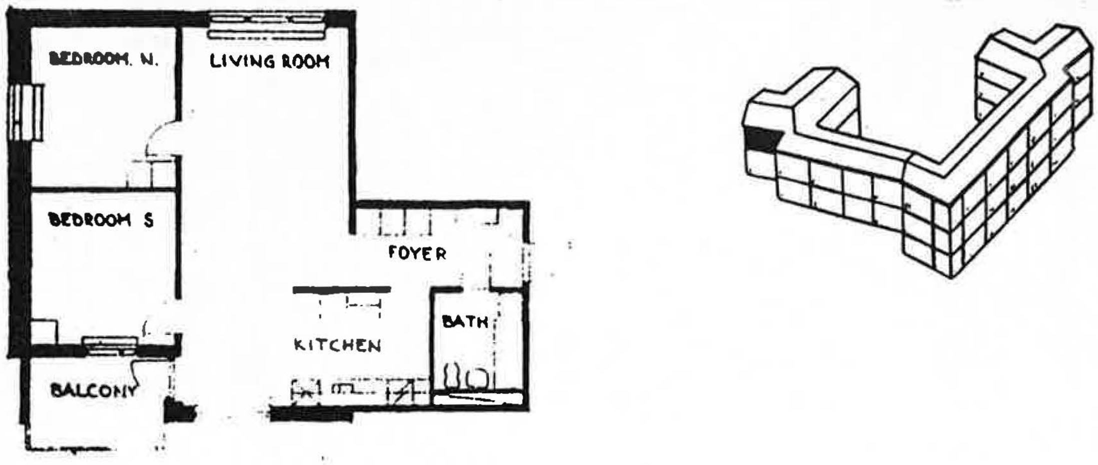

Figure 2. The upper corner apartment in the Sjukskoterskan building (floor area 74.5 m^2, volume 179 m^3).

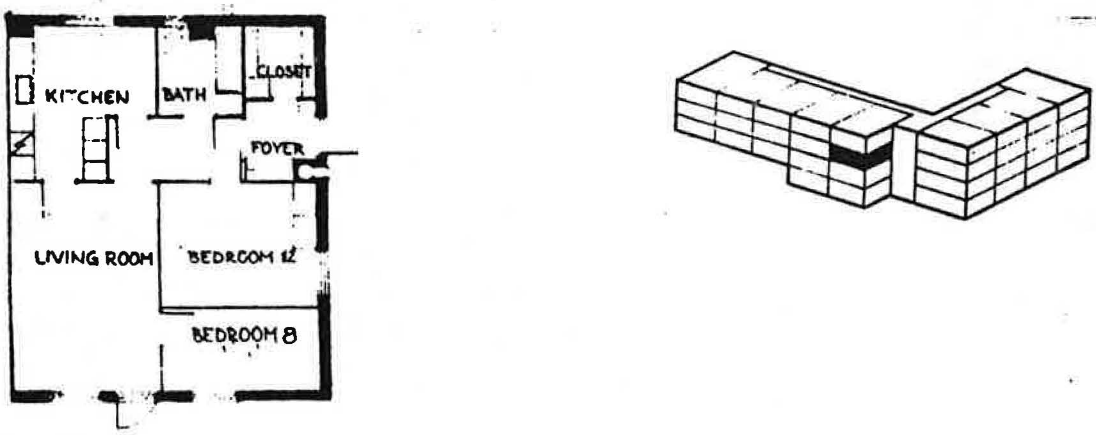

Figure 3. The measured apartment in the Konsolen building (floor area 72 m^2, volume 173 m^3).

MEASUREMENT SYSTEM

The constant concentration tracer gas system stores data every 30 minutes[2]. Hourly averages were made to obtain the same measurement interval as for the climatic measurements.

Hourly averages on outdoor temperature and wind speed were taken from the Stockholm project. Temperatures were measured at each apartment building. Wind speed data was taken from a point 1.5 m above the roof of the Konsolen building, which should be a uniformly exposed location. The distance to the Skogsalmen building is about two kilometers and to Sjukskoterskan about five kilometers.

Wind direction data was taken in three hour intervals from a meterological station near Sjukskoterskan. The data was converted to hourly values by extrapolation. Because the wind direction changed only a few times during the measurement periods, this should not have any effect on the result.

The fan-controlled air flows in the apartments were measured only momentaneously one time during each tracer gas test. However, hourly averages on total air flows from the whole buildings of Sjukskoterskan and Konsolen was taken from the Stockholm project. These flows were checked to see if any variations in air flows from the whole buildings existed.

MEASUREMENT RESULTS

In Figures 4-6, results from the tracer gas and weather measurements are given for the three different apartments. This type of tracer gas measurements give as result the amount of supply air entering each zone, which normally is a room. The supply air comes either from the outside or from adjacent apartments. Thus the rooms where air is extracted, as baths and kitchens, should measure zero supply air because the ventilation systems are designed so that this air is taken from the other rooms in the apartment.

Skogsalmen

Mechanical ventilation flows were measured momentaneously at the end of the tracer gas measurement period to 77 m^3/h of supply air and 75 m^3/h of exhaust air. This is very close to the design values in the Swedish building code. Compared to the total airchange rate given in Figure 4a, it can be seen that the air infiltration is very small. Average total airchange rate as measured by tracer gas was 74 m^3/h with a standard deviation of 5%. Wind speeds between 0-10 m/s and outdoor temperatures between -8 to 9 °C were measured, which can be seen in Figure 4b.

Sjukskoterskan

The mechanical exhaust air flow was momentaneously measured to 64 m^3/h. The design value is 100 m^3/h which show that the system is poorly adjusted. Measurement of the supply air flow was not possible at the time of the test. Data on total mechanical airflow from the whole building was checked and found not to cause the periodic change in airflows, which could be seen in Figure 5a. The average airchange rate from the tracer gas measurements was 68 m^3/h with a 6% standard deviation. There are also indications of some air infiltration in the bath and kitchen. Wind speeds between 0-5 m/s and outdoor temperatures between -2 to -18 °C were measured.

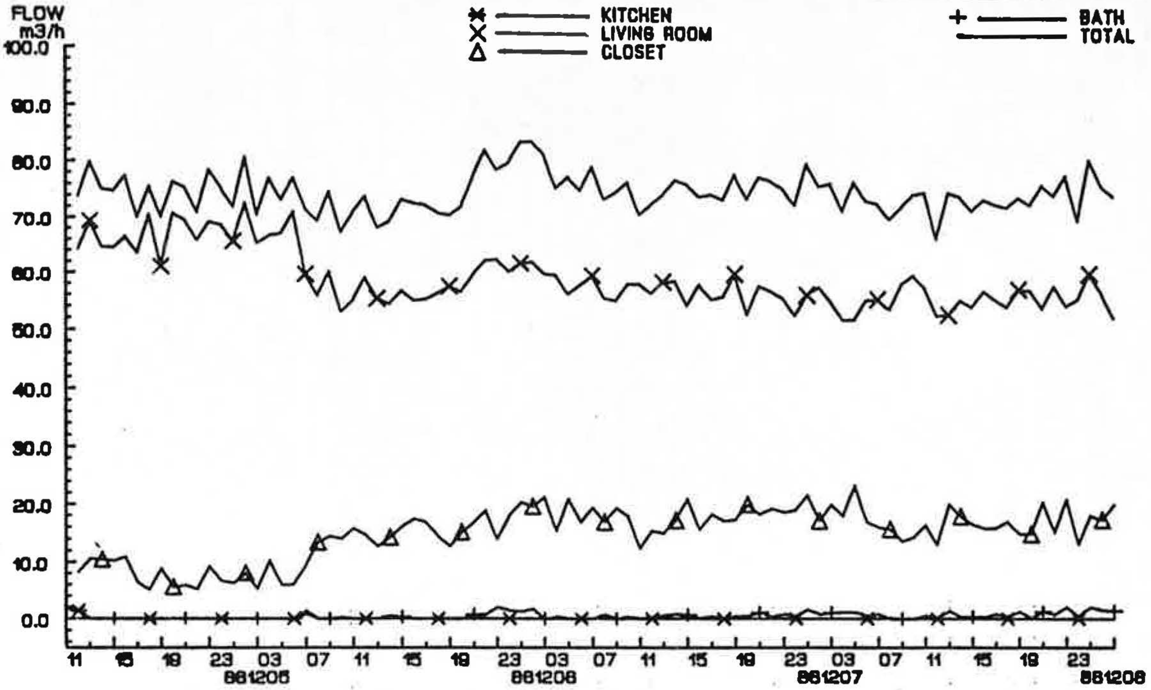

Figure 4a. Results from tracer gas measurements in the Skogsalmen apartment. The living room is the only room equipped with mechanical supply air.

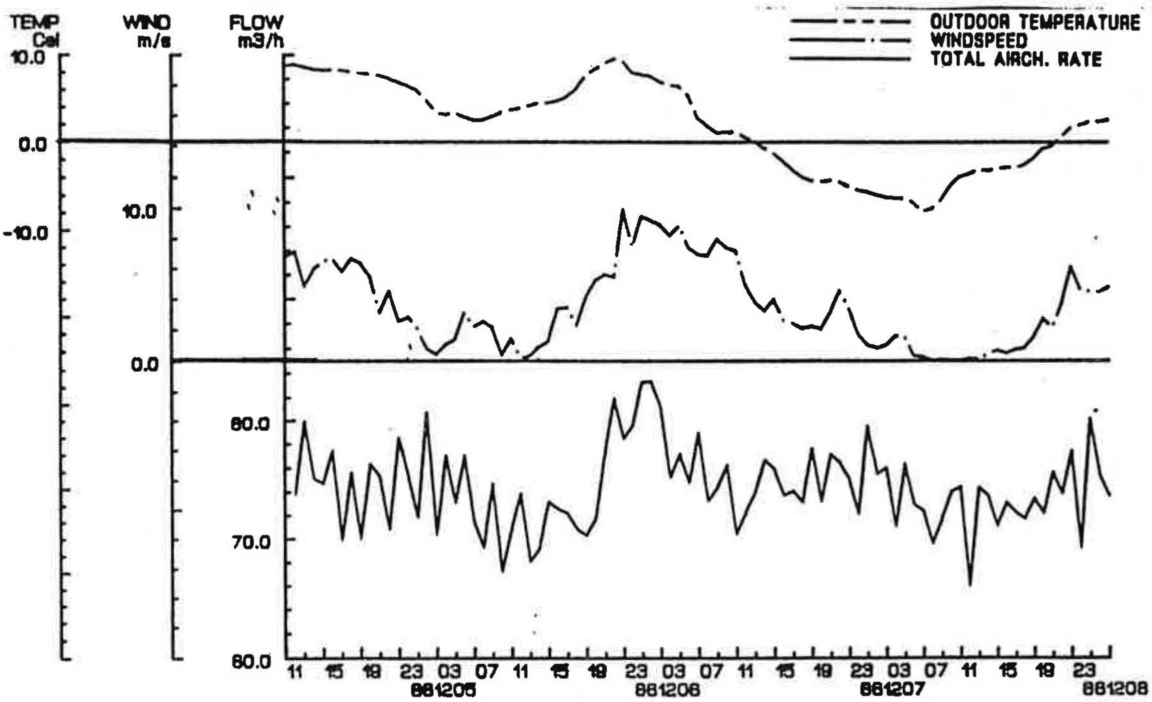

Figure 4b. Results from windspeed and temperature measurements compared to the total airchange rate measured by tracer gas.

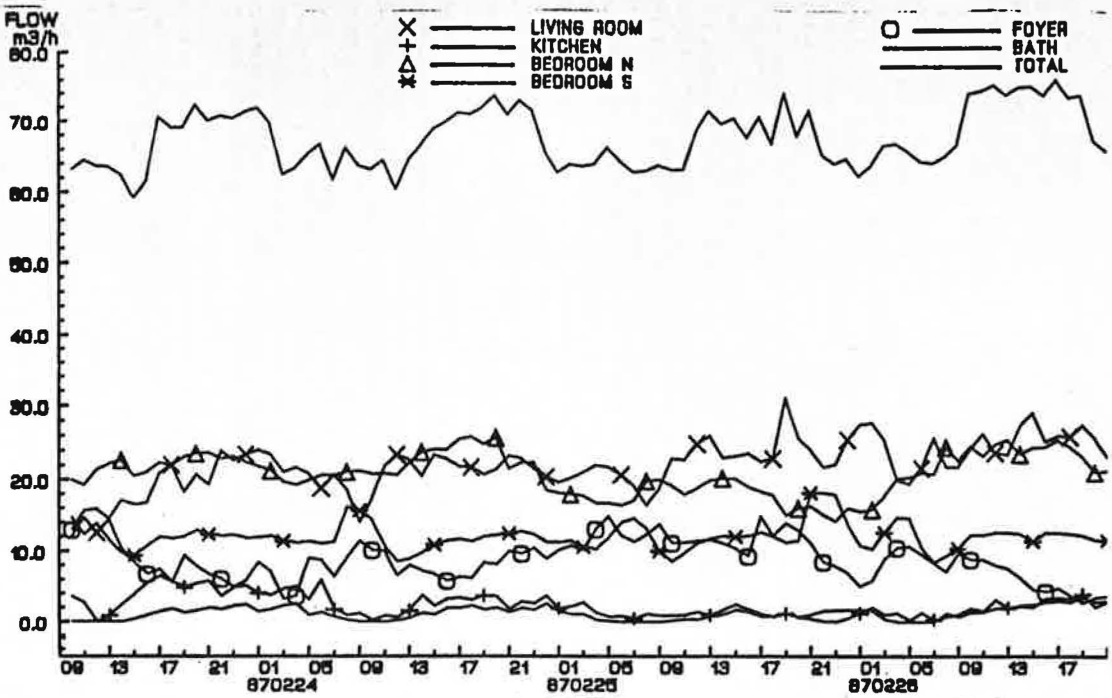

Figure 5a. Results from tracer gas measurements in the Sjukskoterskan apartment. Mechanical supply air is distributed to the living room and the bedrooms.

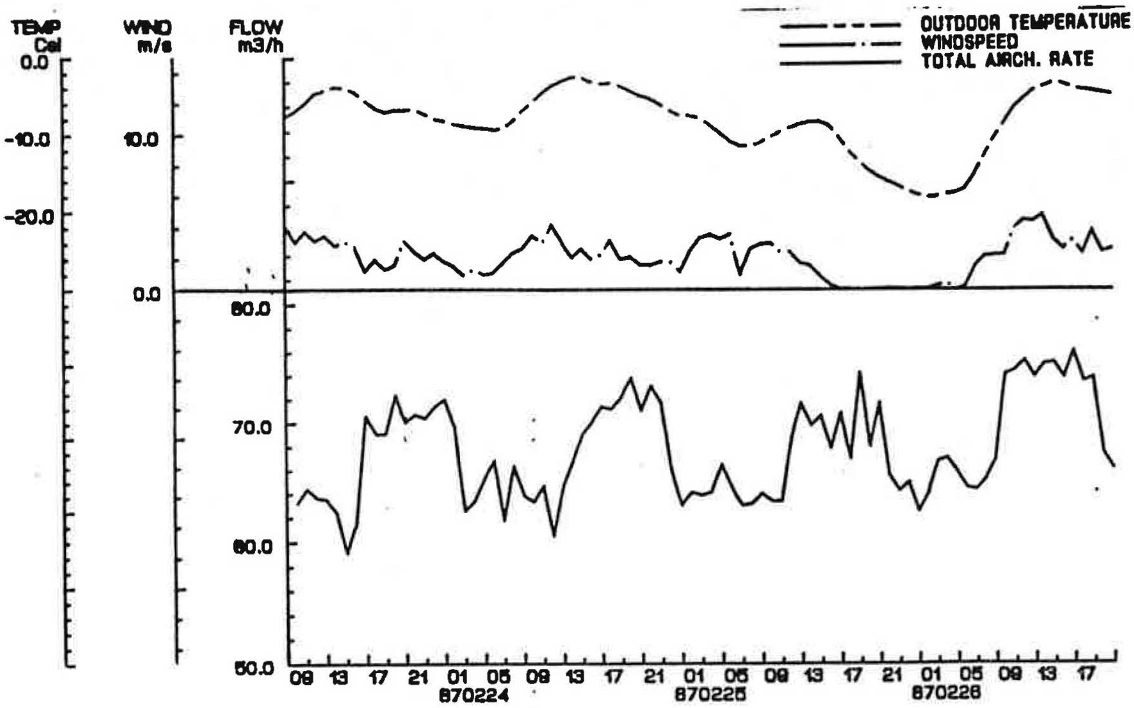

Figure 5b. Results from windspeed and temperature measurements compared to the total airchange rate measured by tracer gas.

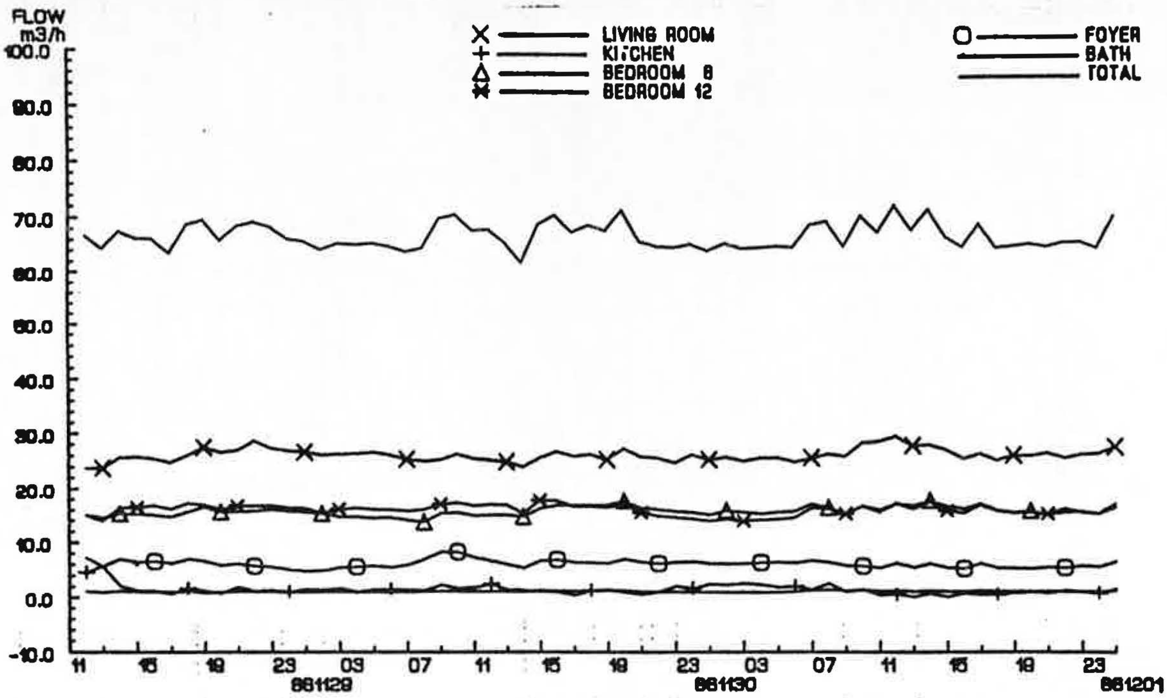

Figure 6a. Results from tracer gas measurements in the Konsolen apartment. Slot vents for supply air is provided in living room and bedrooms.

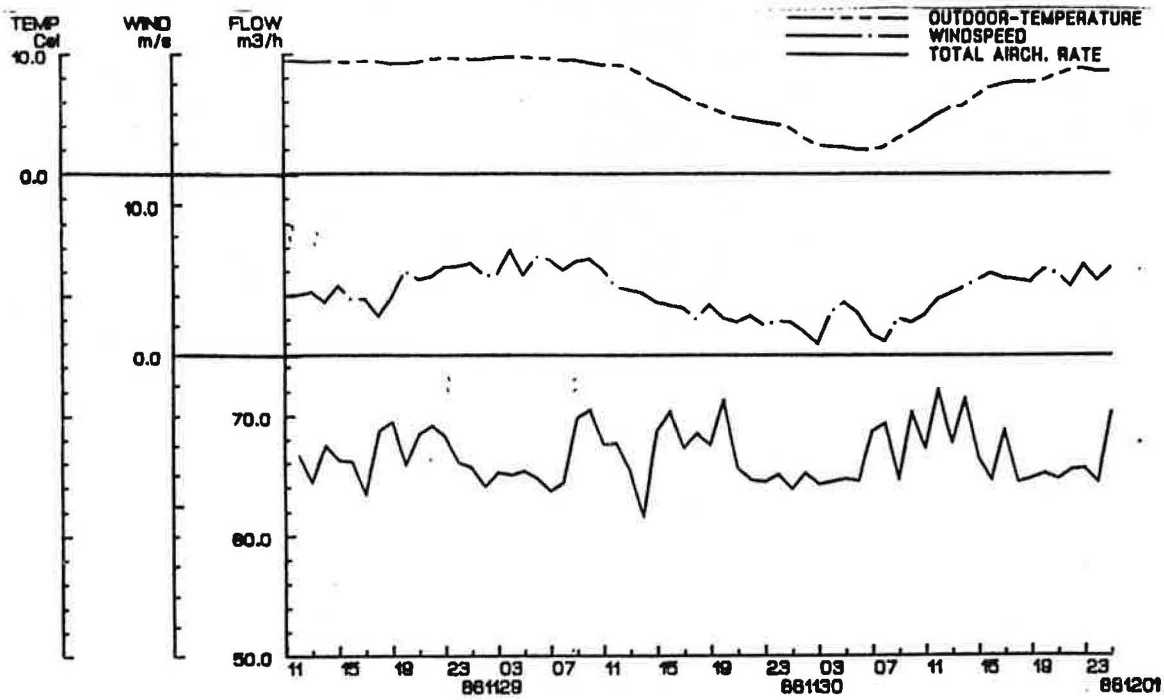

Figure 6b. Results from windspeed and temperature measurements compared to the total airchange rate measured by tracer gas.

Konsolen

Results from Konsolen is given in Figure 6. The mechanical exhaust flow was momentaneously measured to 68 m^3/h at the end of the period, which is low compared to the design value of 91 m^3/h. Total airchange rate with tracer gas averaged 67 m^3/h with a standard deviation of 4%. Wind speeds in the range 1-7 m/s and outdoor temperatures between 2 to 9 °C were recorded.

WIND INFLUENCE

Table I shows the correlation between measured airchange rates in m^3/h as a function of windspeed (m/s) for different wind directions. Owing to the relatively small data sets, the wind direction was only divided into four 90-degree sectors.

Table I. Linear regression constants and R^2-values for airchange ràte versus wind speed for different wind directions and for the complete data sets.

Apartment	Wind Direction	Data points	Slope	Interc.	R^2
SKOGSALMEN					
	East	15	0.94	70.5	0.13
	South	25	1.08	70.0	0.53
	West	48	0.16	74.2	0.02
	All Dir.	88	0.60	72.2	0.21
SJUKSKOTERSKAN					
	North	23	-0.96	68.1	0.16
	South	10	2.01	64.7	0.50
	West	51	0.46	67.1	0.09
	All Dir.	84	0.3	67.1	0.08
KONSOLEN					
	South	47	-0.07	66.9	0.002
	West	15	-0.59	68.5	0.04
	All Dir.	62	-0.10	66.9	0.004

The measurements show a weak correlation between air infiltration and wind speed. The lowest correlation is for the Konsolen apartment. In most cases, the correlation becomes better if only one wind direction is used.

DISCUSSION

The variation in total airchange rates are small in this type of buildings, with standard deviations of 4, 5 and 6%, respectively, from the average airchange rate for the three apartments. The smallest variation was found in Konsolen with the exhaust only system and the biggest in the Sjukskoterskan apartment. The difference between minimum and maximum values show the same pattern with 16, 23 and 25% of average airchange rates. Konsolen is also the most airtight and Sjukskoterskan the leakiest of the three apartments. However, because the measurements were not performed at the same time in the apartments, there is a difference in climatic conditions which makes a comparison difficult. Although the change in the total airchange rate is small, individual rooms could show significant changes in supply air flow.

The measured airchange rates correspond closely to the settings of the mechanical ventilation systems. Two of the apartments have badly adjusted ventilation systems, resulting in airchange rates of less than 75 % of the design values. Unfortunately, this is not an uncommon situation.

The airtight construction makes the unintentional air infiltration because of wind and stack pressures small. Therefore, the measurement result becomes more sensitive to other types of disturbances. A difference between the measured wind speed above the roof and the actual wind pressures on the apartment walls could to some extent explain the weak correlation. The data sets are comparatively small to draw any further conclusions on the effect of different wind directions.

Although significant temperature differences were measured, no effect on the total airchange rate could be seen.

All the airtightness and tracer gas measurements have been performed without consideration whether the air leakage is to the the outside or to adjacent apartments. Measurements of interior leaks with multiple blower door technique in new Swedish apartment buildings of similar construction have shown these to be small compared to exterior leaks[3]. For two corner apartments in different buildings, 14 and 17% of the total leakage at 50 Pa was found to be interior leaks. This means that the possible effect of variations in airflow between apartments owing to changes in wind pressures should be very small.

A further analysis of wind and temperature influence on the total airchange rate in airtight apartments, requires measurements over longer periods of time. The interior leakage pattern should be determined by measuring adjacent apartments simultaneously with different tracer gasses. The exterior leakage distribution should also be determined. The measurements should include wind pressures on the facades and continuous air flows from the mechanical ventilation system.

CONCLUSIONS

As could be seen from the measurement results, the airchange rate in the measured apartments are very constant and close to the fan-controlled air flows, although the driving forces for stack and wind effects were big. This show that the mechanical air flows are dominating in airtight buildings, which is desired. The standard deviation in total airchange rates was found to be between 4 and 6 % of the averages and weakly correlated to wind speed and wind direction. The smallest variation in airchange rates and the least correlation to wind was found in the most airtight apartment with exhaust ventilation system. Although the variation in total airchange rate is small, individual rooms could show significant changes in supply air flow because of wind effects.

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