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AIR EXCHANGE EFFICIENCY IN RESIDENTIAL AND OFFICE BUILDINGS

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ABSTRACT

The paper presents the results of field measurements of the air exchange efficiency in various buildings. The measurements were carried out with a tracer gas technique and a decay method in 9 office and 16 residential buildings. There were 14 different air distribution systems. The average air exchange efficiency varied between 36 % and 57 % in office buildings and between 34 % and 50 % in dwellings. The short circuiting of air between the supply and exhaust grill lowered the efficiency most often in the office buildings. The highest efficiencies were measured when the supply and exhaust devices were on the same wall of the room. In multiroom apartments the variations in the local mean age of the air were small if the doors were open. Closing the door increased the local mean age of the air inside the room considerably. The nominal time constants varied between 0.2 h and 3.5 h in the tests and differed greatly from the design values.

INTRODUCTION

The performance of a ventilation system has a great influence on the quality of the inside air and the economy of ventilation. The ventilation performance can be increased by avoiding short circuiting of fresh air from the supply to the exhaust ducts. The aim of this study was to obtain knowledge of the air exchange efficiency of various ventilation systems and to investigate the performance of different ventilation systems.

MEASUREMENT SETUP

Measurements were carried out with the decay method using Freon 12 (dichlorodifluoromethane) as a tracer gas in 9 office and 16 residential buildings. The internal doors were normally open during the measurements. A homogeneous starting concentration was achieved by using mixing fans during tracer gas injection. Most attention was paid in dwellings to air-exchange efficiency, mixing between different spaces, the differences between local mean ages in different locations and the impact of closing the door. In offices the main goal was to measure the air exchange efficiency with different ventilation patterns.

RESULTS IN RESIDENTIAL BUILDINGS

Measurements were made in both detached and semi-detached houses and also in high-rise residential blocks. The ventilation system was either natural or mechanical. Measurements were also made in one house with balanced ventilation.

The impact of closing the door of the room with a natural ventilation system is represented in figure 1 /1/. On average the mean age of the air when the door is closed is twice the mean age when the door is open. The situation can be improved by leaving a gap under the door. Table 1 shows the results when mechanical exhaust was used.

Table 1. The impact of closing the door in dwellings. Mechanical exhaust /1/.

Dwelling	$\tau_{o,open}$ [h]	$\tau_{o,closed}$ [h]	%
A	3.57	8.23	+ 130.5
B	2.04	2.48	+ 21.5
C	1.14	13.90	+1119.5
D	3.30	9.37	+ 183.9

where $\tau_{o,open}$ = local mean age of air with door open

$\tau_{o,closed}$ = local mean age of air with door closed

It seems that with mechanical extraction the mean age of the air in the room increases due to closing the door more than with natural ventilation. This is because of the different seal of the buildings. With balanced ventilation systems the mean age of the air can either increase or decrease depending on the situation.

The differences in the local mean ages of the air τ_o as a function of the nominal time constant τ_n are shown in figure 2 /1/. The average difference between the local mean age and the nominal time constant varied between +9.0 % and -4.7 %. The local differences were relatively small, which indicates powerful mixing.

The measured air exchange efficiencies ϵ_a as a function of the nominal time constant τ_n are shown in fig. 3 /1/. According to the measurements ϵ_a varied between 34 % and 50 % but was normally below 50 %. This is due to the short circuiting which occurs between cracks in the building and extract ducts. In most cases this short circuiting ended with the WC extract duct.

A typical air flow pattern in a dwelling is represented in figure 4 /1/. Typical aspects are:

1. Short circuiting of air between outside door and WC extract duct.
2. Short circuiting between kitchen window and kitchen extract duct.
3. Sauna-department has individual air flow.
4. Small differences in local mean ages of the air if the internal doors are open.
5. If the door of the room is closed, the average local mean age inside the room increases.
6. In a single room the differences in local mean ages are very small

RESULTS IN OFFICE BUILDINGS

Some of the measured air exhange efficiencies ϵ_a in office buildings as a function of nominal time constant τ_n are represented in figure 5 /1/. The air exchange efficiency varies between 36 % and 57 %. In 50 % of the offices the air exchange efficiency is over 50 %. This can be explained by the high velocities used for air supply and by the good placement of the supply and exhaust devices. Short circuiting of air between the supply and exhaust grills decreased the efficiency in most cases. The differences in the local mean ages of ther air were slightly bigger in offices than in dwellings. This can be explained by the unhomogeneous placing of supply devices and big landscape offices.

CONCLUSIONS

The results of the measurements are shown in figures 6a-6j.

The highest air exchange efficiencies are reached when the supply and exhaust devices are situated on the same wall of the room. Short circuiting can then be avoided provided that the velocity of the air in the supply jet is big enough.

The air in offices is not always fully mixed if the office has a large volume and the supply and exhaust devices are poorly situated.

The powerful mixing in residential buildings is due to the air flows created by non-isothermal surfaces and temperature differences between rooms.

The nominal time constants often differ considerably from the design values.

A summary of the air-exchange efficiency measurements is shown in table 2.

Table 2. Summary of air exchange efficiency measurements

Type of building or room	Floorarea m^2	Number of measurements	Ventilation or air distribution system	Nominal time constant τ_n (h)	Nominal air exhange rate 1/h	Air exhange efficiency ε_a
Detached and semidetached houses	85 - 170	9	Natural	1.7 - 10	0.1 - 0.6	0.34 - 0.51
	210 - 300	2	Mechanical exhaust	2.0 - 3.5	0.14 - 0.50	0.38 - 0.51
	190	1	Balanced ventilation	2.2	0.31	0.44
High rise residential	43	1	Natural	3.0	0.33	0.40
	50 - 70	3	Mechanical exhaust	0.9 - 3.0	0.33 - 1.11	0.4 - 0.45
Landscape office	460 - 1500	2	Ceiling diffusers	0.3	3.3	0.50
	450	1	Window induction units	0.5	2.0	0.41
	90	1	Ceiling registers + exhaust air windows	0.3	3.33	0.50
Office	12	1	Wall registers	0.6	1.67	0.55
	50	1	Window induction units	0.6	1.67	0.52
	8 - 30	13	Mechanical exhaust with supply to hall	0.14 - 1.7	0.59 - 2.5	0.36 - 0.50
Filestorage	10	1	Ceiling diffusers	0.27	3.7	0.58
Conference room	15	1	Ceiling diffusers	0.21	4.76	0.57
Class room	65	2	Wall registers	0.37 - 0.46	2.2 - 2.7	0.48 - 0.55

REFERENCES

1. Roos,R., Majanen, A., Helenius, T., Ilmanvaihdon hyötysuhteen mittaaminen eri ilmanvaihtojärjestelmissä. 1985. Sisäilmastoprojekti, Teknillinen Korkeakoulu, LVI-laboratorio, Raportti C:18

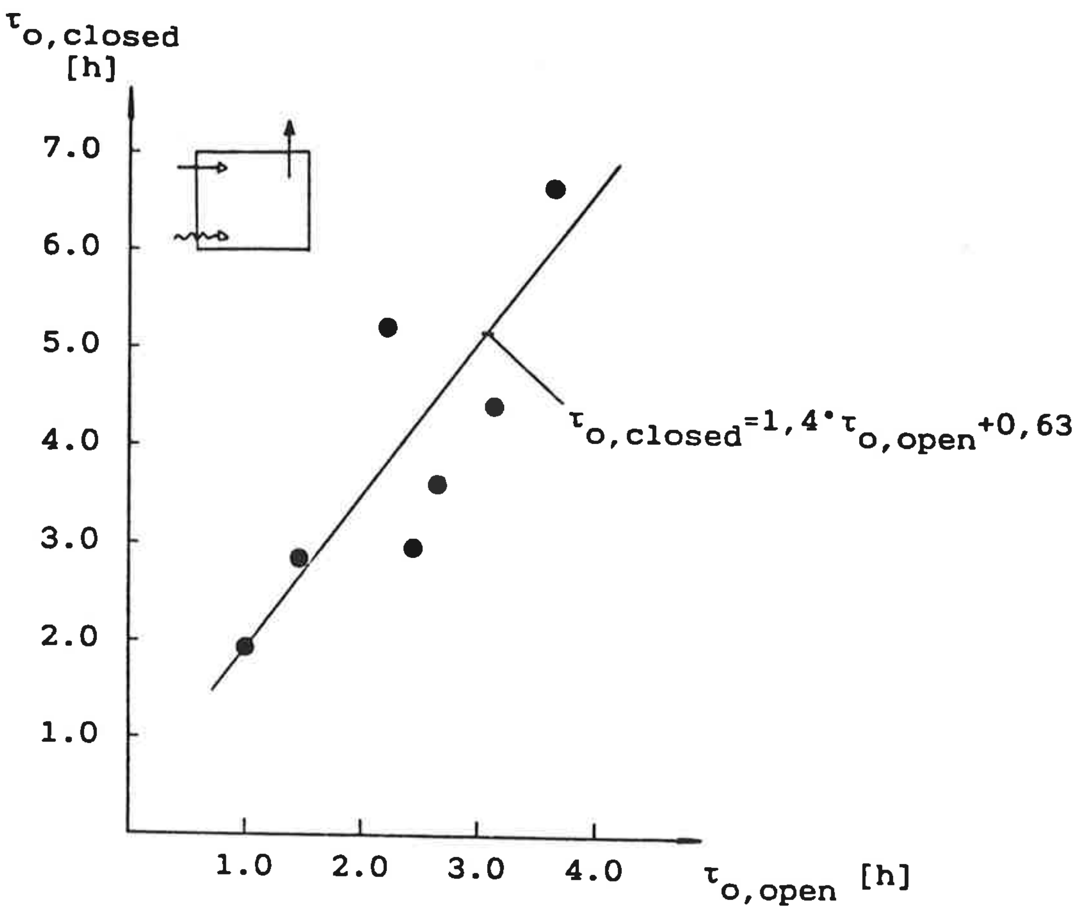


Figure 1. The impact of closing a door in dwellings on the air-exchange rate. Natural ventilation./1/

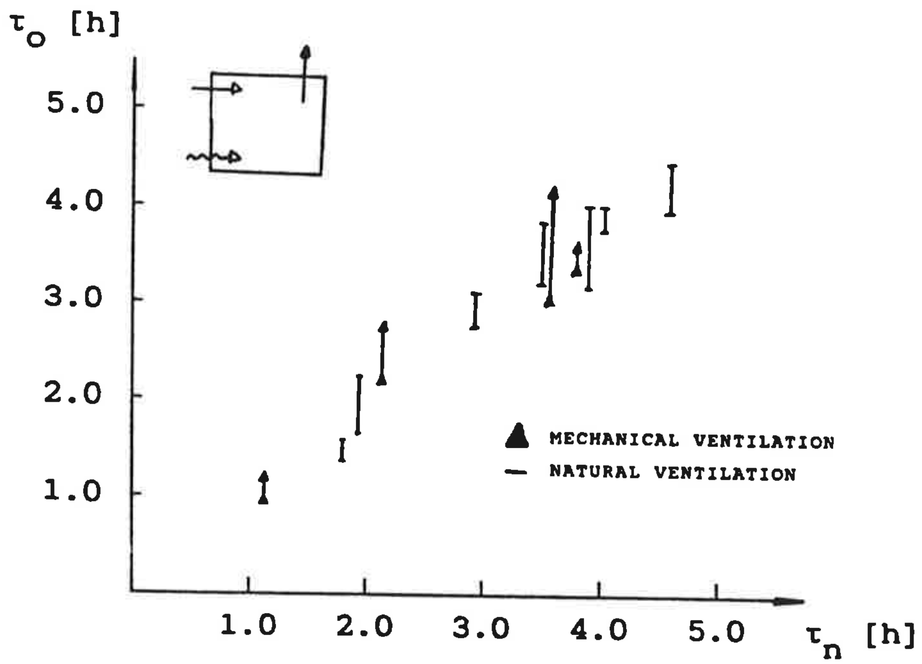


Figure 2. Differences in the local mean ages of the air as a function of the nominal time constant./1/

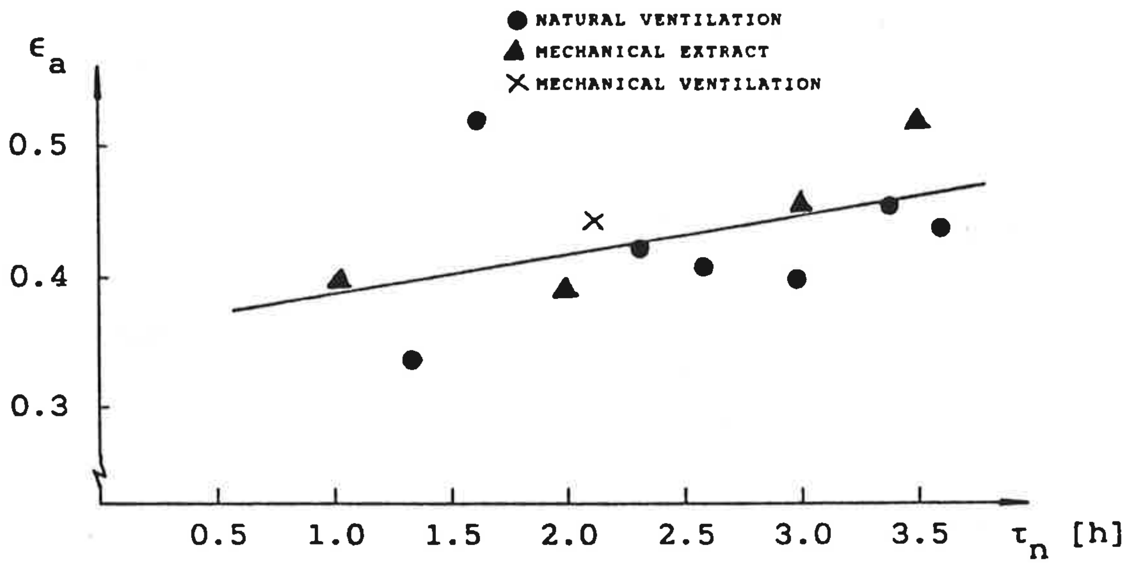


Figure 3. The air-exchange efficiency ϵ_a as a function of the nominal time constant τ_n./1/

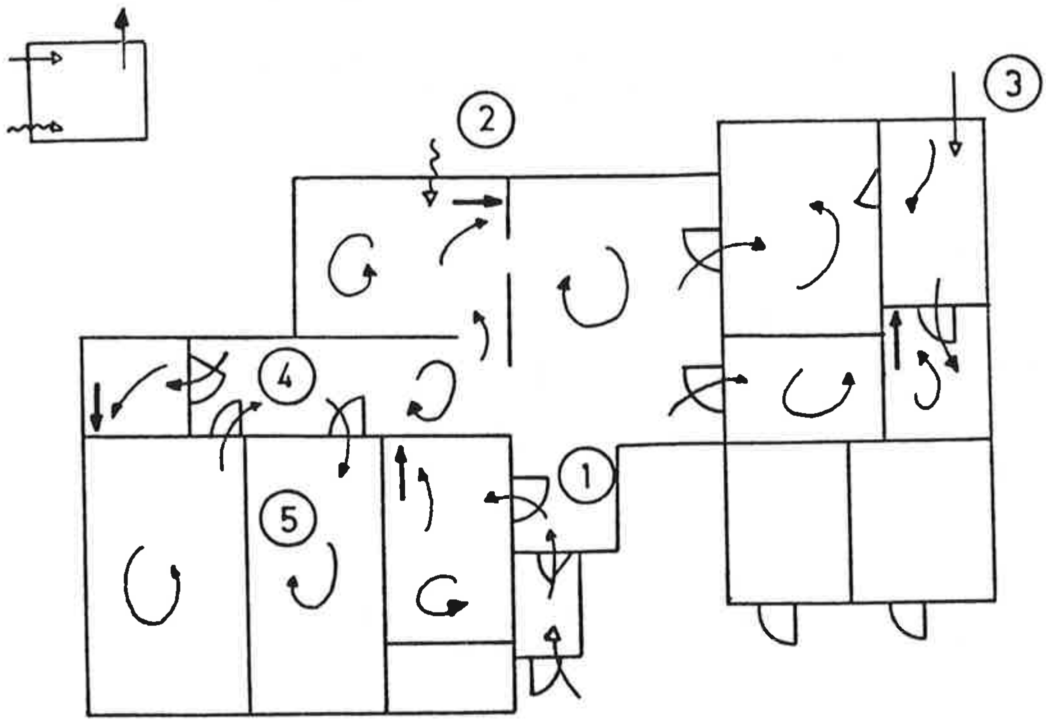


Figure 4. A typical air flow pattern in a dwelling./1/

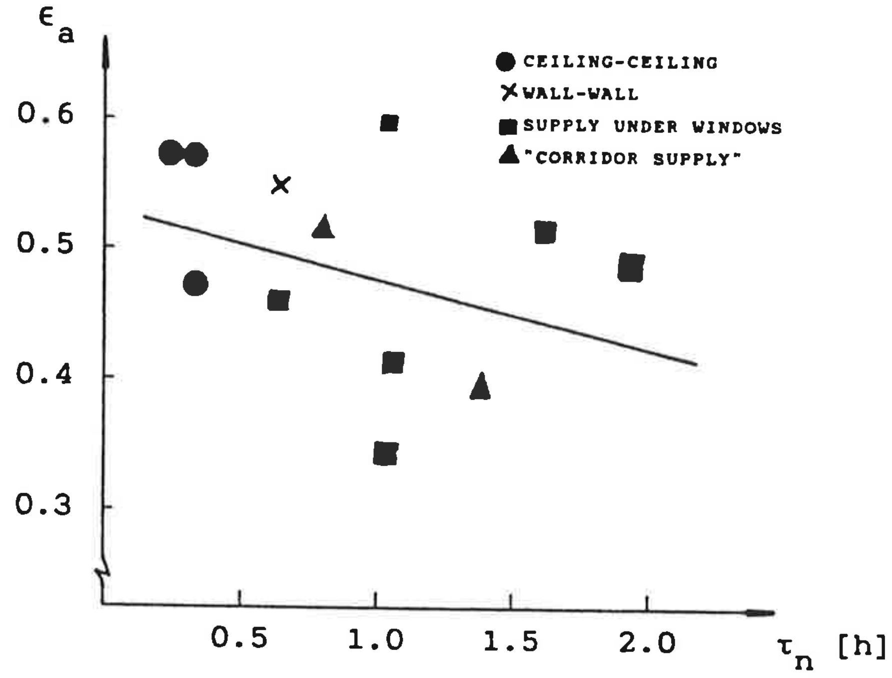
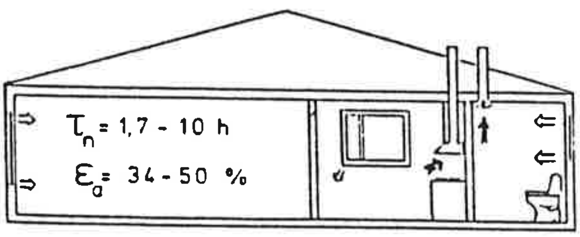
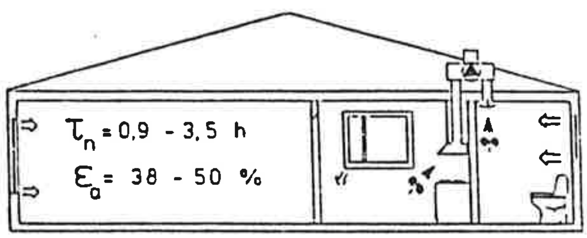


Figure 5. The air-exchange efficiency ϵ_a as a function of a nominal time constant τ_n. Office buildings./1/

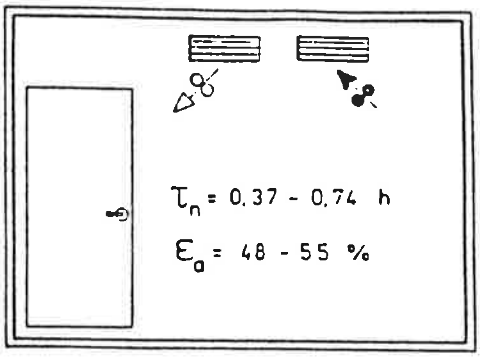


6a. Residential building, mechanical exhaust.

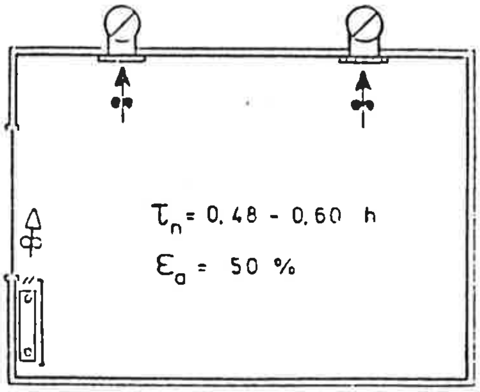


6b. Residential building, Natural ventilation.

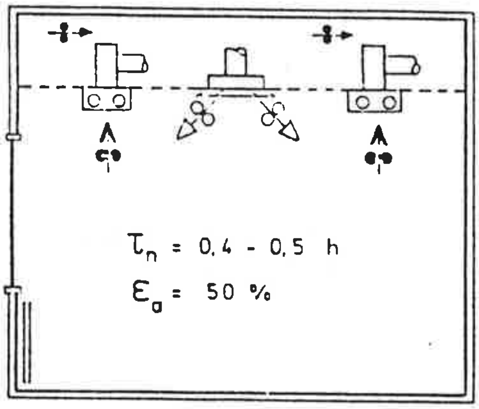
Figures 6a-6b. Results of measurements with two different ventilation patterns./2/



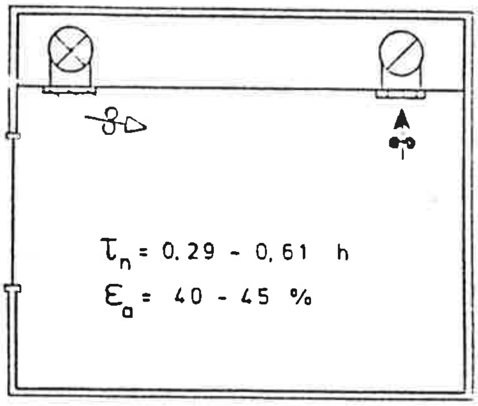
6c. Office, wall registers.



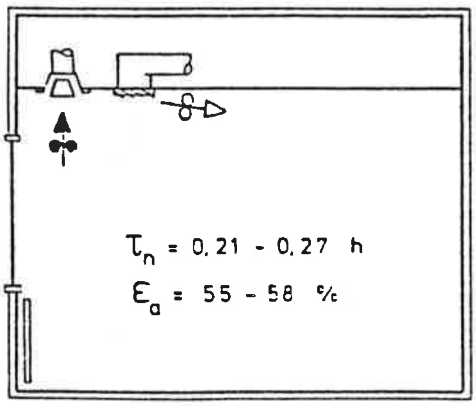
6d. Office, window induction units.



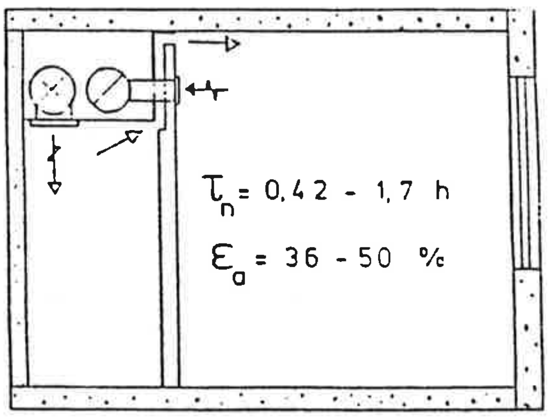
6e. Office, ceiling diffusers.



6f. Office, ceiling diffusers.



6g. Office, ceiling diffusers.



6h. Office, supply to hall.

Figures 6c-h. Results of measurements with various ventilation patterns./2/