

OCCUPANT INTERACTION WITH VENTILATION SYSTEMS

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USER CONTROLLED EXHAUST FAN VENTILATION IN ONE-FAMILY
HOUSES

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SYNOPSIS

A group of 18 identical well-insulated experimental houses in Sweden, utilizing a user controlled exhaust fan ventilation system, was monitored during 1985-1986.

The ventilation rate can be controlled by the user by adjusting the fan speed with a conveniently located three-way switch. No heat recovery is provided for, the idea being that the average ventilation rate will be low, thereby saving energy.

The houses are described. The results from measurements of ventilation efficiency, ventilation rates, run time of fan speeds and energy consumption are presented.

The investigation has shown that a simplified exhaust fan ventilation system can lead to a comfortable indoor climate.

The results so far indicate that the average yearly consumption of electricity for space heating, hot water heating and household use will be as predicted i.e. 12,000 kWh, compared with approximately 20,000 kWh for a well-built house that meets the current Swedish National Building Code. This energy saving was achieved by insulating and tightening the houses very well and installing a user controlled ventilation system.

1. INTRODUCTION

A group of 18 identical well-insulated experimental houses in Stockholm, Sweden, utilizing a user controlled exhaust fan ventilation system, have been built during 1984.

The main principles behind the design of the houses were:

- energy efficient and inexpensive design
- well-insulated and tight building envelope
- resource efficient lightweight construction technique
- simple foundation
- simple heating system with individual thermostats
- energy and water efficient appliances
- instructive owner's manual
- a simple ventilation system

The ventilation rate can be controlled by the user by adjusting a conveniently located three-way switch. No heat recovery is provided for, the idea being that the average ventilation rate will be low, thereby saving energy. The houses were monitored during 1985 and 1986, to assess both thermal performance and comfort conditions.

2. DESCRIPTION OF THE HOUSES

2.1 General Description

All 18 houses are modern wood frame constructions. They are heated with electric baseboard heaters. The houses are 119 m², with three bedrooms upstairs, a kitchen, and a living room downstairs (see figure 1).

The houses have an exhaust ventilation system, mechanically controlling the exhaust air. There are exhaust vents in bathrooms, laundry, and kitchen. Nine of the houses have additional exhaust vents in the bedrooms. Every house has special vents to the outside for supplying fresh air. The ventilation rate can be controlled by the user by adjusting a conveniently located three-way switch: 1 (no one at home) = 0.1 air changes per hour, 2 (the whole family at home) = 0.3 air changes per hour, 3 (maximum) = 0.5 air changes per hour. When the stove is used the ventilation rate can be increased by further opening the outlet device located above the stove. The total air flow through the exhaust fan will remain the same. If this isn't enough the fan speed can be increased with the switch mentioned above.

2.2 Energy Conservation

Insulation: Mineralwool insulation was installed in walls, ceilings, and floors (above a crawl space) in all houses. Thermal resistance of the building envelope is much better than in most conventional Swedish houses. Walls have U-values of 0.13 W/m²K, roofs of 0.10 W/m²K, floors of 0.18 W/m²K. For windows quadruple-glazing (U-values below 1.6 W/m²K) was used.

Tightness: As a moisture and air barrier, a continuous polyethylene sheet was employed between the insulation and the interior finish of walls, ceiling and floor. This was done for all houses except one. The number of penetrations through the continuous polyethylene sheet was limited. The building envelope of all houses meets Sweden's National Building Code requirement for airtightness, 3.0 air changes per hour at 50 Pa (excluding vents). The average

tightness is 1.6 air changes per hour, excluding the house without polyethylene sheet, which has a value of 3.1. Traditional modern Swedish construction (those buildings erected prior to Sweden's 1975 introduction of airtightness standards) commonly evidence 5.5 air changes per hour.

Heat recovery: No heat is recovered. Instead of recovering heat from the exhaust air substantial energy savings are achieved if the occupants lower the ventilation rate e.g. when they aren't at home. The average ventilation rate will then be low.

3. DESCRIPTION OF MONITORING PROGRAM

The houses were monitored continuously for 2.0 years, to assess both thermal performance and comfort conditions (1,2). Short unoccupied periods were used for special measurements and one-time tests which included the following:

- pressurization (airtightness) (3)
- tracer gas measurements (ventilation efficiency and ventilation rates including mechanical ventilation and air infiltration) (4,5,6)
- infrared photography scans (airtightness and thermal insulation)
- air flow measurements in ducts
- indoor temperature measurements.

During the long-term monitoring the following factors were recorded:

- electric energy use, measured separately for space heating, hot water, and household
- indoor and outdoor temperature
- run time for different exhaust fan speeds etc.

4. RESULTS

4.1 Ventilation Rates

The ventilation rates i.e. the supply of fresh air from the outside was monitored using the constant concentration tracer gas technique. The measurements show that the ventilation rate for the whole house was as planned, 0.25 air changes per hour (70 m³/h) when the exhaust fan is set on the "at home" position and 0.15 air changes per hour (50 m³/h) when set on the "no one at home" position. Some variation with time can be noticed (see figure 2 and 3). This variation shouldn't have any practical significance. The

above results weren't obtained the first time the measurements were made. More than half a year of changing and adjusting the ventilation system was required by the contractor to obtain the desired ventilation.

The measured mechanical ventilation rate is somewhat higher than the measured total ventilation rate i.e. the sum of mechanical ventilation and air infiltration. The difference is within the inaccuracy of the two measurements. A definite conclusion which can be drawn is that the air infiltration is usually very small i.e. all the air is leaving the house through the exhaust fan. When the fan is turned off the air infiltration will be approximately 0.10 air changes per hour.

The amount of fresh air supplied to individual rooms varies with the outdoor temperature and the wind. The total ventilation rate for the whole house is almost constant. When the temperature sank drastically the supply of fresh air directly from the outside increased on the first floor and decreased on the second floor (see figure 4,5,6 and 7). This can be explained by the change in pressure distribution caused by the temperature drop. There was a shift in the pressures caused by the exhaust fan. Then the air flow from the first floor to the second floor was probably increased.

If the house had been tighter the shift in ventilation would have been less drastic. The actual airtightness for this particular house was 2.4 air changes per hour (excluding the vents). In a previous report (7) it was estimated that the airtightness for a house with an exhaust fan ventilation system should be better than 3.0 air changes per hour (including vents).

All individual rooms get fresh air directly from the outside. There doesn't seem to be any difference in the bedroom ventilation rates between houses where the used air is removed directly out of the bedrooms (parallel flow) as opposed to indirectly (serial flow) (see table 1). By indirectly is meant that the outgoing air has to pass through an adjoining room, i.e. the upstairs hall, before leaving the house, through the exhaust vent in the bathroom.

Table 1. Average ventilation rate i.e. fresh air coming directly from the outside into the individual rooms.

	Serial flow	Parallel flow
Outdoor temp.	1 °C	0.6 °C
Wind speed	0.6 m/s	0.6 m/s
Duration of measurements	17 h	12 h
Living room	5 m ³ /h	14 m ³ /h
Hall downstairs	28 m ³ /h	10 m ³ /h
Laundry	7 m ³ /h	6 m ³ /h
Kitchen	1 m ³ /h	3 m ³ /h
Entrancehall	6 m ³ /h	18 m ³ /h
Master bedroom	9 m ³ /h	10 m ³ /h
Bedroom	4 m ³ /h	5 m ³ /h
Bedroom	4 m ³ /h	4 m ³ /h
Total	64 m ³ /h	70 m ³ /h

The average mechanical ventilation rate during the heating season (November through March) is 0.3 air changes per hour, which is as predicted. This value is based on recorded values of run times (see table 2) for the different settings of the fan speed and one-time tests of the ventilation rates.

Table 2. Recorded values of run times (hours) for different settings of the exhaust fan speed for the period November through March. All 18 houses are included.

Fan setting, air changes per hour	0.1	0.3	0.5
Lowest	0.0 h	1,390 h	12 h
Average	875 h	2,700 h	200 h
Highest	2,620 h	3,575 h	600 h

4.2 Ventilation Efficiency

The ventilation efficiency was measured using the tracer gas decay technique. The decay was monitored in 17 different points.

The distribution of fresh air within the individual rooms seems to be satisfactory (see figure 8 and 9). The ventilation in the bedrooms upstairs is not affected by the fact whether the door is closed or not.

4.3 Energy Consumption

During one year (April 1985 - March 1986) the houses consumed 12,800 kWh (± 2250) of electricity. This is an actual measured consumption, where the indoor temperature for the different houses varied between + 19 and + 22 °C during the heating season. The mechanical ventilation system didn't work properly until December. The actual ventilation rate before December is therefore uncertain. The results seem to be close to the predicted yearly energy consumption rate of 12,000 kWh.

Of the total consumption of electricity, space heating consumed 7,200 kWh (± 1000), domestic hot water heating 2,450 kWh (± 1350) and household electrical use (lights, washer, dryer, range, and miscellaneous) 3,200 kWh (± 1150).

With a conventional mechanical ventilation system the energy losses due to ventilation would have been 4,050 kWh during the heating season or 6,500 kWh in a year. In the experimental houses the same losses are lowered to 2,250 kWh resp. 3,600 kWh due to the reduced average ventilation. This is assuming an average value of 0.5 air changes per hour for a conventional ventilation system and that the average ventilation rate for the experimental houses are the same for the heating season as for the whole year.

5. CONCLUSIONS

The investigation has shown that the simplified exhaust fan ventilation system can lead to a comfortable indoor climate, with fresh air and comfortable temperatures. The results up to now indicate that without any heat recovery the average yearly consumption of electricity for space heating, hot water heating and household use will be close to the predicted value i.e. 12 000 kWh. A well-built house, that meets the current Swedish National Building Code, uses approximately 20,000 kWh. This energy saving was achieved by insulating and tightening the houses very well and installing a user controlled exhaust fan ventilation system. The houses will be evaluated in greater detail once the monitoring is finished by the end of 1986 and presented in a final report.

6. ACKNOWLEDGEMENTS

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7. REFERENCES

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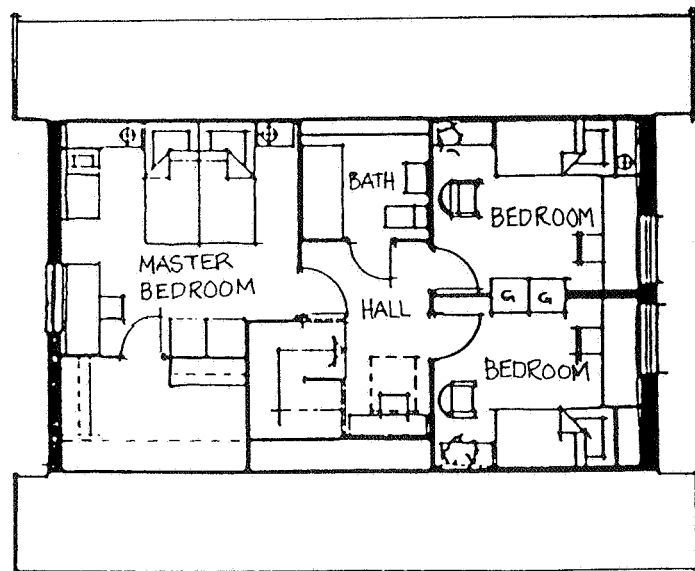
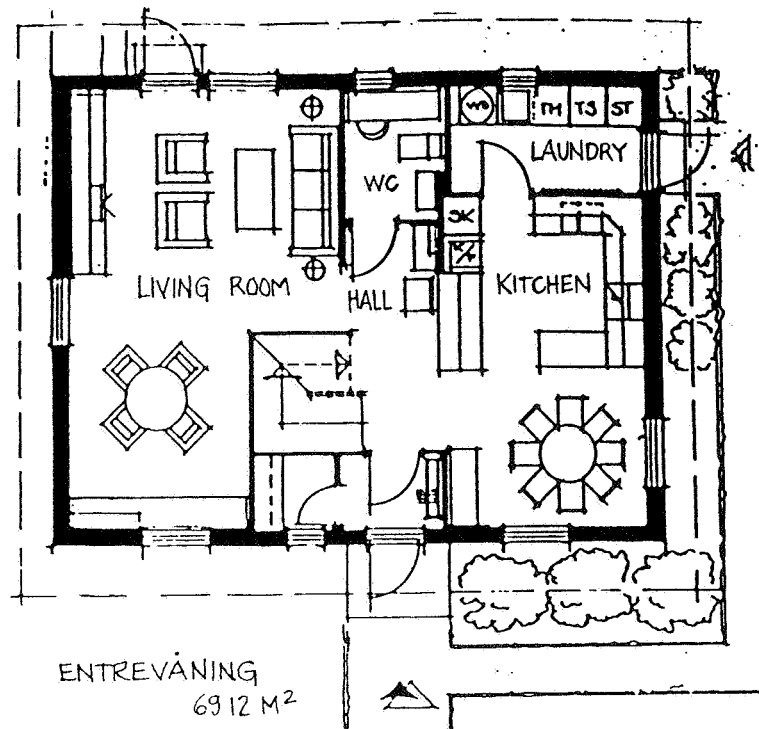


Figure 1 Plan of the experimental houses.

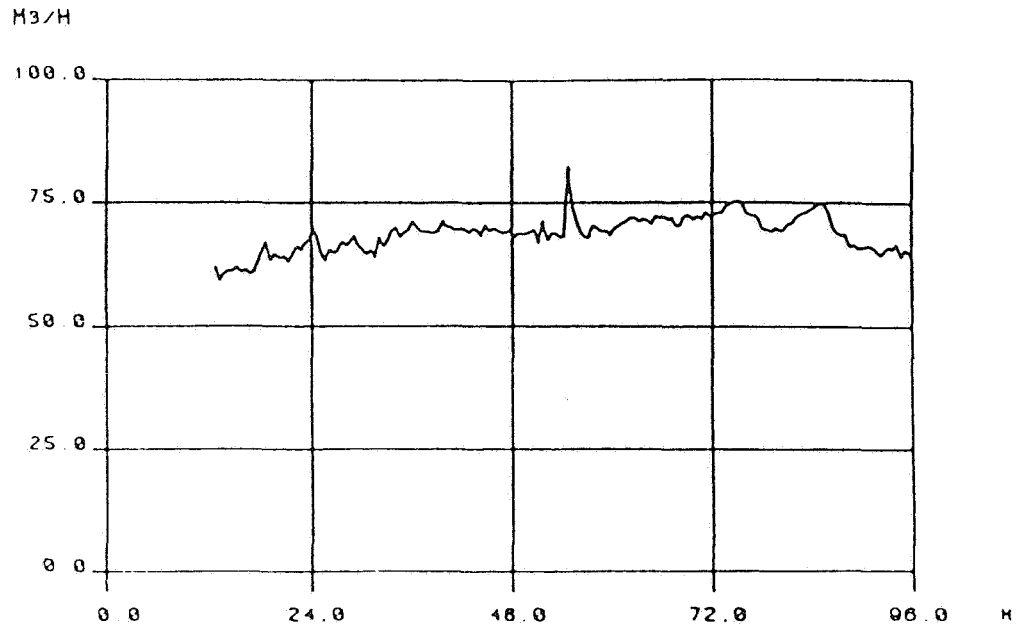


Figure 2 Measured ventilation rate (mechanical ventilation + air infiltration) when the exhaust fan is set on the "at home" position. The average wind speed was 0.3 m/s and the average outdoor temperature was -14 °C (see figure 4).

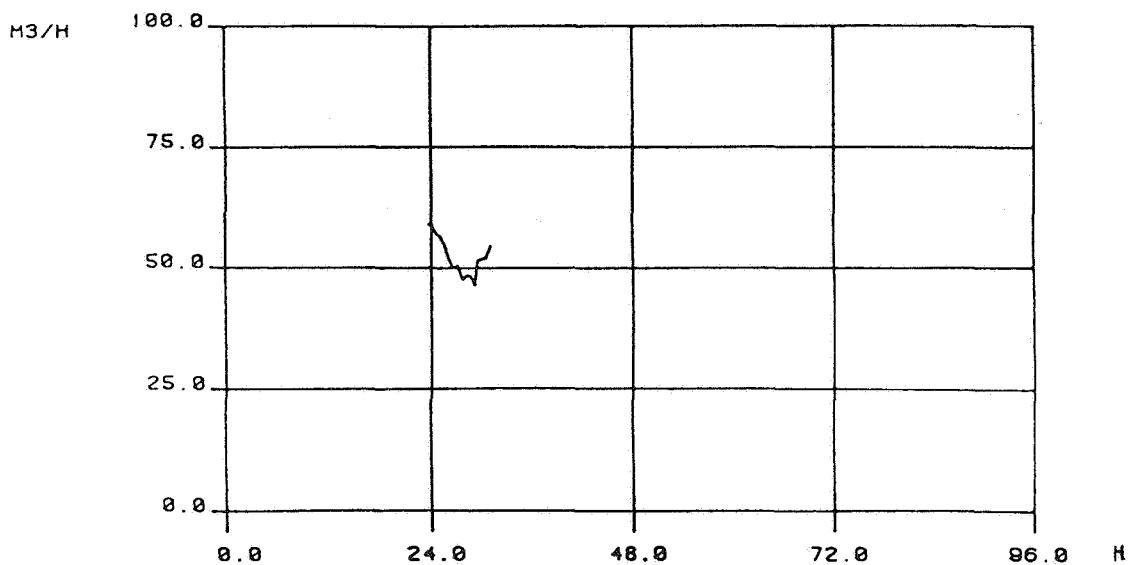


Figure 3 Measured ventilation rate (mechanical ventilation + air infiltration), when the exhaust fan is set on the "no one at home" position. The average wind speed was 0.8 m/s and the average outdoor temperature was -0.9 °C.

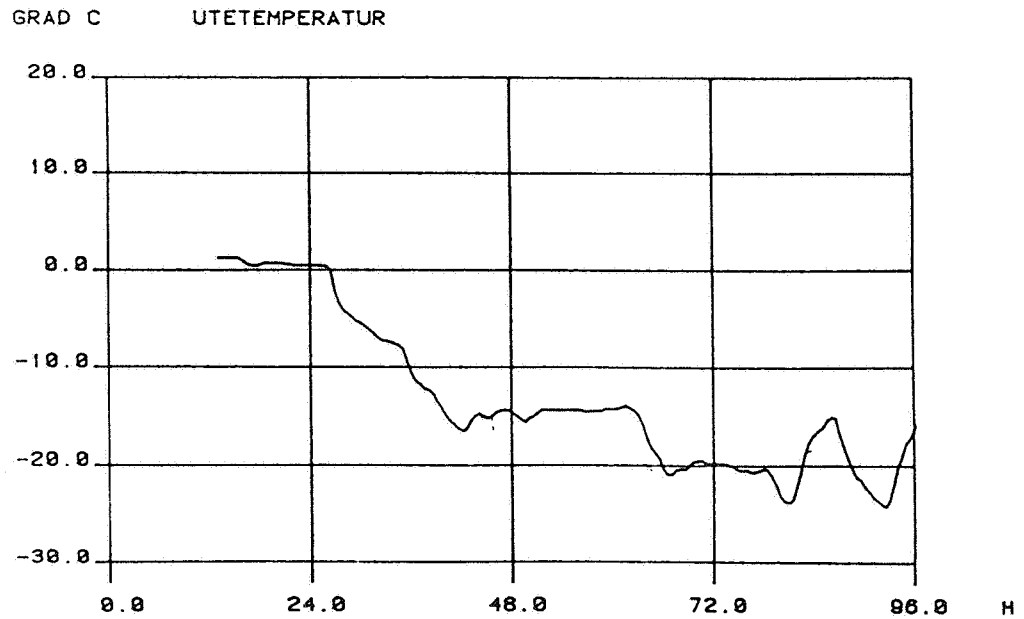


Figure 4 Outdoor temperature.

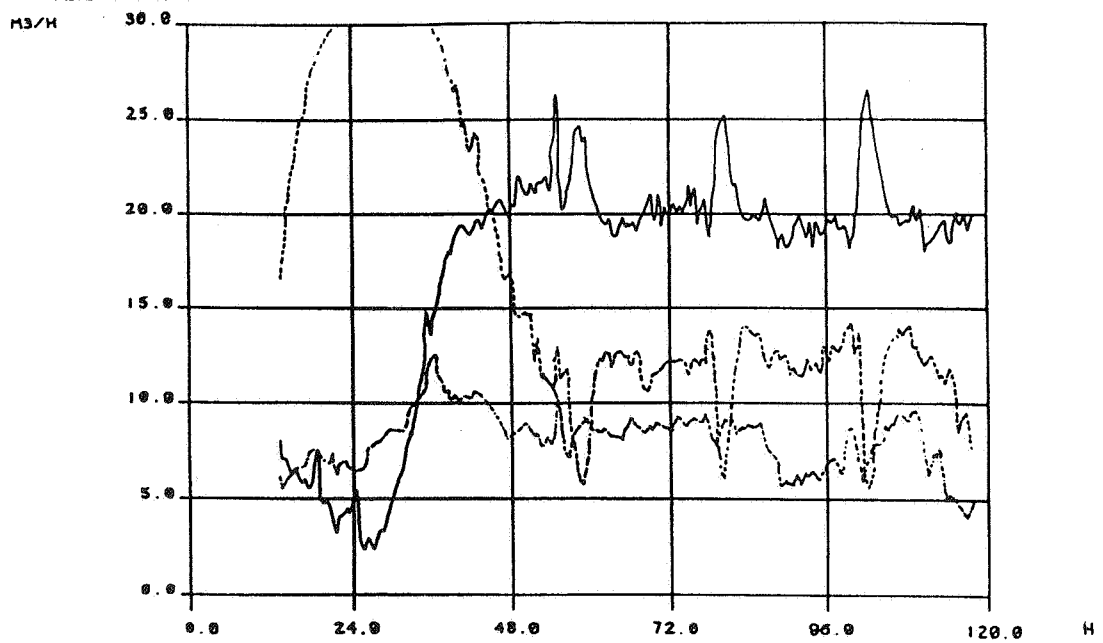


Figure 5 Measured ventilation rates (mechanical ventilation + air infiltration), when the exhaust fan is set on the "at home" position.

————— living room
 ----- hall downstairs
 - . - . - . laundry

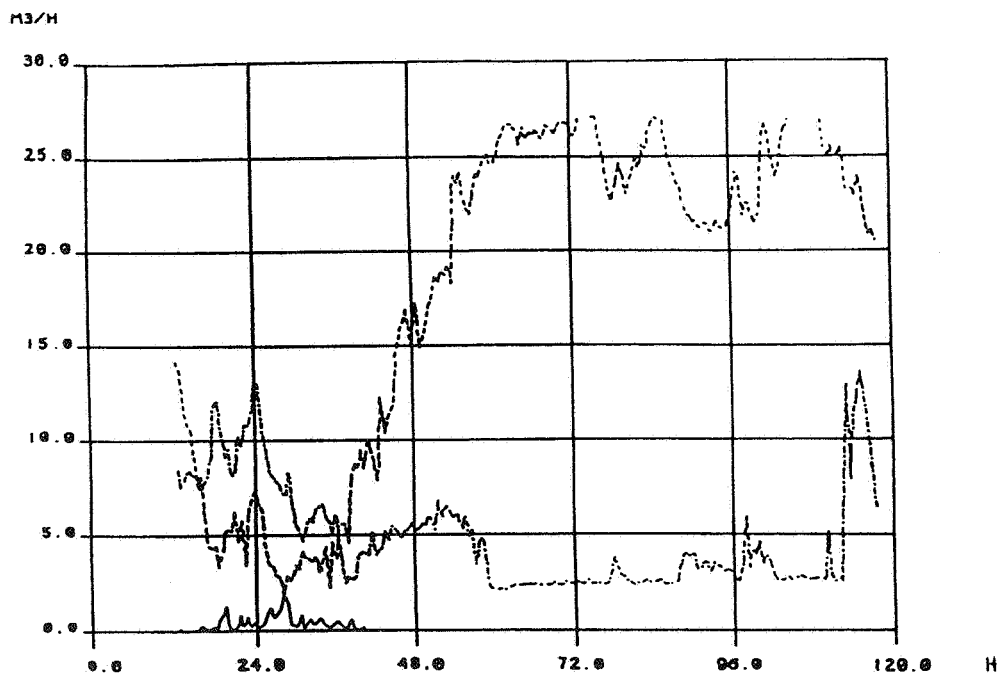


Figure 6 Measured ventilation rates (mechanical ventilation + air infiltration), when the exhaust fan is set on the "at home" position.

————— kitchen
 - - - - - entrance hall
 - . - . - master bedroom

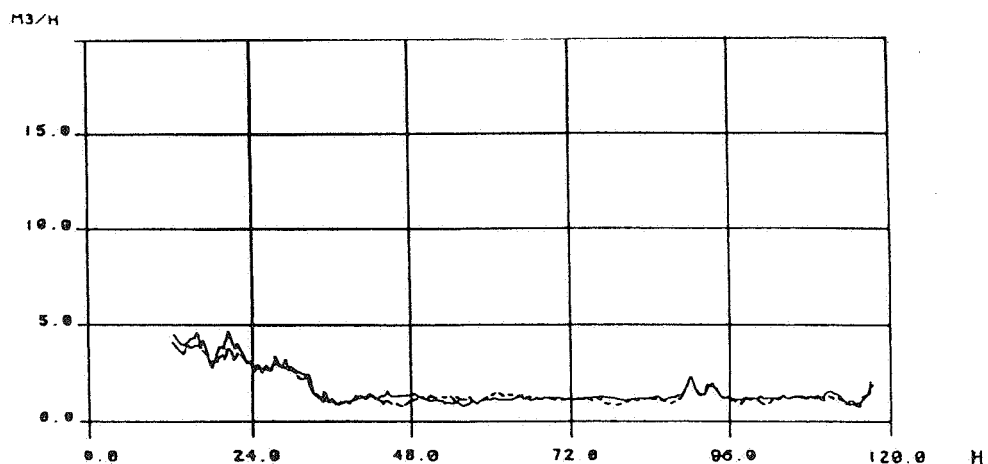


Figure 7 Measured ventilation rates (mechanical ventilation + air infiltration), when the exhaust fan is set on the "at home" position.

————— bedroom
 - - - - - bedroom

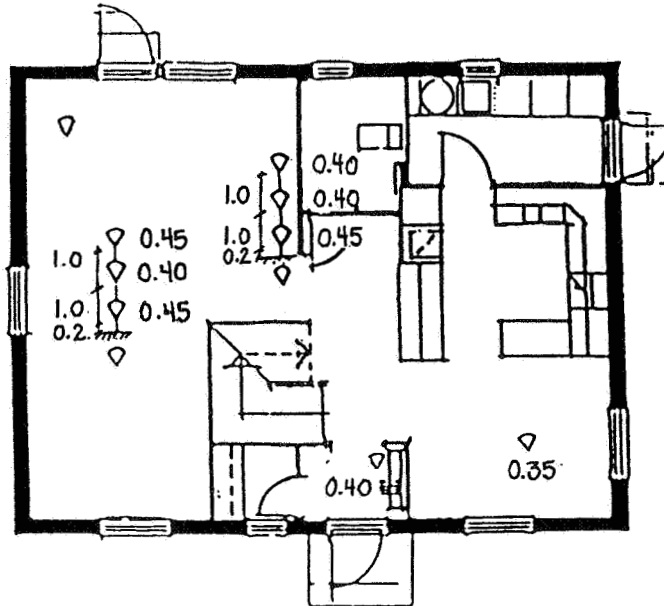


Figure 8

Ventilation efficiency downstairs in air changes per hour at 0.2 m, 1.2 m and 2.2 m above the floor. The exhaust fan was set on the "at home" position. The wind speed was 0.2 m/s and the outdoor temperature was -5°C .

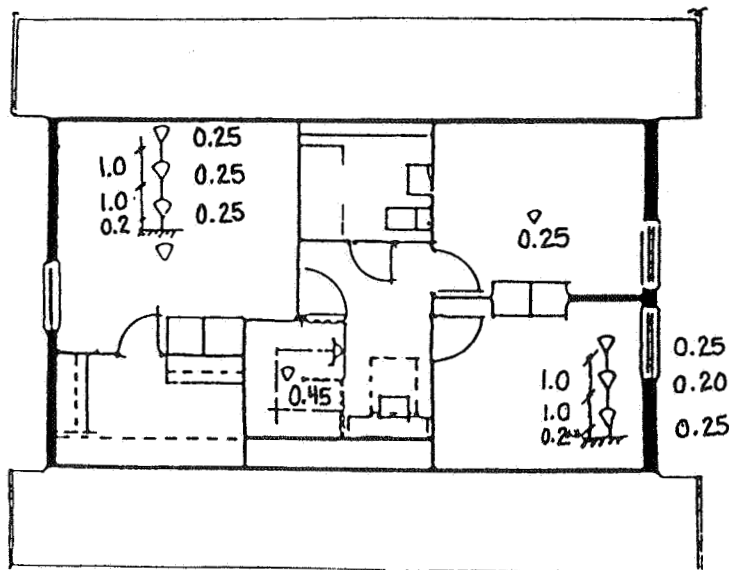


Figure 9

Ventilation efficiency upstairs in air changes per hour at 0.2 m, 1.2 m and 2.2 m above the floor. The exhaust fan was set on the "at home" position. The wind speed was 0.2 m/s and the outdoor temperature was -5°C .