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AIR TIGHTNESS OF BUILDINGS – RESEARCH IN SWEDEN

IEA SEMINAR ON R & D PROJECTS IN THE AREA OF INFILTRATION IN BUILDINGS, PARIS APRIL 1978

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AIR TIGHTNESS OF BUILDINGS - RESEARCH IN SWEDEN

In energy balance of buildings the ventilation losses are a big part and this part is getting relatively bigger the better the enclosure of the building is insulated. All ventilation that is larger than what is wanted for hygiene and comfort can be regarded as undesired and thus be considered as heat loss. For energy conservation it is therefore essential that ventilation rate can be controlled.

It was therefore quite natural that many officials, institutes and researcher started investigating air tightness of buildings and ventilation rates in Sweden after the energy crisis. Many research projects were presented to the Swedish Building Research Board. In order to coordinate this research a coordinating group was established with members from authorities, research and industry.

The coordinating group has been working in five subgroups

1 Nomenclature
2 System analysis
3 Measurements and testing methods
4 Technical solutions in design
5 Influence of microclimate

Technical solutions in design will be presented to the IEA seminar by Mr A. Elmroth.

NOMENCLATURE

Nomenclature in Swedish is rather uninteresting in international relation but we have not been able, so far, to reach an agreement. The problem is more to define the different terms than to name them, and that might be an international problem.

SYSTEM ANALYSIS

Ventilation rate depends upon many factors

- Wind conditions around the building
- Temperature differences
- Shape of the building and the environment
- Air tightness of the building enclosure
- Air tightness between rooms in the buildings
- Ventilation system

The relations can be demonstrated by figure 1 that shows a principal algorithm for calculating the ventilation rate. By calculating for each day of the year it should be possible to establish a frequency diagram from which the extra energy loss over the year can be estimated.

So far, research in Sweden has been mainly concerned with measuring air tightness of buildings, specially houses, by pressure method or tracer gas technique. In figure 1 this corresponds to the pressure flow relations. It should, however, be noted that most measurements deal with the whole building and very little is done concerning the different building components, except windows which have been tested to a certain extent. Thermography has been widely used to check the thermal performance of the building and the tendency to air leakage.

MICROCLIMATE

The influence of wind depends upon wind velocity and wind direction close to the building, and the shape factors. It will therefore be necessary to find a method to transfer the meteorological observations to nearby conditions.

Shape factors have generally been determined for the purpose of structural design, which means that one has generally tried to find the highest wind loads. In our studies it is more interesting to study the average conditions. For houses in a group it is obvious that both wind velocities and shape factors are different from those for a single house.

In Sweden we will start a research project to study shape factors for houses in a group and after that the relation between "meteorological" wind and wind in a built area will probably be studied.

AIR LEAKAGE CHARACTERISTICS

The air leakage characteristics i.e. primarily pressure flow relations for building components and connections between building components are of course an essential part of the calculation of the ventilation intensity. Mostly the relation between air flow through buildings or building components and pressure differences is described by the expression

$$Q = a * \Delta p^b \qquad (1)$$

where
- Q = volume flow rate (m^3/h)
- Δp = pressure difference (Pa)
- a = specific constant
- b = specific constant, $0,5 \leq b \leq 1$

The value $b = 0,5$ corresponds to completely turbulent flow while $b = 1,0$ stands for completely laminar flow. Equations of this type lack generality because they are not dimensionally homogenous. That is, they are in conflict with a fundamental law of fluid mechanics - Reynolds law of similitude. However, alternatives to this kind of expressing the relation are not yet being used to any greater degree. This exponential equation is probably so commonly used because of the fact that results from air leakage measurements often are plotted on a logaritmic paper and the result being a straight line. The a- and b-values are thus obtained graphically. For many cases regarding building components and whole buildings a b-value around 0,7 is obtained. This could be considered as a combination of laminar and turbulent flow. The region in which laminar flow generally is supposed to exist is often referred to flow situations where Reynold´s number, Re, is below 2300. Bearing this in mind figure 2 shows the field of variation for the air velocity and the crack width and the resulting Re-number.

By means of thermography and quantitative measurements mean velocities (v) in cracks are often observed to be 0 - 3 m/s at at pressure difference of 50 Pa. Air velocities and corresponding crack widths (b) along the transition curve ($Re = Re_{cr}$) are:

v m/s	3	2	1	0,5
$b * 10^3$ m	1	1,5	3	5

Those values are all between 1 mm and 1 cm.

Thus, for ordinary cracks in and interstices between building elements and the observed air velocities mentioned it seems reasonable to find air flows through buildings with elements of both turbulent and laminar flow. Consequently, depending on the proportion between presence of cracks giving laminar and cracks giving turbulent flow it is difficult to make calculations in order to predict air flow rate and even if that proportion is given it is diffucult to make a correct calculation especially concerning the turbulent part.

An alternative more correct way of calculating the air flow rate is given by, for example, Etheridge (1977). These results are, however, not yet applicable for practice. Research concerning air flow rate calculations is very requested.

CALCULATIONS

Within the work in the coordinating subgroup for the system analysis P.O. Nylund has performed calculations using an algorithm similar to the one showed in figure 1. Hitherto it has resulted in calculations of air change rates as a function of wind velocity for a number of cases concerning the building, the pressure distribution, air leakage characteristics and ventilation system.

The building used in this calculation has an area of 10 * 10 m and a height of 3 m. The window area is 20% of the facade. The ouside pressure distribution is chosen to be either A or B in figure 3.

The air permeability characteristic for the building envelope is settled in a rather simplified way by first stating a specific level of the overall air leakage at a pressure method measurement at 50 Pa divided with the house volume ($m^3/m^3 \cdot h$). Three main levels called n_{50} are used: 1,0, 3,0 and 5,0 $m^3/m^3 \cdot h$. The corresponding air flow is split up in air leakage values ($m^3/m^2 \cdot h$) for windows (2 $m^3/m^2 \cdot h$), walls (q) and ceiling (0,5 * q). To obtain air leakage values at other pressure levels than 50 Pa it is necessary to state the form of the pressure difference - air leakage curve. Two assumptions are used: the exponent in (1) being either 0,5 or 1,0. The ventilation system could be either of:

- o no ventilation system - balanced ventilation
- o exhaust fan ventilation 0,5 air changes/hour at calm
- o exhaust fan ventilation 0,25 air changes/hour at calm
- o natural ventilation with pipe (μ = -0,5 at the orifice)

Figure 4 - 6 show the calculated ventilation rate as a function of the wind velocity for different values of the b-exponent. Effects of stack effect are not included.

The main aim of calculations of this kind is to give the optimal air tightness value for minimizing energy comsumption and simultanously keep the indoor comfort at proper level. To make such decisions it is obviously necessary to include effects of different weather conditions during for example a heating season. This is the next step of this work and is recently started.

TESTING METHODS - PRESSURIZATION

At present the pressure method has a very dominating position in Sweden as method for testing whole houses for air leakage.

Principle

The test is performed by making a serie of pressure differences act across the building envelope and measure the air leakage caused by these pressure differences. The air leakage rate at a certain pressure difference level is chosen as an air leakage characteristic of the house.

Test equipment

A fan capable of producing pressure differences between inside and outside conditions of at least 55 Pa and equipped with speed or capacity control can be used to perform the test. For flats a recommendation value for the air flow capacity could be 1200 m^3/h and for single family houses 2000 m^3/h at a working pressure of 55 Pa. These values are chosen according to experiences of air tightness of Swedish houses and may differ from values suitable for other countries with another building technology. Some kind of air flow measurement device is used to measure the air flow rate through the fan and may be for example an orifice plate, pitot tube or something similar. The subgroup for measurements and testing methods has suggested that there should be an upper limit for the error (m) of the air flow measurement of ± 6%.

$$m = \sqrt{m_1^2 + m_2^2 \dots}$$

m_1, m_2 etc. stand for the errors of each component of the total flow measurement. Manometers must be used to measure pressure differences between at least 0 to ± 55 Pa with an accuracy of ± 2 Pa. It is recommended that the fan and flow measurement device should be easy to turn and thus change the flow direction.

The test

Inside and outside temperatures, wind direction and wind velocity is to be determined. The test should preferably not take place if the local wind velocity exceeds 8 m/s or if the temperature difference between inside and outside exceeds 30 ^{0}C.

Before the test all openings for the volontary ventilation must be sealed. For example exhaust and supply air equipments, furnace openings, chimneys or letter boxes are sealed with tape. Parts of the plumbing installation which are connected to open air must be sealed too. Doors within the test volume are to be open during the test. The fan is mounted to the house envelope. Most common is perhaps to attach it to the outer-door opening using a wood fibre board plate with the fan attached to it. The pressure difference between inside and outside is measured between the inside of test volume and a place on the ground a couple of meters from the house. An example of the equipment mounted for testing is shown in figure 7.

At least four pairs of values - pressure difference/air flow - is monitored within the range of 20 - 55 Pa. Both positive (higher pressure inside) and negative pressure difference is applicated. The inlet air flow should be compensated for temperature expansion by multiplying with a term T_I/T_0 where T stands for the absolute temperature and I and 0 stand for inside and outside conditions.

The volume of the building is defined as the volume inside the inner of the outer walls, ceilings etc. However, inner-walls and -floors should be excluded.

As the air leakage characteristic of the building, normally the mean of the air flow rates (positive and negative) at 50 Pa is chosen. The result of the test may also be given as in figure 8 with measured values and the fitted curves.

The method is fast and easy to handle. The result is to a great degree anambigous. You get a value of the air leakage characteristic that can be used for manufacturing control, comparisons between buildings and building code controls etc.

It must be pointed out, however, that the testing method determines only the overall air leakage characteristic of the building and could not, at least at present, be used for energy loss calculations concerning natural conditions. This method must be completed to make it possible to detect the localization of leakage paths. Infra red camera and anemometer are excellent tools to determine where leaky parts are and how leaky they are.

TESTING METHODS - TRACER GAS TECHNIQUE

Tracer gas technique has in Sweden been used for about 15 years to determine ventilation rates of buildings. Initially helium and hydrogen gas were the most commonly used tracer gases but now the nitrous gas N_2O has an overwhelming popularity. Infra red absorption is the principle for measuring the concentration of tracer gas when N_2O is used. The widest used equipment in Sweden works with concentrations between 0 and 1000 ppm and this measuring range has proved to be suitable for this kind of measurements. For a normal detached house with a volume of 300 m^3 it means that 300 l of N_2O must be used. With the density being ∿ 1,7 kg/m^3 it is equivalent to ∿ 0,5 kg N_2O. In Sweden the gas is manufactured in relatively small and easy handled bottles of 7 kg and would consequently be used for about 10 - 15 measurements. The density of N_2O (1,7 kg/m^3) is much more close to that of air than is the case for He (0,2 kg/m^3) and H_2 (0,1 kg/m^3) and this gives great advantages. As far as it has been observed there are no problems to get a complete mixing of the tracer gas in the air and no layer effect is observed. This is a rather great problem when using He och H_2.

As can be seen in the following registration papers tests have to a certain degree been performed using both pressure method to determine air leakage characteristics of houses and tracer gas technique to measure the ventilation rate due to air infiltration/exfiltration under natural weather conditions of the same objects.

TESTING METHODS - THERMOGRAPHY

Thermography is a qualitative testing method perhaps initially meant for determining heat insulation performance but also as mentioned before an excellent tool to localize air leaks in building enclosures. It has been and is widely used in Sweden for these purposes. Recently a Swedish standard for the thermographing procedure was established and is used by ISO Technical Committee 163 as a basis for a proposed international standard.

The application of thermography to air leak detecting has been done in several reserch projects in Sweden on air tihgtness of buildings. The difficulty in making good prints from photographies makes it impossible to include pictures within this paper. However, especially when applying a negative pressure difference over the building enclosures it is quite easy to detect air leaks by means of thermography.

REGISTRATION OF MEASUREMENTS

The subgroup for Measurements and testing methods has suggested a registration form mainly for pressurization tests. (Encl 1). In this form the house is described, the test result and the prevailing weather conditions are given. The form has been approved by the coordinating group with some remarks: It should be possible to mark if a single air leakage value is a mean value. The other remark concerns a lack of a code for a not very unusual house type in Sweden the "souterrain" house with one basement wall and one ordinary outer wall on the opposite side on the ground floor of a two storey building.

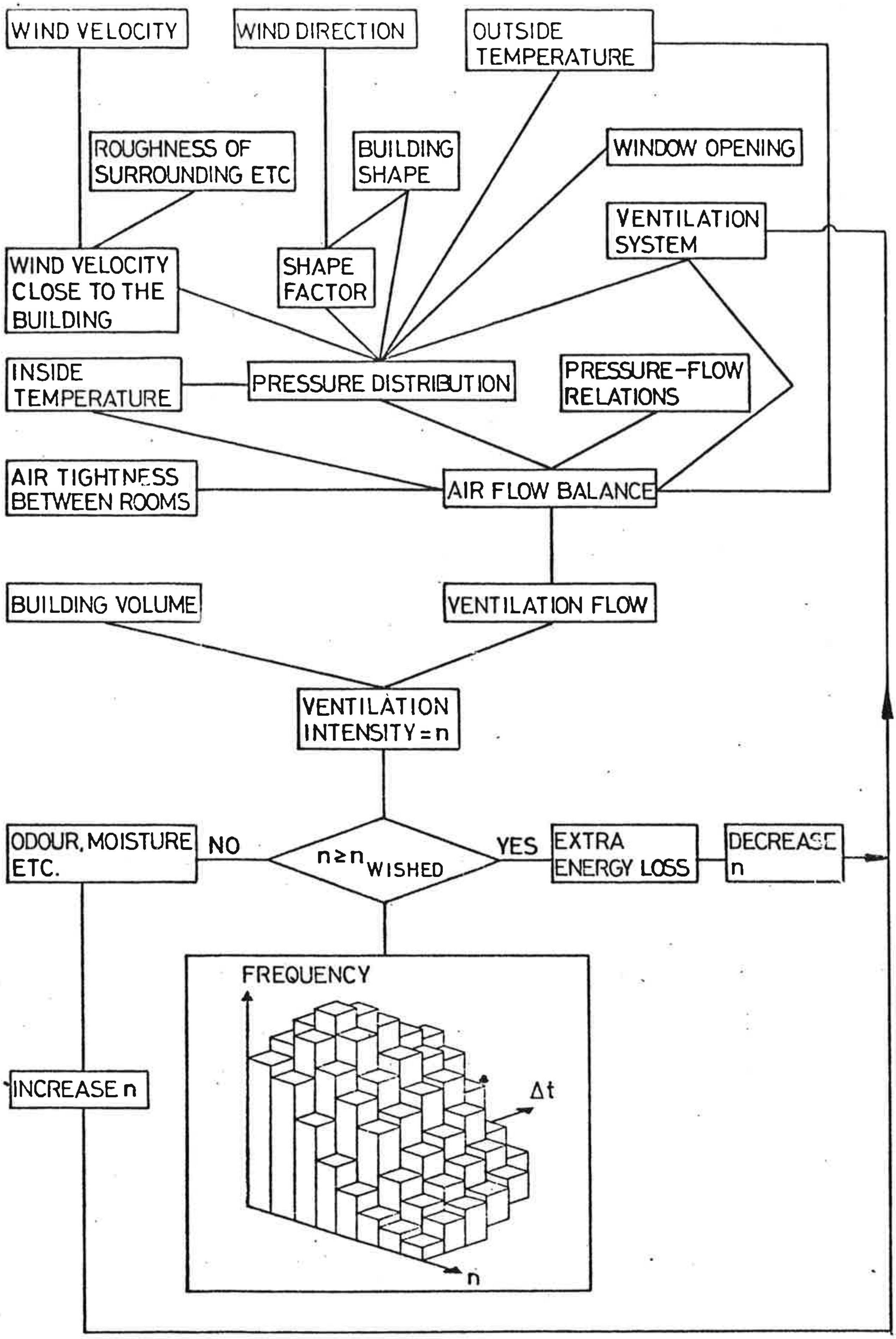

Fig. 1 Principal algorithm for calculating ventilation rate and heat loss.

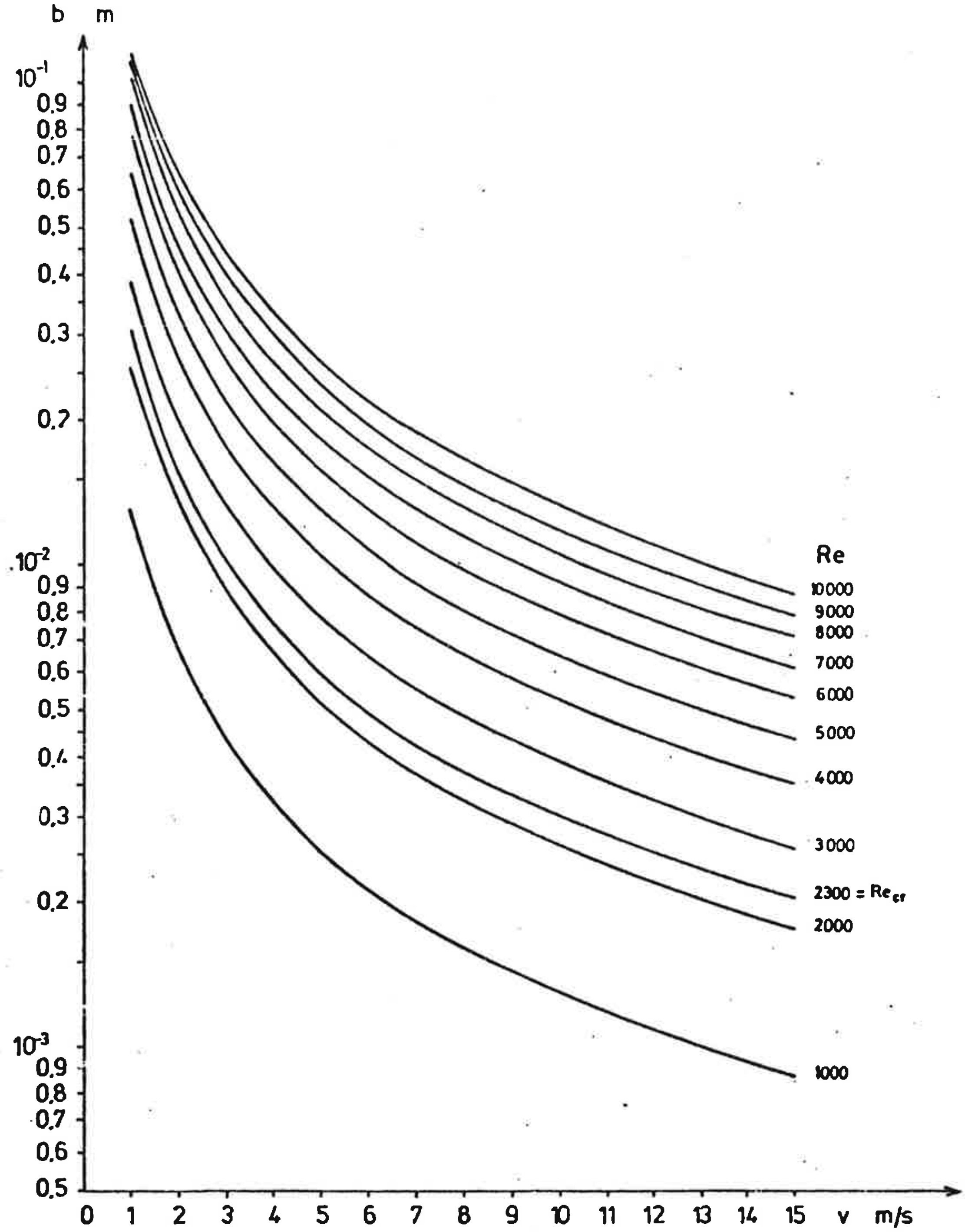

Fig. 2 The Re-number as a function of mean air velocity and crack width for air flow between parallell plates.

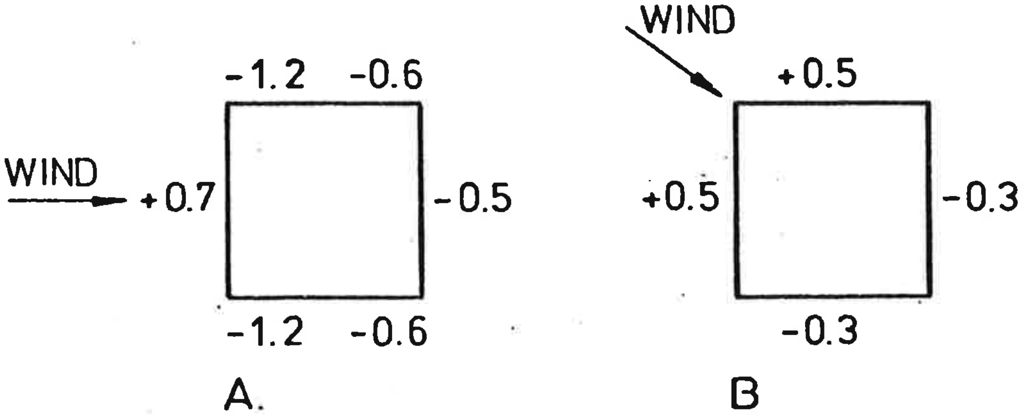

Fig. 3 Pressure distributions (assumptions)

NO VENT. OR BALANCED VENTILATION

n_{50} = NUMBER OF AIR CHANGES PER HOUR AT PRESSURIZATION TO 50 Pa

b = EXPONENT IN FLOW EQUATION

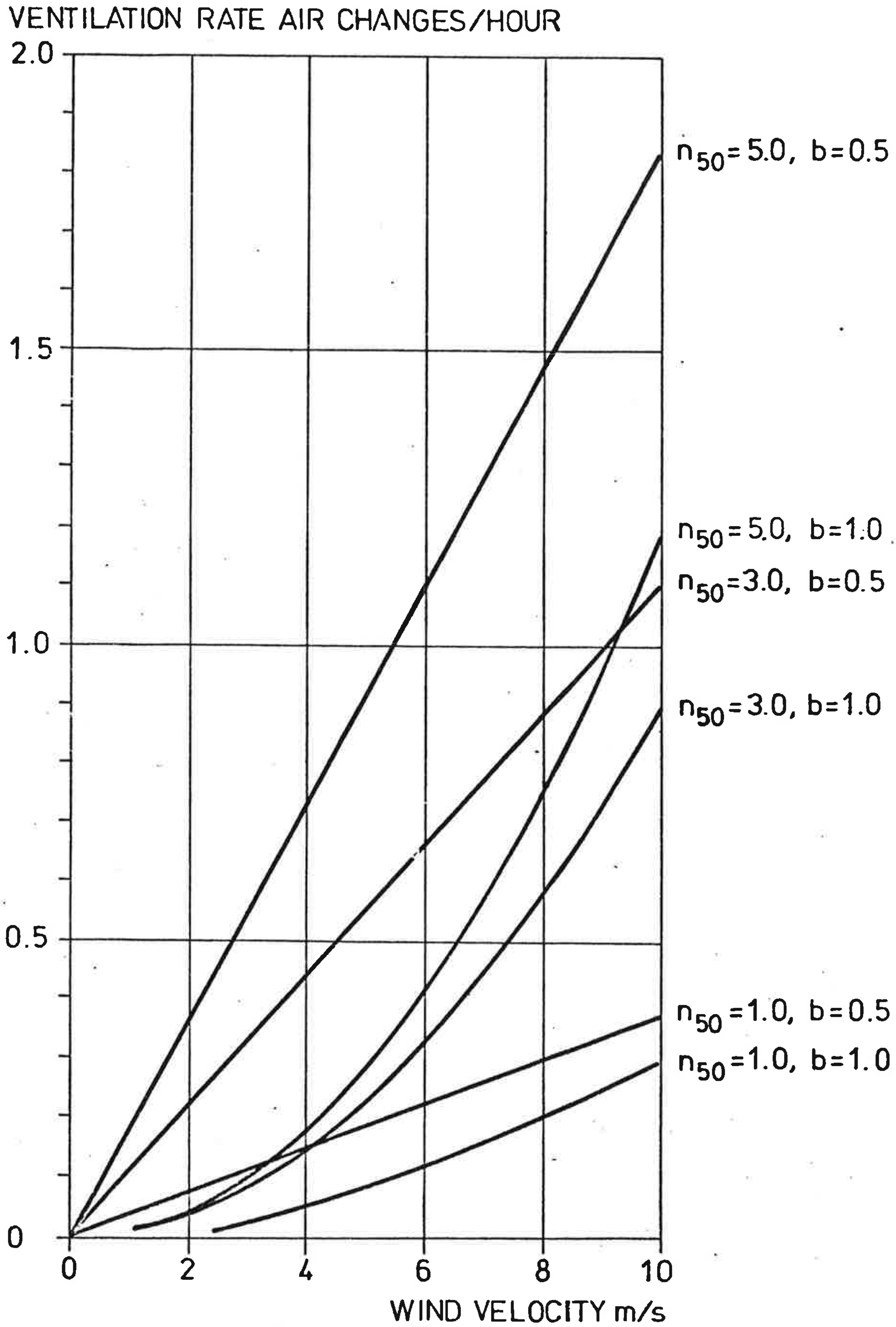

Fig. 4

EXHAUST FAN VENTILATION

$150 m^3/h$ - 0.5 AIR CHANGES / HOUR

n_{50}= NUMBER OF AIR CHANGES PER HOUR AT PRESSURIZATION TO 50 Pa

b = EXPONENT IN FLOW EQUATION

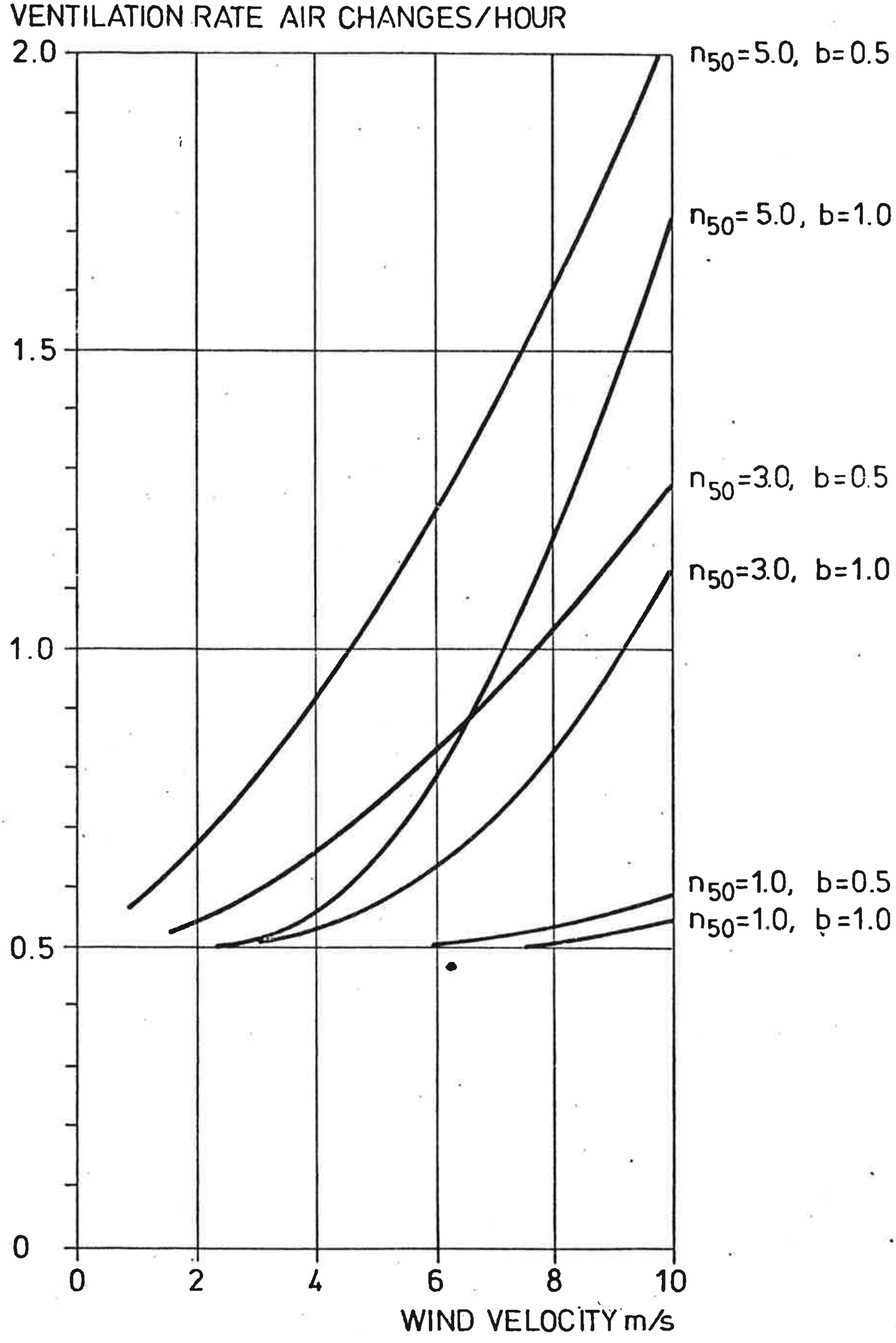

Fig. 5

NATURAL VENTILATION

n_{50} = NUMBER OF AIR CHANGES PER HOUR AT PRESSURIZATION TO 50 Pa

b = EXPONENT IN FLOW EQUATION

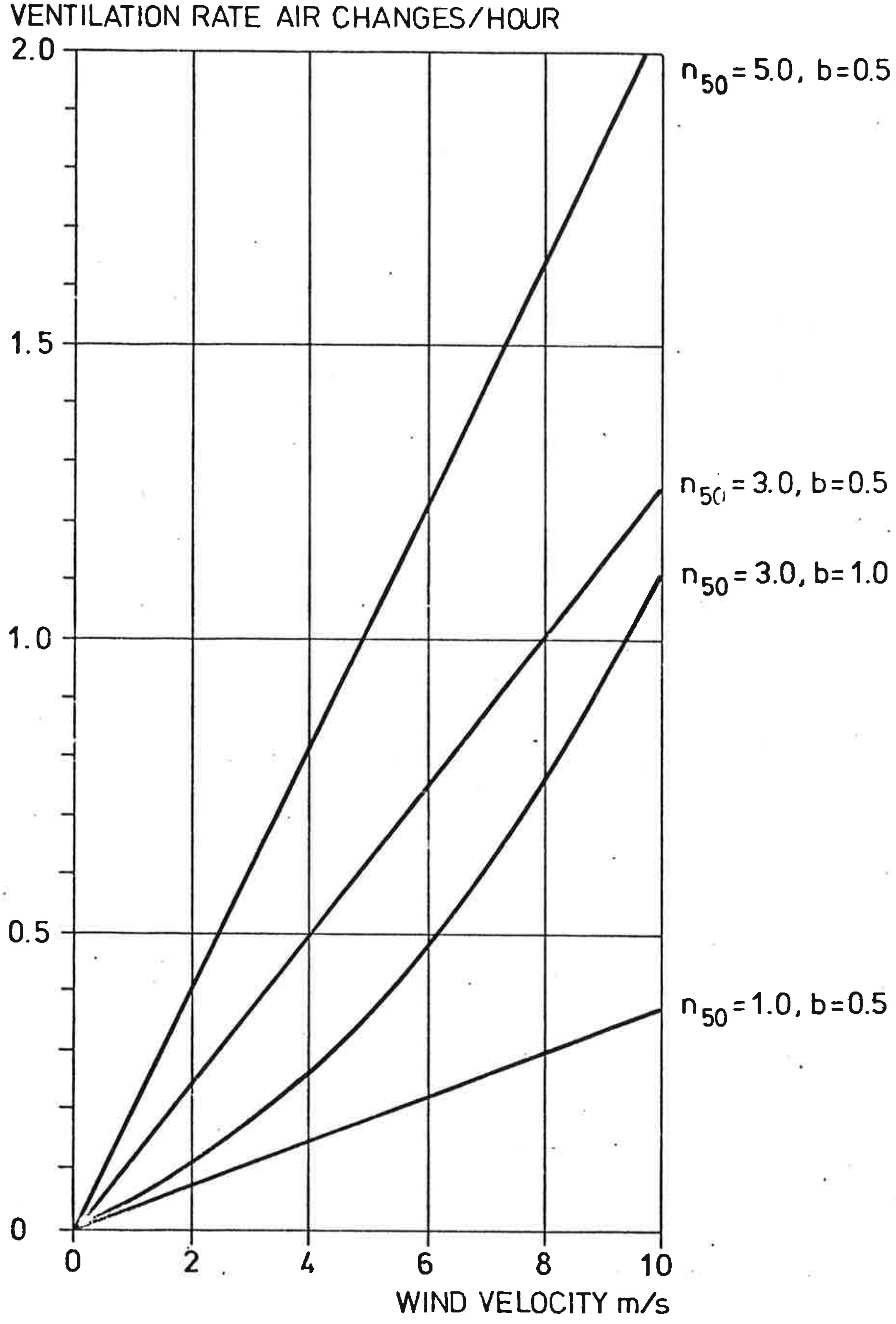

Fig. 6

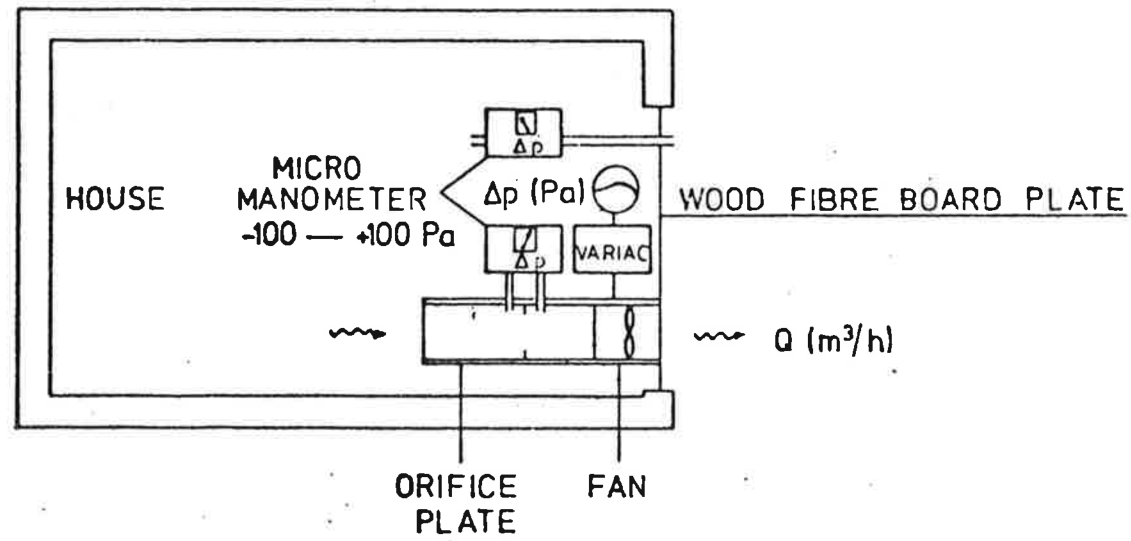

Fig. 7 The "pressure method" test equipment.

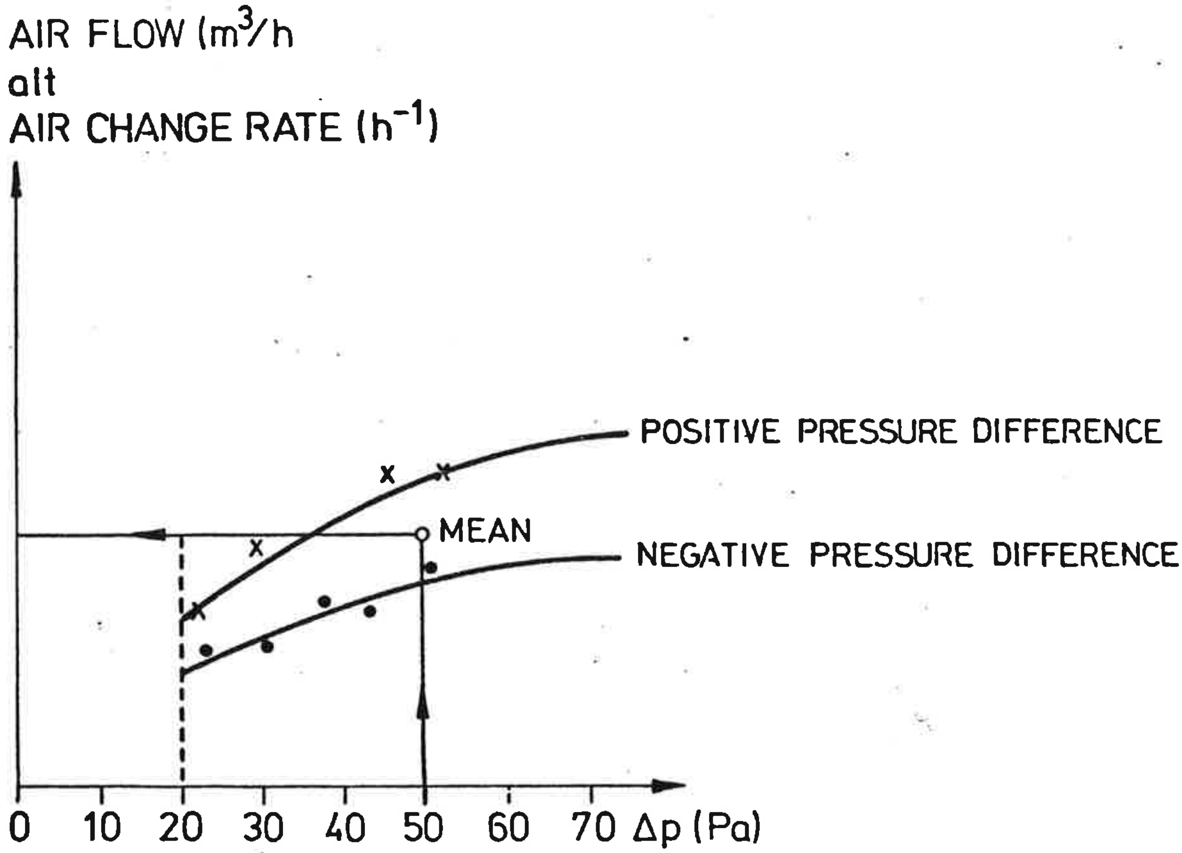

Fig.8 Presentation of test result.

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LUND, Sweden

1 OBJECT NUMBER
2 YEAR OF ERECTION
3 NUMBER OF STOREYS
4 PRODUCTION — P=PREFABRICATED; V=VOLUME ELEMENT, S=SURFACE ELEMENT; S=BUILT ON SITE
5 HOUSE — D=DETACHED HOUSE; R=ROW HOUSE; L=LINKED HOUSE
6 MATERIAL — W=WOOD; L=LIGHT WEIGHT CONCRETE; C=CONCRETE; B=BRICK; M=CONCRETE/CURTAIN WALL
7 VENT.SYSTEM — S=NATURAL VENTILATION; F=EXHAUST AIR; FT=BALANCED
8 WINDOW OPEN.DIR. — O=OUTWARDS; I=INWARDS; B=BOTH DIRECTIONS
9 GROUND — C=CRAWL-SPACE BASEMENT; B=BASEMENT STOREY; F=FLOOR SLAB ON GROUND
10 VOLUME, M**3
11 AREA, M**2
12 VOLUME/AREA
13 AREA, WINDOWS&DOORS
14 AIR LEAKAGE + M**3/H
15 AIR LEAKAGE - M**3/H
16 AIR LEAKAGE + M**3/M**3*H
17 AIR LEAKAGE - M**3/M**3*H
18 AIR LEAKAGE + M**3/M**2*H
19 AIR LEAKAGE - M**3/M**2*H
20 NATURAL INFILTRATION*100PER HOUR
21 OUTSIDE TEMPERATURE, C
22 INSIDE TEMPERATURE, C
23 WIND VELOCITY, M/S
24 WIND DIRECTION

CTH

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
1	77	1.5	PV	D	W	FT		C	380	315	1.2		1820	1900	4.8	5.0	5.8	6.0	21	-6	21	1	
1													1640	1500	4.3	4.0	5.2	4.8	6	+20	23	3	
2	77	1.5	PV	D	W	FT		C	381	315	1.2		1475	1400	3.9	3.7	4.7	4.4	12	+2	23	3	
3	77	1.5	PV	D	W	FT		C	370	315	1.2		2370	2270	6.4	6.1	7.5	7.2	22	0	21	1	
3	77	1.5	PV	D	W	FT		C	370	315	1.2		1930	2030	5.2	5.4	6.1	6.3	42	+20	26	10	
4	77	1.5	PV	D	W	FT		C	379	315	1.2		1860	1840	4.9	4.9	5.8	5.7	32	+2	21	12	
5	77	1.5	PV	D	W	FT		C	375		1.2		1950	2015	5.2	5.4	6.2	6.4	29	+4	21	3	
5	77	1.5	PV	D	W	FT		C	375		1.2		1870	1960	5.0	5.2	5.9	6.2	19	+23	25	10	
6	77	1.5	PV	D	W	FT		C	381	315	1.2		1710	1760	4.5	4.6	5.4	5.6	15	+2	22	2	
7	77	1.5	PV	D	W	FT		C	379	315	1.2		1415	1440	3.7	3.8	4.5	4.6	18	+3	21	5	
8	77	1.5	PV	D	W	FT		C	380	315	1.2		1600	1540	4.2	4.1	5.1	4.9	13	+7	23	4	
9	77	1.5	PV	D	W	FT		C	373	315			1870	1970	4.9	5.2	5.8	6.1	22	+3	23	1	
9	77	1.5	PV	D	W	FT		C	373	315			2020	2070	5.3	5.5	6.3	6.5	12	+15	21	0	
10	77	1.5	PV	D	W	FT		C	379	315			1290	1310	3.4	3.5	4.1	4.2	10	+7	22	3	
11	77	1.5	PV	D	W	FT		C	381	315	1.2		1450	1530	3.8	4.0	4.6	4.9	18	-3	20	3	
11	77	1.5	PV	D	W	FT		C	381	315	1.2		1440	1510	3.8	4.0	4.5	4.8	13	+15	26	5	
12	77	1.5	PV	D	W	FT		C	380	315	1.2		1520	1710	4.0	4.5	4.8	5.4	21	+3	22	4	
12	77	1.5	PV	D	W	FT		C	380	315	1.2		1620	1670	4.3	4.4	5.2	5.3	7	+22	28	3	
13	77	1.5	PV	D	W	FT		C	-379	315	1.2		1560	1590	4.1	4.2	5.0	5.0	32	-2	22	5	
13	77	1.5	PV	D	W	FT		C	379	315	1.2		1530	1550	4.2	4.1	5.1	4.9	9	+22	26	2	
14	77	1.5	PV	D	W	FT		C	380	315	1.2		1350	1460	3.6	3.8	4.3	4.5	13	+2	23	[illegible]	
14	77	1.5	PV	D	W	FT		C	380	315	1.2		[illegible]	1380	3.5	3.6	4.3	4.3	8	+17	23	[illegible]	

15	77	1.5	PV	D	W	FT		C	380	315	1.2		1550	1010	4.1	4.8	4.9	5.8	12	+7	21	2
15	77	1.5	PV	D	W	FT		C	380	315	1.2		1520	1500	4.0	4.0	4.8	4.8	9	+16	22	4
16	77	1.5	PV	D	W	FT		C	379	315	1.2		1550	1620	4.1	4.3	4.9	5.2	12	+11	21	2
16	77	1.5	PV	D	W	FT		C	379	315	1.2		1580	1500	4.2	4.0	5.1	4.8	7	+16	23	3
17	77	1.5	PV	D	W	FT		C	378	315	1.2		1930	2010	5.1	5.3	6.1	6.4	11	+11	19	2
18	77	1.5	PV	D	W	FT		C	382	315	1.2		1240	1360	3.3	3.6	4.0	4.3	8	+7	24	3
19	77	1.5	PV	D	W	FT		C	380	315	1.2		1380	1270	3.6	3.3	4.3	4.0	12	+26	24	4
20	77	1.5	PV	D	W	FT		C	380	315	1.2		1920	1870	5.1	4.9	6.1	6.0	18	+10	24	2
21	77	1.5	PV	D	W	FT		C	382	315	1.2		970	930	2.5	2.4	3.1	2.9	8	+12	22	3
22	77	2	PV	D	W	FT		B	415				2000	2080	4.8	5.0			11	+12	23	0
22													1800	1700	4.3	4.1			15	+18	22	0
23	77	2	PV	D	W	FT		B	491				2450	2500	5.0	5.1			30	+1	21	5
23													1860	1690	3.8	3.4			9	+19	19	5
24	77	1	PV	D	W	FT		C	276				1710	1740	6.2	6.3			18	+5	20	1
24	77	1	PV	D	W	FT		C	276				1730	1530	6.3	5.5			6	+16	21	1
25	77	2	PV	D	W	FT		B	419				2370	2290	5.7	5.5			32	+3	21	3
25	77	2	PV	D	W	FT		B	419				2340	2110	5.6	5.0			6	+17	23	2
26	77	2	PV	D	W	FT		B	415				2100	2040	5.1	4.9			16	+7	20	1
26	77	2	PV	D	W	FT		B	415				2080	1940	5.0	4.7			18	+14	18	4

TH

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
1	76	1	PS	R	C			F			0.9				1.2		1.1					1	
2	76	1	PS	R	C			F			0.9				1.2		1.1					1	
3	76	1	PS	R	C			F			0.9				1.5		1.4					1	
4	76	1	PS	D	C			F			1.0				1.7		1.6					1	
5	76	1	PS	D	C			F			1.0				1.0		1.0					1	
6	76	1	PS	D	C			F			1.0				0.8		0.7					1	
7	76	1	PS	D	C			F			1.3				2.0		2.7					2	
8	76	1	PS	D	C			F			1.3				2.2		3.0					2	
9	76	1	PS	D	C			F			1.3				2.1		2.7					2	
0	76	1	PS	R	W			F								2.8						2	
1	76	1.5	S	D	W			F			1.4				4.7		6.5					4	
2	76	1.5	S	D	W			F			1.4				5.1		7.0					4	
3	76	1	PS	D	W			F			1.1				3.1		3.4					3	
4	76	1	PS	D	W			F			1.1				3.1		3.4					3	
5	76	1	PS	D	W			F			1.1				3.8		4.1					3	
6	76	1	PS	D	W			F			1.1				3.8		4.2					3	
7	76	1	PS	D	W			F			1.1				4.1		4.5					3	

TH

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
1	76	1.5	PV	D	W	FT	O	C	374	312	1.2		1930	1594	5.2	4.3	6.2	5.1	20	+1	12	7	
2	75	1	PV	D	W	FT	O	C	289	353	0.9		1730		5.9		4.9		16	+5	20	6	
3	69	1.5	PS	D	W	S	O	C	418	369	1.1		1770		4.2		4.8		29	+10	21	5	
4	69	1.5	PS	D	W	S	O	C	418	369	1.1								39	+9	20	7	
5	69	1	PV	R	W	F	O	F	122	126	1.0		800		6.6		6.4		18	+10	23	8	
6	76	1.5	PV	D	W	F	O	F	215	190	1.1		740		3.5		3.9		7	+18	24	9	

7	76	1.5	SV	D	W	F	O	F	215	190	1.1		740		3.5		3.9		10	+14	22	6	
8	65	1	S	D	W	S	O	C	300	380	0.8		3190		9.9		8.4		34	+9	22	7	
9	76	1	PS	D	W	FT	O	F	285	349	0.8		940		3.4		2.7		6	+19	23	4	
10	76	1	PS	D	W	FT	O	F	285	349	0.8		660		2.4		1.9		3	+18	24	4	
11	76	2	S	D	L	FT	O	C	393	346	1.1		490		1.2		1.4		6	+9	17	<2	
12	74	2	S	D	L	F	O	B	548	244	2.2		850		1.6		3.5			+14	23	<2	
13	77	1	PS	D	W	S	O	F	218	345			1050		4.8		3.0		6	+4	10	4	
14	77	1	PS	D	W	S	O	F	214	180	1.2			465		2.3		2.7	15	+6	11	4	
15	76	1.5	PV	D	W	FT	O	F	457	338	1.4		2106		4.8		6.5		33	+4	22	2	
16	77	1.5	S	D	W	F	O	F	497	308	1.6		1421	1511	2.9	3.0	4.6	4.9	15	+2	10	2	
17	77	1.5	S	D	W	F	O	F	345	243	1.4		1350	1269	3.9	3.7	5.6	5.2	22	+1	22	4	
18	77	1	S	D	W	F	O	F	214	181	1.2		583	598	2.7	2.3	3.2	3.3	9	+7	21	2	
19	76	1	PS	D	W	F	O	C	252	313	0.8		709	690	2.8	2.7	2.3	2.2	19	+2	22	6	
20	77	1.5	PS	D	L	F	I	F	409	286	1.4		2810	2115	6.9	5.2	9.8	9.6	41	+6	20	5	
21	77	1.5	S	D	W	F	O	F	378	281	1.4		1859	1675	4.9	4.4	6.6	6.0	20	+8	21	2	
22	77	1.5	S	D	W	F	O	F	378	281	1.4		1740	1524	4.6	4.0	6.2	5.4	12	+10	22	2	
23	77	1.5	PS	D	W	F	O	F	276	201	1.4		1160	1239	4.2	4.5	5.8	4.5	22	+10	15	4	
24	77	1.5	S	D	W	F	I	F	347	251	1.4		938	919	2.7	2.6	3.7	3.7	10	+11	20	0	
25	77	1.5	PS	R	W	F	O	C	238	228	1.0		2180	2180	9.2	9.2	9.6	9.6	41	+12	21	2	
26	77	1.5	PS	R	W	F	O	C	238	228	1.0		1440	1220	6.1	5.1	6.8	5.7	17	+19	21	6	
27	77	1	S	D	W	F	O	F	327	255	1.3		670	680	2.1	2.1	2.6	2.7	12	+14	18	2	
28	75	1.5	PS	D	W	S	I	F	366	262	1.4		1585	1446	4.3	4.0	6.0	5.5	20	+18	22	2	
29	77	1.5	PS	D	W	FT	O	F	431	273	1.6		912	910	2.1	2.1	3.3	3.3	3	+18	14	2	

UTH

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
1	67	1	PS	D	W	S		C	280				2505		9.0					-1			
2	67	1	PS	D	W	S		C	280				1560		5.6					+3			
3	67	1	PS	L	W	S		C	260				4030		15.5					+5			
4	67	1	PS	L	W	S		C	260				3430		13.2					+5			
5	75	1	S	D	W	S		B	260				2010		7.7					-2			
6	75	2	S	D	W	S		B	335				2340		7.0					+1			
7	75	2	S	D	W	S		B	335				2135		6.4					+1			
8	75	2	S	D	W	S		B	335				2210		6.6					+8			
9	70	1	S	D	W	S		C	300				825		2.8					+2			
0	70	1	S	D	W	S		C	300				775		2.6					+2			

P

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
1	72	1	PS	R	W		I	F	300				1205	1425	4.0	4.8				-4	19	0	
2	76	2	PS	D	L		I	C	396					550		1.4				-1	2	3	
3	76	1.5	PS	D	W		I	F	293				880	830	3.0	2.8				-2	20	3	
3													1010	985	3.5	3.4				-2	20	3	
3													800		2.7					-2	20	3	
3													714		2.4					-2	20	3	
4	77	1.5	PS	L	W		B	F	317				1060	817	2.3	2.7				-3	21	2	
5	77	1.5	PS	L	W		B	F	317				1130	1040	3.6	3.3				+1	20	2	

6									662	633	2.1	2.0	+1	18	2
7	77	1.5	PS	L	W	B	F	317	1235	1070	3.9	3.4	+1	19	2
8	77	1.5	PS	D	W	B	F	343	1530	1450	4.5	4.3	-1	18	1
9	77	1.5	PS	D	W	B	F	340	1360	1405	4.0	4.1	+2	17	1
10	77	1.5	PS	D	W	B	F	340							
11	77	1.5	PS	D	W	B	F	343	1410	1290	4.1	3.8	+2	17	1
12	77	1.5	PS	D	W	B	F	346	1280	1250	3.7	3.6	+2	17	1
13	77	1.5	PS	D	W	B	F	340	1290	1240	3.8	3.6	+2	16	1
13									1010	990	3.0	2.9	+2	16	1
14	77	1.5	PS	L	W	B	F	317	1170	1085	3.7	3.4	+14	21	2
15	77	1.5	PS	L	W	B	F	317	950	720	3.0	2.3	+14	21	2
16	77	1.5	PS	L	W	B	F	403	1460	1370	3.6	3.4	+15	22	2
17	77	1.5	PS	L	W	B	F	408	1410	1360	3.5	3.3	+15	18	2
17									1410	1360	3.5	3.3	+15	18	2
18	76	1.5	PS	L	W	B	F	324	1390	1360	4.3	4.2	+16	18	2
22	69	4	PS		W	I	F	215	220	610	1.1	2.8	+15	20	0
23	77			R	W			580		1960		3.4	+20	19	1
24	73	1.5	S		W	I	F	309	1240	1180	4.0	3.8	+13	20	1
5		1			W		F	274	1280	1020	4.7	3.7	+23	23	1
6		1.5			W		F	397	1500	1290	3.8	3.2	+23	23	1
7	77	1	PS		W	O	F	304	1260	1050	4.1	3.5	+24	23	1
8	74	1	S		W	O	B	432	1340	1170	3.1	2.7	+20	20	
9	77		S		W	O	B	476	1500	1420	3.2	3.0	+18	26	2
9									1060	1100	2.2	2.3	+18	26	2
0	68		P		W	B	B	610	2020	1850	3.3	3.0	+15	21	0
1	69	1	S		W	I	B	538	2300	1880	4.3	3.5	+17	20	2
2		2		R	W		F	332	820	760	2.5	2.3	+20	21	3
3	77	1.5	P	D	W	O	F	390	1800	1440	4.6	3.7	+14	20	3

PA

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
1	76	1.5	S	D	W	F		F	440				1630		3.7								
2	76	1.5	S	D	W	F		F	440				1410		3.2								
3	76	1.5	S	D	W	F		F	440				1450		3.3								
4	76	1.5	S	D	W	F		F	440				1500		3.4								
5	76	1	S	D	W	F		F	259				1010		3.9								
6	76	1	S	D	W	F		F	259				1399		5.4								
7	76	1	S	D	W	F		F	259				1166		4.5								
8	76	1	S	D	W	F		F	259				1554		6.0								
9	76	1.5	S	D	W	F		F	380					1672		4.4							
0	76	1	S	D	W	F		F	278				584		2.1								
1	76	1	S	D	W	F		F	278				778		2.8								
2	76	1	S	D	W	F		F	353				1694		4.8								
3	76	1	S	D	W	F		F	353				1730		4.9								
4	76	1	S	D	W	F		F	353				1624		4.6								
5	76	1	S	D	W	F		F	366				1647		4.5								
6	76	1	S	D	W	F		F	366				1720		4.7								
7	76	1	S	D	W	F		F	366				1720		4.7								
8	76	1	S	D	W	F		F	286				944		3.3								
9	76	1	S	D	W	F		F	286				887		3.1								
0	76	1.5	S	D	W	F		F	450				1215		2.7								
1	76	1.5	S	D	W	F		F	355				994		2.8								
2	76	1.5	S	D	W	F		F	470				1692		3.6								
3	76	1	S	D	W	F		F	148				533		3.6								
4	76	1.5	S	D	W	F		F	213				1693		7.9								
	76	1.5	S	D	W	F		F	213				1598		7.5								

26	76	2	S	D	W	F	F	244	1220		5.0	
27	76	2	S	D	W	F	F	244	1269		5.2	
28	76	1.5	S	D	W	F	F	396	1346		3.4	
29	76	1.5	S	D	W	F	F	396	1188		3.0	
30	76	1	S	D	W	F	F	146	496		3.4	
31	76	2	S	D	W	F	F	230	1244		5.4	
32	76	2	S	D	W	F	F	230	1405		6.1	
33	76	1.5	S	D	W	F	F	342	1163		3.4	
34	76	1.5	S	D	W	F	F	342	1163		3.4	
35	76	1.5	S	D	W	F	F	348	1044		3.0	
36	76	1.5	S	D	W	F	F	348	1148		3.3	
37	76	1.5	S	D	W	F	F	348	940		2.7	
38	76	1.5	S	D	W	F	F	456	1140		2.5	
39	76	1.5	S	D	W	F	F	456	1322		2.9	
40	76	1	PS	D	W	F	F	281	731		2.6	
41	76	1.5	PS	D	W	F	F	331	563			1.7
42	76	1.5	PS	D	W	F	F	331	596		1.8	
43	76	1.5	PS	D	W	F	F	331	530		1.6	
44	76	1	PS	D	W	F	F	200	380		1.9	
45	76	1.5	PS	D	W	F	F	386	1119		2.9	
46	76	1.5	PS	D	W	F	F	386	1235		3.2	
47	76	1.5	PS	D	W	F	F	386	926		2.4	
48	76	1.5	PS	D	W	F	F	282		846		3.0
49	76	1.5	PS	D	W	F	F	282		959		3.4
50	76	1.5	PS	D	W	F	F	373		1194		3.2
51	76	1.5	PS	D	W	F	F	373		1231		3.3
52	76	1.5	PS	D	W	F	F	331		927		2.8
53	76	1.5	PS	D	W	F	F	331		927		2.8
54	76	1.5	PS	D	W	F	F	386		888		2.3
55	76	1	PS	D	W	F	F	230	391		1.7	
56	76	1	PS	D	W	F	F	230	414		1.8	
57	76	1	PS	D	W	F	F	230	391		1.7	
58	76	1	PS	D	W	F	F	230	483		2.1	
59	76	1.5	PS	D	W	F	F	374	748		2.0	
60	76	1.5	PS	D	W	F	F	374	785		2.1	
61	76	1.5	PS	D	W	F	F	288	576		2.0	
62	76	1.5	PS	D	W	F	F	288	605		2.1	
63	76	2	PS	D	W	F	B	319	479		1.5	
64	76	2	PS	D	W	F	B	319	446		1.4	
65	76	2	PS	D	W	F	B	402	603		1.5	
66	76	2	PS	D	W	F	B	402	563		1.4	
67	76	1.5	S	R	W	F	F	223	1160		5.2	
68	76	1	S	R	W	F	F	190	589		3.1	
69	76	1	S	R	W	F	F	190	760		4.0	
70	76	1.5	S	R	W	F	F	254	711		2.8	
71	76	1.5	S	R	W	F	F	203	731		3.6	
72	76	1.5	S	R	W	F	F	203	832		4.1	
73	76	1	S	R	W	F	F	110	451		4.1	
74	76	1.5	PS	R	W	F	F	281	618		2.2	
75	76	1.5	PS	R	W	F	F	281	646		2.3	
76	76	1.5	PS	R	W	F	F	281	618		2.2	
77	76	2	PS	R	W	F	F	404	606		1.5	
78	76	2	PS	R	W	F	F	404	606		1.5	

BLOCK OF FLATS

KTH

1	65	S				17	2
2	40	S	B	S	1.6		1
3	40	S	B	S	2.8		1
4	40	S	B	S	1.5		1
5	40	S	B	S	3.4		1
6	40	S	B	S	1.2		1
7	40	S	B	S	1.4		1
8	40	S	B	S	1.5		1
9	40	S	B	S	1.2		1
10		PS	C		1.1		2
11		PS	C		1.1		2
12		PS	C		0.8		3
13		S	M		0.8		3
14		S	M		0.7		3
15		S	M		0.7		
16		S	M		0.5		
17		S	M		0.8		

SP

18	69	6	PS	I	B	198	485	470	2.4	2.4	+15	18	0
19	69	6	PS	I	B	198	510	370	2.6	1.9	+15	18	0
20	69	6	PS	I	B	198	450	2.3	2.26	1.9	+15	18	0
21	69	4	PS	I	B	215	220	610	1.1	2.8	+15	20	0

BPA

22		PS	C	257	1.5
23		RS	C	257	1.1
24		PS	C	257	0.8
25	2			238	0.3
26	2			238	0.4

TYRENS

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
1									386	250	1.5		1100		2.9		4.4						
1															1.6		2.5						
2	65	2	S	D	W			B	577	591	1.0		2600		4.5		4.4						
3	?	1.5	S	D	W	S		C	892	676	1.3		5000		5.6		7.4						
4	53	3	PS	D	W	S		B	400	288	1.4		1325		3.3		4.6						
5	65	2	S	D	W	S		B	400	400	1.0		1560		3.9		3.9						