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HELSINKI UNIVERSITY OF TECHNOLOGY
LABORATORY OF HEATING VENTILATION
AND AIR CONDITIONING

PROCEEDINGS OF THE WORKSHOP ON INDOOR AIR QUALITY AND ENERGY CONSERVATION

International Council of Building Research Studies
and Documentation (CIB)
W 67 Energy Conservation in the Built Environment

Edited by A. Punttila and J. Railio

ISBN 951-753-078-1
ISSN 0780-2811

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Report B3 Paper 4. P. Saarnio. ESPOO 1983

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AIRTIGHTNESS, PRESSURE DIFFERENCES AND INDOOR CLIMATE IN THE EXPERIMENTAL BUILDING, KASARMINKATU 24

1. COMMON

The experimental building "Kasarminkatu 24" is in the centre of Helsinki. It was constructed in 1897 and renovated in 1981. Having been unoccupied several years before renovation, it is now a museum of architecture. It consists of two exhibition halls, a library and office rooms for the personnel.

For experimental purposes the ventilation system was built so that parts of it could be closed by airtight valves. Three alternative systems were studied in the same building:

System A. Balanced mechanical supply and exhaust into/from all rooms
System B. Exhaust from all rooms
System C. Exhaust only from toilets

No heat recovery from exhaust air to supply air was arranged. Nowadays the use of return air is not possible. The exhaust fans and the supply air units were installed in the different plant rooms in the attic floor.

The original exhaust ducts (masonry) were partly utilized, but serious leakages were observed in these ducts and their joints to the new ductwork.

The outside walls are massive masonry walls (thickness 0,6 - 1,1 m). The window constructions are renovated. The new windows are triple-glazed. The sealing of the window construction is presented in Figures 1 and 2.

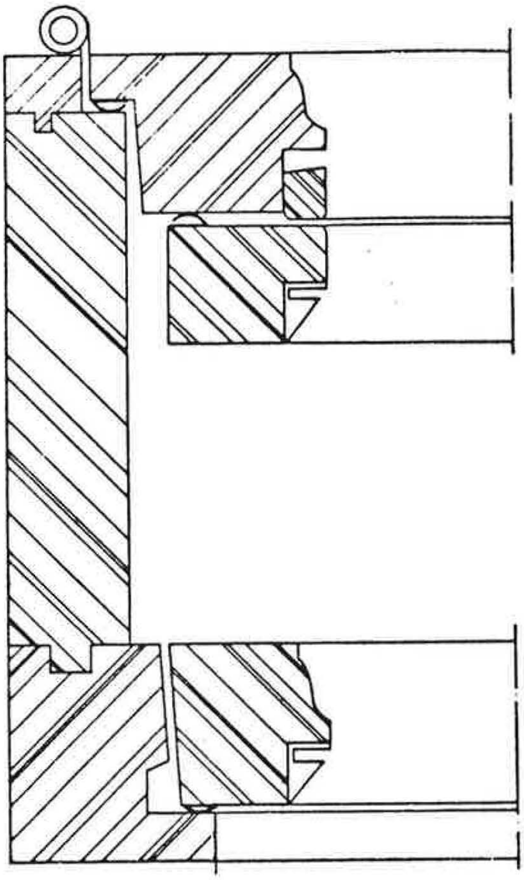

Figure 1. Window frame joints sealing with sealing trip (V-profil). Horizontal section.

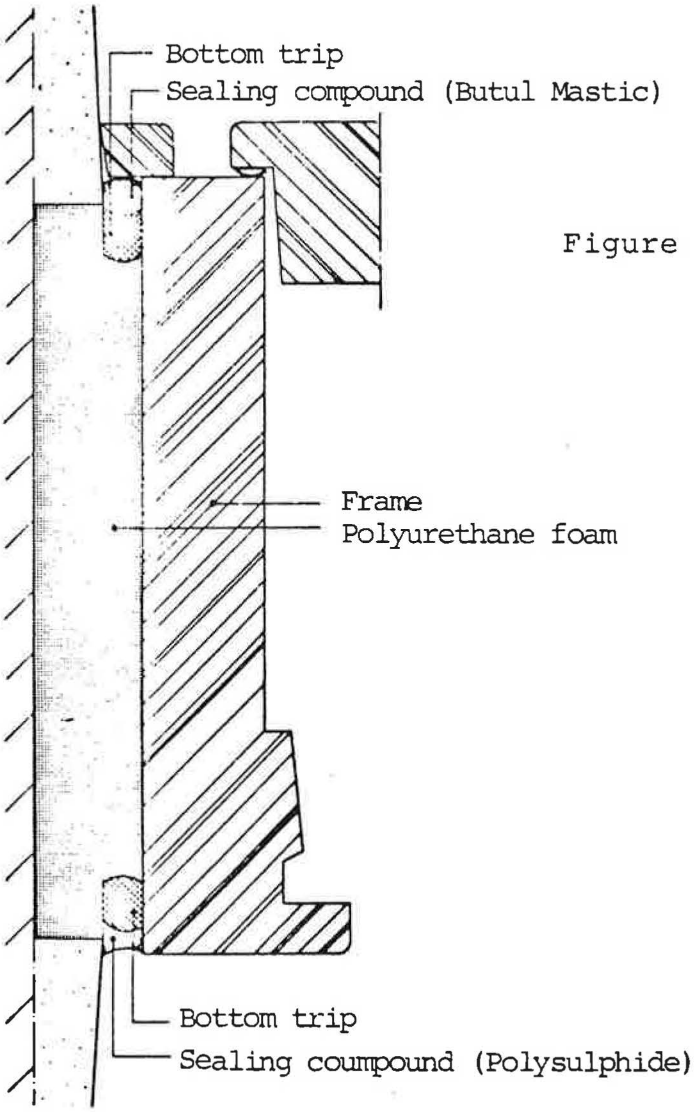

Figure 2. Sealing the window jamb joints to outside wall with polyurethane foam. Horizontal section.

2. RESULTS OF PRESSURE DIFFERENCE MEASUREMENTS

The outside - inside pressure difference was measured from 30 points around the building envelope. The measurements were made by micromanometer. Also an electrical manometer was used.

Before measurements capillary sonds were installed fixed at each measurement point so that the pressure difference could be measured quickly.

The measurements were made for the day and night operation in winter conditions. Typical pressure distributions at each system are presented in Figures 3, 4 and 5. According to the measurements, outside overpressure was prevailing at all three systems A, B and C. The mean pressure difference, standard deviation and outside weather conditions of each measurement are presented in Table 1.

TABLE 1. Average outside - inside pressure difference, its standard deviation and outside weather conditions.

System	Measurement 1982	Average Pa	Standard deviation Pa	Wind speed m/s	Outside temperature °C
A	15.3	13,8	±17,8	4-2	+1,1 – +1,5
A	19.3	10,5	± 7,1	2-3	-1,6 – +0,5
B	8.3	23,4	±18,8	2	-2,9 – +2,0
B	12.3	31,4	±19,6	6-7	-4,1 – -2,6
C	2.3	10,0	± 5,0	5-2	+1,1 – +1,0
C	4.3	9,9	± 5,7	3	+0,7 – +1,0

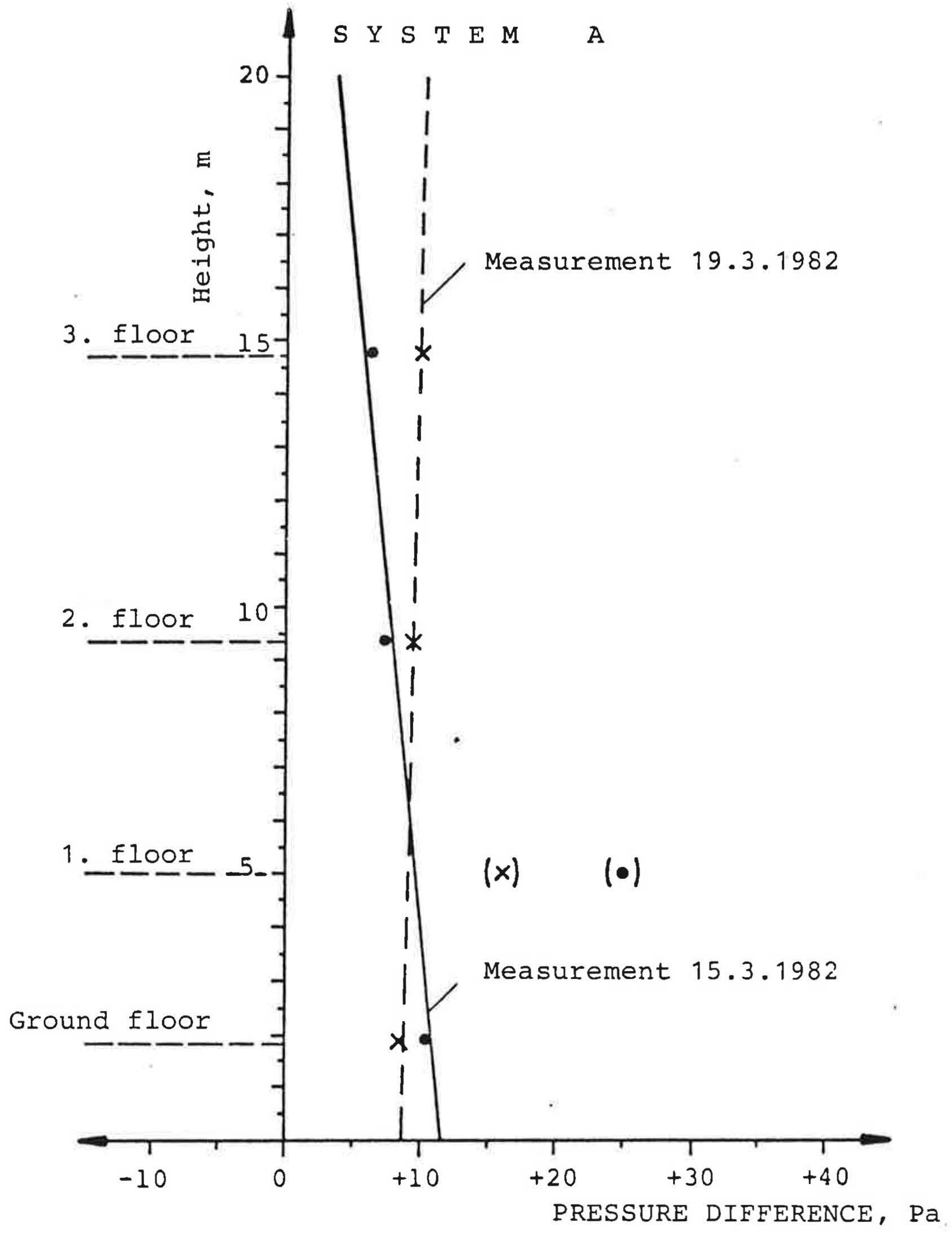

Figure 3. Outside - inside pressure difference by System A (all exhaust and supply fans under operation). Points marked in the Figure represent the average pressure difference of the floor. Positive pressure difference means outside overpressure.

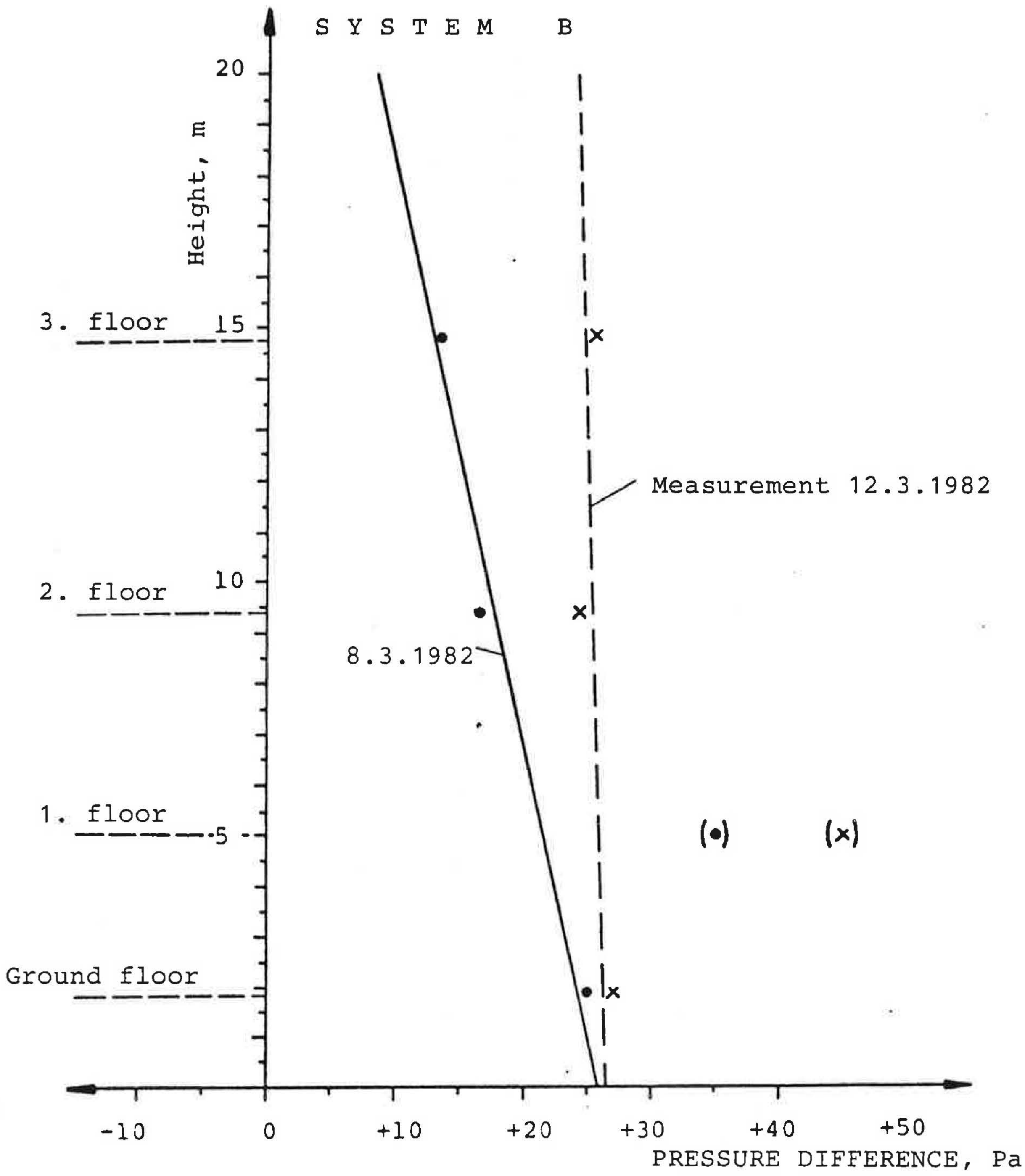

Figure 4. Outside - inside pressure difference by System B (all exhaust fans on full power, supply fans cut off). Points marked in the Figure represent the average pressure difference of the floor. Positive pressure difference means outside overpressure.

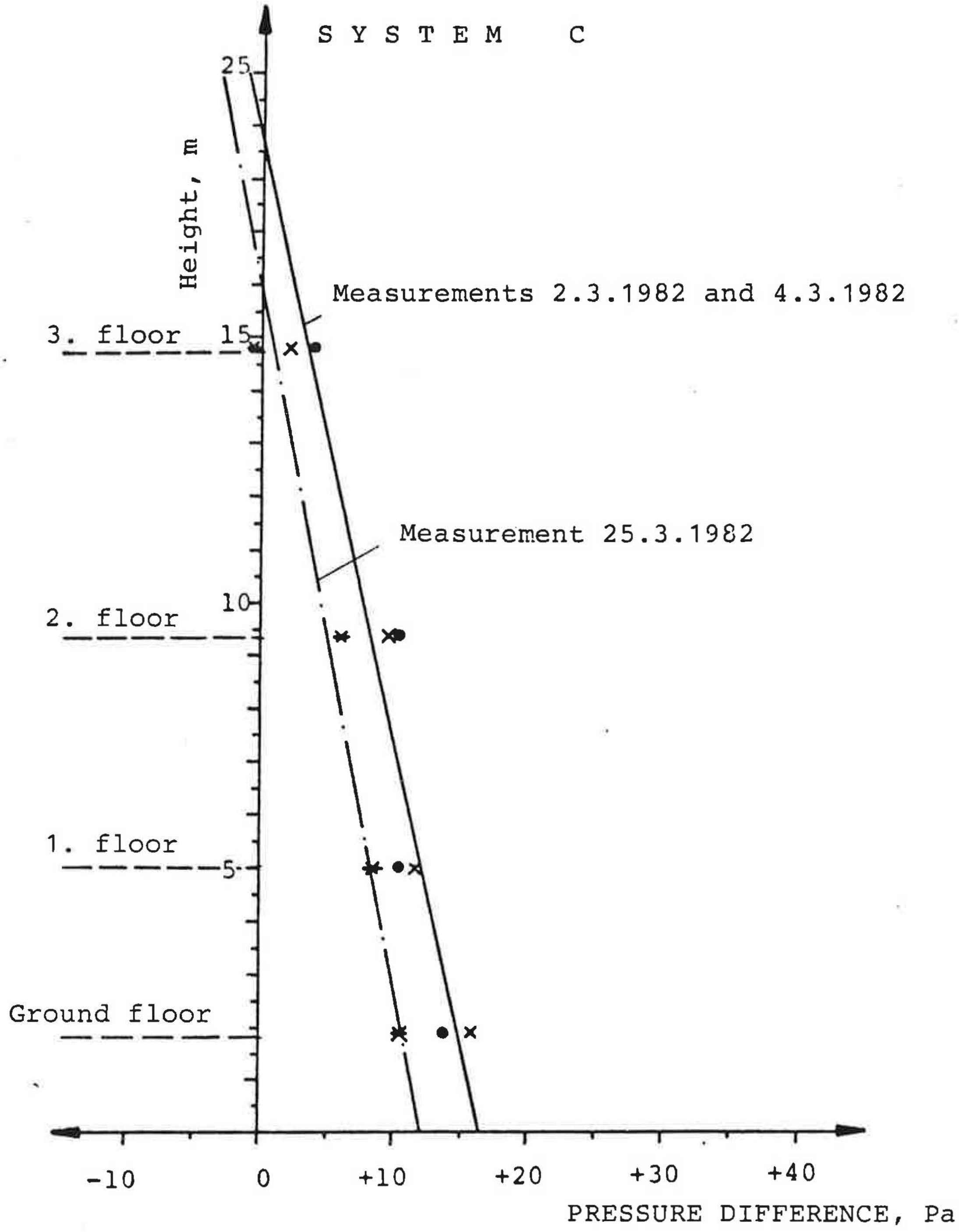

Figure 5. Outside - inside pressure difference by System C (= night operation; only the exhaust fan of toilets under operation, all other fans cut off). Points marked in the Figure represent the average pressure difference of the floor. Positive pressure difference means outside overpressure.

3. AIRTIGHTNESS OF WINDOW STRUCTURES

The airtightness of the window structures was measured by the guarded box method /1/. The airtightness of the whole window opening and the airtightness of the frame joists were measured separately for each window so that the airtightness of the window jamb joints to outside wall could be calculated. The results of the air tightness measurements are presented in Figures 6 and 7. The mean airleakage values at 10 Pa and 50 Pa outside overpressure difference were:

	PRESSURE DIFFERENCE 10 Pa	50 Pa
- window jamb joints to outside wall	0.0058 dm^3/ms	0.0151 dm^3/ms
- frame joists	0.043 dm^3/ms	0.120 dm^3/ms

4. AIRTIGHTNESS FOR BUILDING ENVELOPE

The airtightness of the building envelope was measured by the pressure test using the fans of the building:

- the building was pressurized using its own fans so that the total airleakage through the building envelope could be calculated from air flow values measured for each fan. During the test all the doors inside the building were opened. The outside doors and windows were closed.

Two points were measured for outside overpressure and one point for inside overpressure. The results are in Figure 8. The air flow rates of the fans under service were measured from the plant rooms. The outside - inside pressure difference was measured from about 30 points located at various floors.

The pressure distributions of the various facades measured when all the exhaust fans were under operation (half power), are presented in Figure 9. Outside overpressure was prevailing around the whole building envelope in this operating condition, and the total airleakage through the building envelope agreed exactly with the total exhaust. Flow direction was from outside to inside.

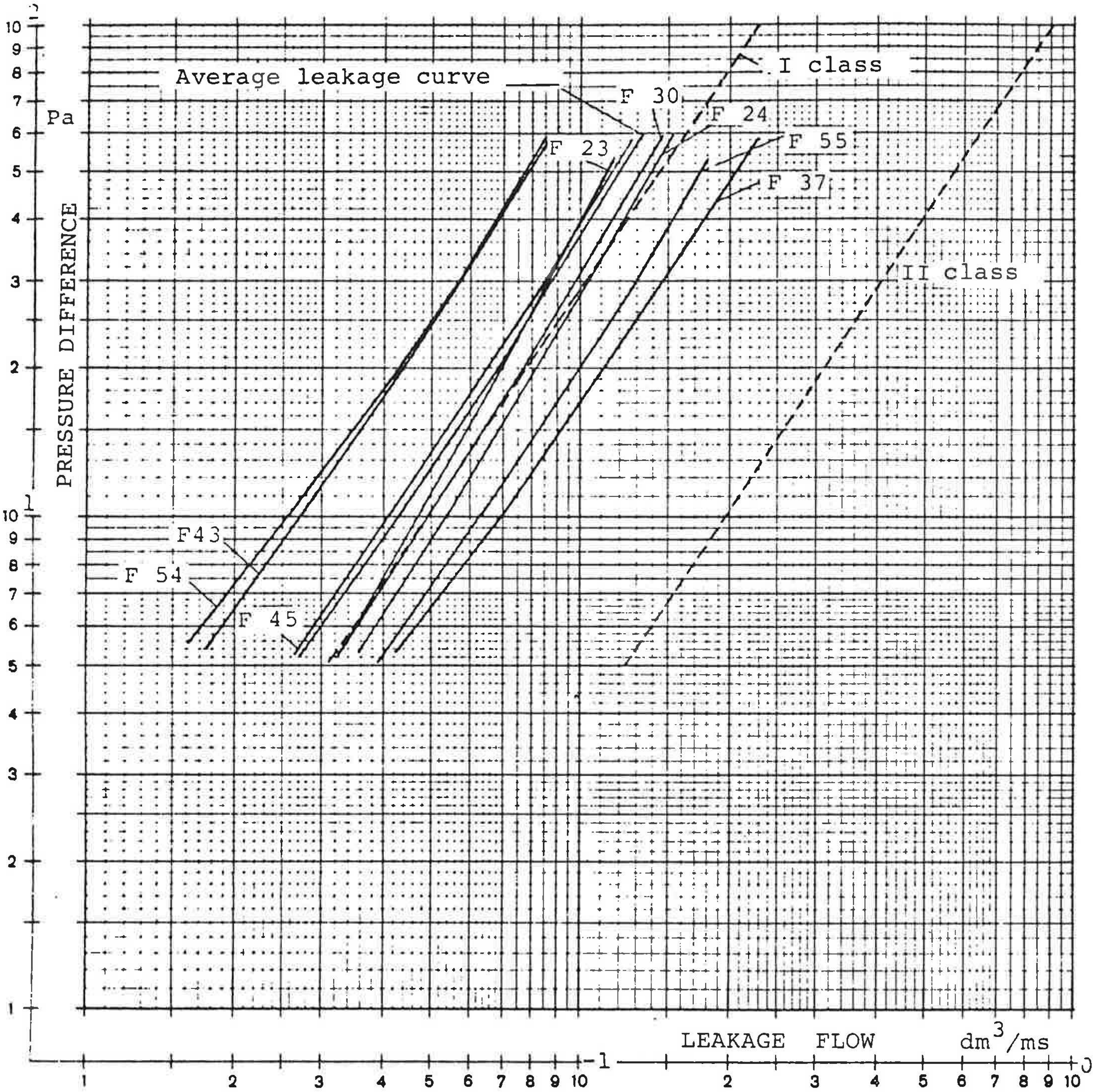

Figure 6. Leakage flow of window frame joints per crack length. Leakage flow measured with collector chamber method. Curves marked with dotted line represent the SFS 3304 standard's requirement to airtightness of window frame joints.

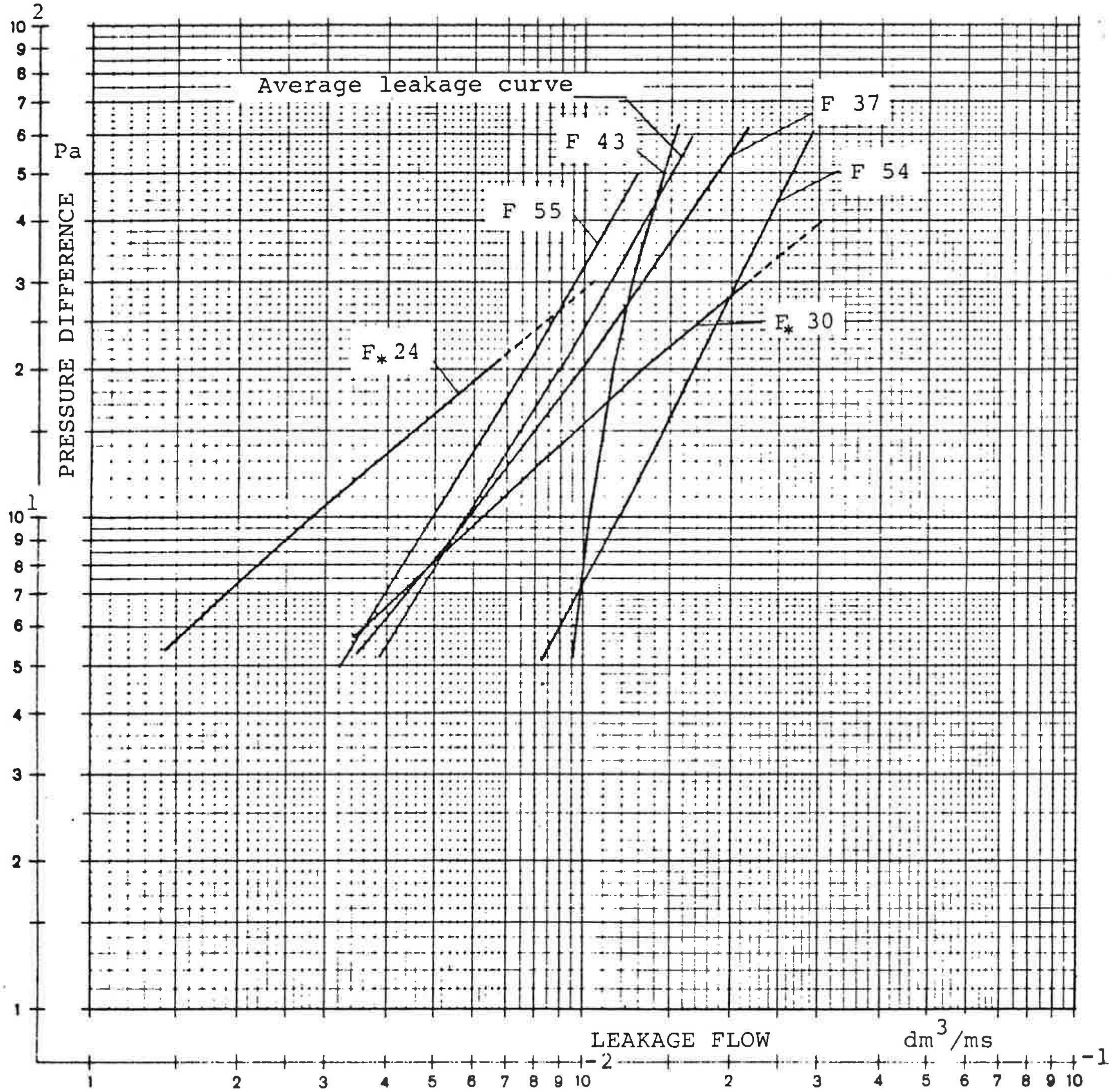

Figure 7. Leakage flow of window jamb joints to outside wall per crack length measured with collector chamber method. With *-marked curves are not theoretically correct. In these cases the air leakage of window jamb joints was in the limits of the measurement accuracy.

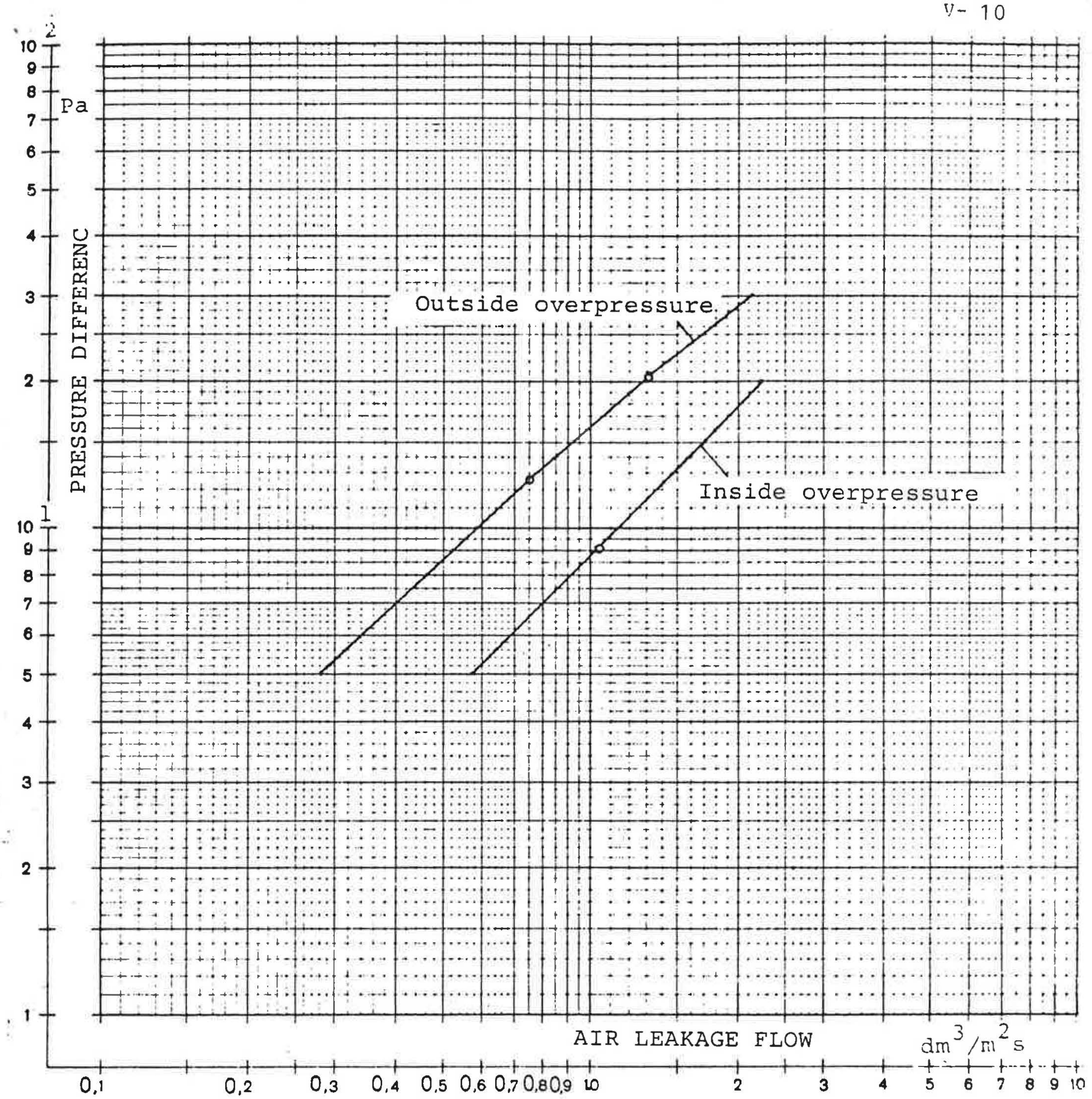

Figure 8. Total air leakage (per wall area) through the building envelope. The pressure test was made by using the fans of the building.

The total airleakage by using inside overpressure was measured by the same principle. In this operation condition only the supply fans were in use and the valves after the exhaust fans were closed. The direction of the airleakage flow was from inside to outside over the whole building envelope. The pressure distributions of the various facades are presented in Figure 10.

OUTSIDE OVERPRESSURE
OPERATION CONDITION

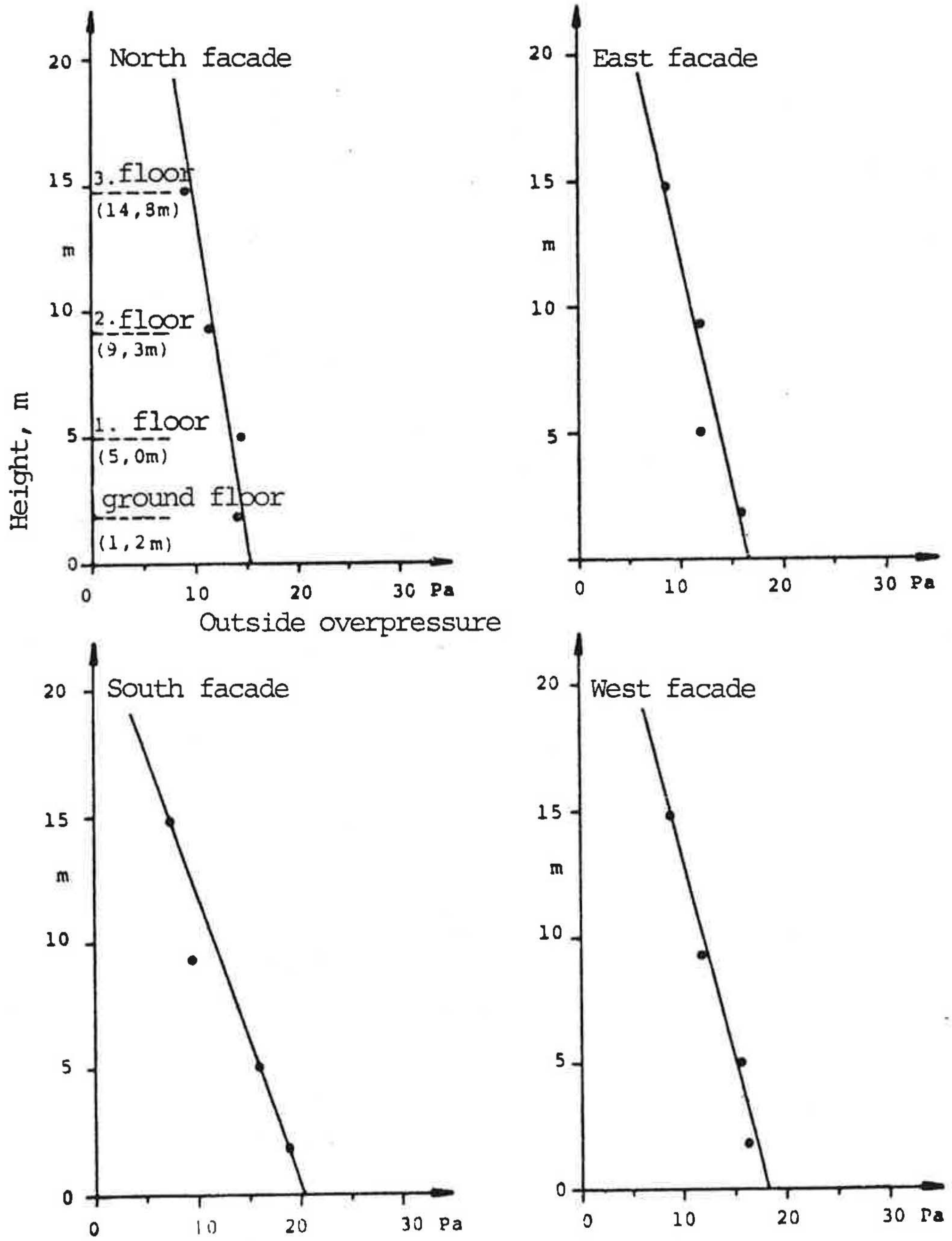

Figure 9. Outside overpressure measured to various facades and floors. Operation condition with the pressure test: exhaust fans on half power, supply units cut off (valves closed), outside doors and windows closed, all doors inside opened.

INSIDE OVERPRESSURE
OPERATION CONDITION

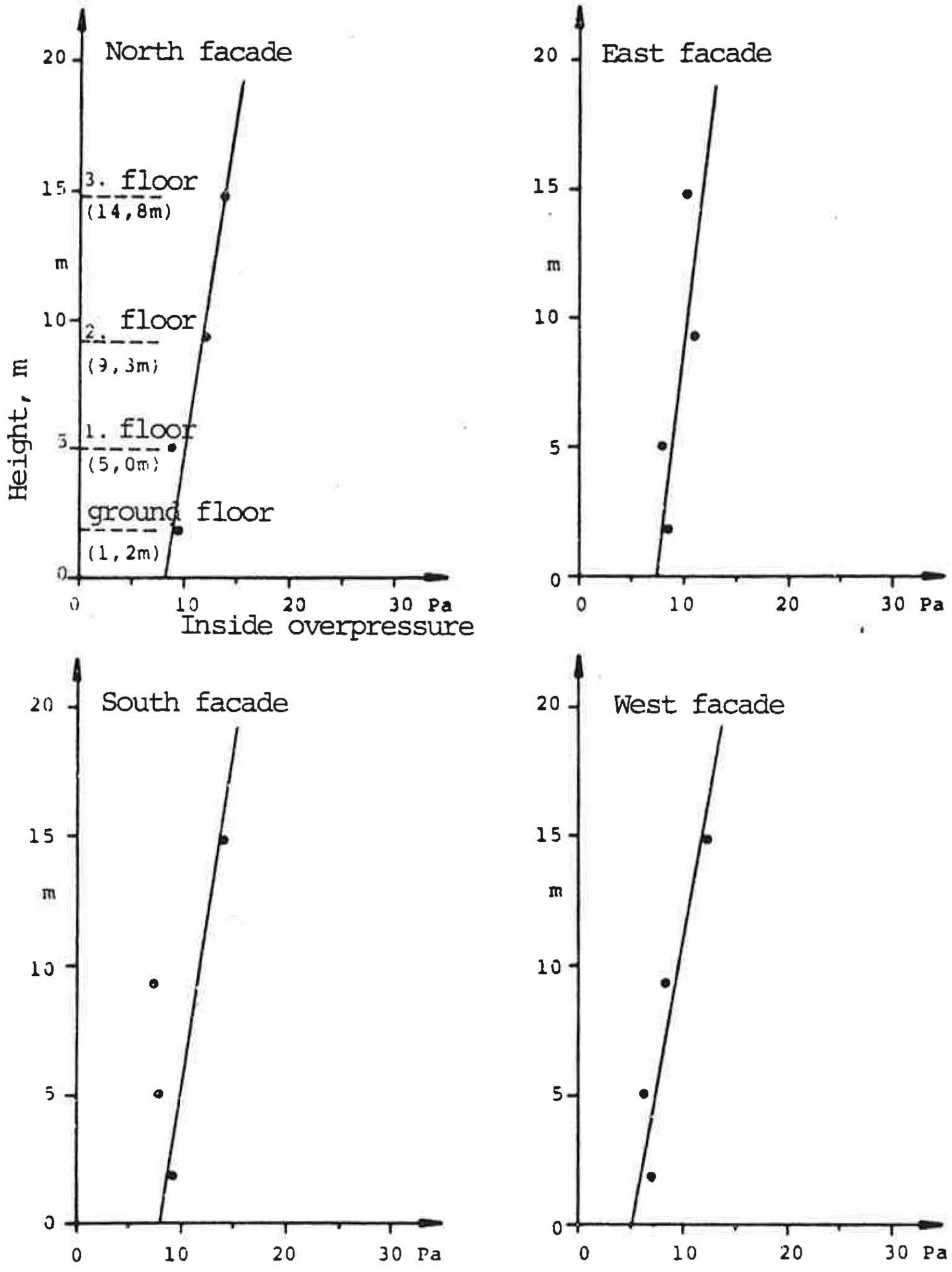

Figure 10. Inside overpressure measured to various facades and floors. Operation condition with the pressure test: supply unit on half power, exhaust fans cut off and valves after fans closed, outside doors and windows closed, all doors inside opened.

Specific airleakage value to inside overpressure at 10 Pa is about two times higher compared with the corresponding value to outside overpressure at 10 Pa (see Fig. 8). If we assume that the flow resistance is independent of flow direction, the result means that there are considerable leakage points on the attic floor. Due to density differences between inside and outside air the total airleakage to inside overpressure is higher than to the same outside overpressure. An inspection was made with smoke on the attic floor, and we could find untight spots in the wooden roof structure.

If we use for the specific airleakage the mean value calculated from the specific values at under- and overpressures we can eliminate the effect of density. According to an estimation made in this way, the specific airleakage at 10 Pa is about 0.87 dm^3/m^2s. The corresponding air change number is 0.7 h^{-1}. The air change number at 50 Pa is estimated by using the following equation:

$$n_{50} = n_m \cdot \left(\frac{50}{\Delta p_m}\right)^{0.7} , \quad \text{where} \qquad (1)$$

n_{50} is the air change number at 50 Pa, h^{-1} and
n_m is the air change number with the pressure difference Δp_m, h^{-1}.

The empiric value 0.7 of the exponent is an approximate value. The air change number at 50 Pa calculated from the above equation is about 2.0 air changes per hour (h^{-1}).

According to the estimation made on the basis of the results of airtightness and pressure difference measurements, the major part of the total airleakage of the building envelope (about 70 %) came through the wooden roof structure when only the exhaust fans were used. Only 5 - 10 % of the total airleakage (total air change) came through window structures by the mechanical exhaust system (System B). We must keep this in mind when reading the measured results of thermal indoor environment, because the supply air intake included no special arrangements.

5. INDOOR CLIMATE

The purpose of the climate measurements was to study possible differences in thermal conditions between the alternative ventilation systems (A, B and C).

The measured environmental parameters in the same rooms at various systems were:

- vertical temperature difference,
- operative temperature (= the globe temperature),
- local air velocity and temperature.

According to the measurements in the thermal enviroment of the building there were no significant differences between the various systems. The vertical temperature differences in all measured cases were under 3 K between the levels 0.1 m and 1,8 m from the floor. The mean operative temperature was in all cases about 21 °C. The local air velocities and temperatures, which did not satisfy the comfort criteria used, were measured in two rooms at the first floor. In both rooms cold air flows from the corridor caused discomfort.

The total air change of the building (the sum of the exhaust air flows) was about 0.7 h^{-1} (air changes per hour) at A and B systems and 0.2 h^{-1} at C system.

Indoor air quality was controlled only by measuring the concentration of radon in the indoor air. According to the results the mean concentrations of radon were rather high with the exhaust ventilation systems examined: 450 Bq/m^3 with B system and 480 Bq/m^3 with C system. The source of the radon could not be pointed out. Possibly radon is emitted from the ground soil and from the building materials.

6. SUMMARY

The airtightness of the building envelope was measured by the pressure test (using the fans of the building) and the airtightness of windows and outerdoors was measured separately by the guarded box method. According to the results the airtightness of the building envelope was rather good (about two air changes per hour at 50 Pa pressure difference). The major part of the total air leakage (about 70 %) came through the wooden roof structure and only 5 - 10 % through the window structures.

Further investigation is required, as to the energy use of the various systems. The source of radon should also be verified.

REFERENCES:

1. Siitonen, V., Measurement of local airtightness in Buildings. Espoo 1982. Technical Research Centre of Finland, Research Notes 125. 17 p + app. 12 p.

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