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Air Transfer in Residential Buildings

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AIR TRANSFER IN RESIDENTIAL BUILDINGS

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1. Introduction

In the Netherlands the calculation of heating requirements is based on German standard DIN-4701 with modifications. The Netherlands Standards Commission for "Calculation of The Heating Requirements of Buildings" is at present occupied with the preparation of a Netherlands Standard.

One of the components entering into the calculation is the determination of ventilation heating requirements. The starting point taken is the transfer of air by the wind through the chinks in windows which can be opened. However, in practice it is found that in many cases the air transfer which actually occurs is greater than that through the chinks. In order to investigate the air transfers on which the calculation must be based, the Commission has caused measurements of air transfers in houses to be carried out.

2. Method of Measurement

The measuring method used was the so-called "pumping up (inflation) method" which does not require much apparatus and can be performed in a very simple manner, even in inhabited residences (Ref 1).

Comparative measurements using different methods both in the Netherlands and abroad have shown that the results of the method adopted are fully reliable in practice. The measurements were carried out apartment by apartment, selecting the living room and one bedroom, since the calculation of heating requirements is performed on an apartment basis. When a complete housing unit is thus dealt with, this has the advantage of making it easier to detect any cracks which develop subsequently.

The investigation was carried out in apartments and single-family houses which were inhabited in a number of instances. Some of them were new buildings, while others were of earlier date (in certain cases renovated).

For the purpose of the measurements an adjustable door was placed in one of the door openings of the room to be investigated. The adjustable door consisted of two moveable, overlapping leaves which could be adapted to any door width found (Fig. 1). One of the leaves contained an opening to which a fan could be connected via a hose. The fan had a controlled-speed electric motor.

The fan set up an excess pressure in the room as compared with the outside atmosphere and had to inject a certain quantity of air to maintain a selected pressure. The airflow was measured using a specially adapted fan-wheel anemometer.

The investigation was carried out in circumstances in which the variable wind exerted a negligible influence on the measurements. The airflow was measured with different values of excess pressure in the following circumstances successively:

1. all the cracks inthe room which were expected to admit air were sealed with adhesive tape, including wall-mounted contact plugs and any ventilation grills and ducts for flue gas and/or ventilation which happened to be present.
2. the chinks of windows which could be opened were not sealed
3. the chinks and joints between the glass and the window frame were not sealed
4. the chinks and the joints between the glass and the window frame and also the joints between the window frame and the facade construction were not sealed.

In this context the terms "chinks" and "joint" are in accordance with the definitions which appear in NEN 3660 (Ref. 2), i.e.:

a chink is the space between members adapted to be moved in relation to one another

a joint is the space between members which are not adapted to be moved in relation to one another.

Excess pressure was used exclusively for the measurements in the room, since both Netherlands and foreign investigations show that in practice the difference in airflow as between excess pressure and negative pressure is negligible.

3. Processing of the measuring results

The relation between the airflow and the pressure difference for chinks and joints can be represented by $V = C\ell\Delta p^{1/n}$

where: V = airflow (m^3/sec)

C = air penetration of chink or joint - i.e. the air flow per m of chink length with a pressure difference of 1 Pa ($m^3 \cdot m^{\frac{1}{2}}.sec^{\frac{1}{2}}.Pa^{-1/n}$)

ℓ = chink or joint length (m)

Δp = pressure difference (Pa)

n = exponent (between 1 and 2) (⁻)

The values of C and n must be derived, by means of double logarithmic paper or the method of least squares, from the differences between airflows in the situations set forth under 2, the adjusted values of the pressure difference and the measured chink and joint lengths respectively. From the measurements in situation 1 (all visible cracks sealed) the $C\ell$ value can be derived from the invisible cracks. To obtain an idea of the air penetration of the paper adhesive strip used, in one room a comparative measurement was carried out with an aluminium adhesive strip, on the assumption that the latter has an air penetration which is negligible in practice.

4. Results of the measurements

Attention is drawn to Ref. 3 for a detailed report on the investigation. A comparison between paper and aluminium adhesive strips respectively shows that the former has a C value of 0.002×10^{-3} $m^3/m.sec.$ with a pressure difference of 1 Pa and a n value of 1.56.

The influence of this on the other measuring results is negligible. The measuring results of the C and n values of the chinks and joints are shown in Table 1 for the windows and outer doors of the living rooms and in Table 2 for those of the bedrooms.

The C values of all the chinks investigated are presented in the form of a histogram (Fig. 2).

If the n values of the chinks and joints investigated derived from the measurements are examined room by room, we find that in the majority of cases the differences between the values are negligible. For this reason the mean value was used for each room. In the case of the chinks the C value varies from 0.007 to 0.972, while in the case of the joints it varies from 0 to 0.621 ($x10^{-3}m^3/m.sec.Pa^{1/n^1}$), the joints between the glass and the window frame generally showing relatively low values. The C values are low in the case of metal or plastic frames; in frames with draught-proofing high C values occur as a result of careless installation (living rooms of nos. 36 and 37 and bedrooms of nos. 34,35, 39, 43 and 46).

The n value lies between 1.21 and 1.91, with a mean value of 1.55. In Situation 1 (everything sealed) the airflow is included in the Tables as a residual value which is expressed as a percentage of the airflow in the situation with nothing sealed.

In the majority of cases this percentage is lower than 45%. Air transfer will occur through invisible joints and the like, and also through the materials of which the walls, floor and ceiling are made.

The higher percentages in the living rooms must be explained bythe use of porous MBI blocks (nos. 29 and 30), ceiling panels and the like. In the case of the bedrooms there are a number of attics with roof monitors, ceiling or roof panels, partitions acting as walls, and the like (nos. 35, 42, 43)

Table 1 - See page 7

Table 1
C and n values for the living rooms

		$10^3.C\ m^3/m.sec.Pa^{1/n}$				
Type of building		chinks		joints	residual value 1)	
no	n	window	door	glass/frame	frame/wall	%
apartments						
21	1.29	0.177		0.042	0.289	22
	1.29	0.196	0.201	0.046	0.438	
22	1.44	0.302		0.032	0.067	32
	1.44	0.134		0.046	0	
23	1.56	0.268	0.019	0.003	0.011	37
	1.56			0.035	0.037	
25	1.62	0.049		0.018	0.119	61
26	1.80	0.142	0.026	0.046	0.047	22
27	1.48	0.007	0.963	0	0.036	22
29	1.21	0.064		0.003	0.014	56
30		not completely investigated (porous walls)				
31	1.49	0.434		0.097		34
	1.49	0.464				
32	1.73	0.424		0.003	0.003	37
33	1.66	0.135		0.013	0.483	72
single-family dwellings						
20	1.76	0.972		0.046	0.317	24
24	1.52	0.035		0.019	0.313	28
28	1.72	0.183		0.006	0.268	33
34	1.23	0.037	0.179	0.0004	0.003	18
35	1.33	0.045		0.0001	0.006	55
36	1.91	0.393	0.226	0	0.024	
37	1.57	0.250	0.069	0.009	0.031	8
38	1.76	0.115	0.175	0.008	0.015	62
39	1.36		0.095	0.064		59
40	1.36	0.029	0.090	0.008	0.133	39
				0.010		
41	1.54	0.180	0.236	0.006	0.057	60
	1.54	0.127				
42	1.53	0.032		0.010	0.038	76
43	1.55	0.067		0.007	0.165	51

1) residual value in % of the quantity of air if there is no sealing.

Table 2
C and n values for the living rooms

		$10^3 C$ $m^3/m.sec.Pa^{1/n}$				
Type of building		chinks		joints	residual value 1)	
nb	n	window	door	glass/frame	frame/wall	%
apartments						
21	1.56	0.171		0.095	0.366	8
22	1.52	0.161		0.028	0.133	26
23	1.74	0.542	1.112	0.011	0.028	15
25	1.63		0.149	0.013	0.047	62
26	1.48		0.024	0.007	0.025	44
27	1.64	0.036		0.021	0.110	33
44	1.37	0.014				45
45	1.60	0.923		0	0.042	26
46	1.62	0.693		0.010	0.121	
single-family dwellings						
24	1.74	0.818		0.012	0.039	26
34	1.76	0.392		0	0.037	33
35	1.62	0.320		0.007	0.031	10
	1.65	0.660		0	0.225	
36	1.36	0.137		0	0.012	46
37	1.39	0.054		0	0.009	60
39	1.61	0.562		0.058	0.066	20
	1.45	0.085		0.137	0.437	12
40	1.77	0.190		0.057	0.272	32
41	1.61	0.205		0	0.621	50
42	1.65	0.204		0	0.347	11
43	1.67	0.421		0.011	0.342	71

1) residual value in % of the quantity of air if there is no sealing

5. Comparison with the values nowadays used

Table 3 gives a survey of the values of C and n measured by TNO, the calculation values presented by the TVVL and the ACI, and the values discovered by the Standards Commission in the investigation described in this Paper.

For the individual wooden window frames and doors without draught-proofing the C value in about 31% of the measured values is seen to be higher than that given by the TVVL (according to (Ref.4) 0.36 x 10^{-3}) and in about 20% higher than the upper limit according to the ACI (for Ref. 5 - 0.48 x 10^{-3}).

If draught-proofing is provided, the living rooms satisfy the usual values; in the case of the bedrooms the values are generally higher.

In the case of aluminium window frames (a total of 5 items) there is one construction which has a higher value than the one normally used.

Table 3

Survey of C and n values of chinks

	10^3.C				n value	
construction	TNO	TVVL	ACI	Standards Commission	TNO	Standards Commission
wood/plastic						
individual windows and doors	0.35-0.53	0.36	0.36-0.48	0.04-0.46	1.7	1.5 - 1.7
ditto with draught-proofing strip		0.15	0.18-0.42	0.12-0.96		1 - 2
sliding windows	0.10-0.22		0.18		1.5	
double-glazed windows	0.17-0.44	0.24			1.6	
ditto with draught-proofing strip		0.12				
steel/non ferrous						
individual windows and doors	0.08-0.17	0.18	0.09-0.18	0-0.34	1.5	1 - 1.8
ditto with draught-proofing strip		0.12				
sliding windows with draught-proofing strip				0.02-0.03		1.4
double-glazed windows		0.15	0.07			
ditto with draught-proofing strip		0.09				

6. Testing air transfer to NEN 3661

NEN 3661 (Ref. 6) lays down for the quality of chinks a maximum air transfer value of 5ℓ/m.sec. Testing pressures are laid down at which this maximum transfer may occur, in dependence on the location of the building (on the coast or inland) and its height. The maximum quantity laid down for joints is 0.05ℓ/m.sec.)

Although the Standard is a Product Standard, so that data from this Standard may not be used as a starting point for the calculation of heating requirements, the measuring results are nevertheless comparable. For a testing pressure of 150 Pa, applicable to a building with a maximum height of 15m situated inland, the air transfers through chinks and joints were calculated from the measured C and n values and are set forth in Tables 4 and 5 for living rooms and bedrooms respectively. Of the chinks only 59% satisfy the Standard, which is met by only 1 of the 24 joints between the window frame and the frontage construction. These Tables also show whether the windows and doors have draught-proofing or not.

Before the investigation described in this Paper, a preliminary investigation had been carried out which was mainly limited to measurements of chinks and joints (Ref. 3).

The result revealed that only about 66% of the chinks investigated satisfied the Standard, which was met by only about 34% of the joints between the window frame and the frontage construction.

If the results of the two investigations are combined, 61% of the chinks meet the Standard, and 23% of the joints.

To avoid misunderstandings in the use of the Table as regards classification and the associated testing pressures to NEN 3661 the following must be noted.
The Standard lays down requirements for the quality of the windows, but not for the airflow which must be used in the calculation of the ventilation heating requirements. For windows which according to the Manufacturer meet a certain category of the Standard and are fitted in a building of a different location and height category, the Table is decisive as to whether such a window may or may not be used in the building.

Table 4 - see Page 12

Table 4

Air transfer per m with Δ p = 150 Pa in l/sec for living rooms

dwelling	chinks			joints	
no	window	door	draught-proofing	glass/window frame	window frame/ wall
20	16.8		-	0.79	5.46
21	8.6		+	2.0	14.1
	9.5	9.8	+	2.2	21.3
22	9.8		+	1.0	2.2
	4.3x		+	1.5	
23	6.7	0.5x	-	0.07	0.3
				0.9	0.9
24	0.9x		-	0.5	8.5
25	1.1x		+	0.4	2.6
26	2.3x	0.4x	+	0.7	0.8
27	0.2x	28.4	-	0 x	1.1
28	3.4x		-	0.11	4.9
29	4.0x		+	0.19	0.9
31	12.5		-	2.8	
	13.4		-		
32	5.7		-	0.05 x	0.05x
33	2.8x		-	0.27	9.9
34	2.2x		+	0.02 x	0.18
35	1.9x		+	0.004x	0.26
36	5.4	3.1x	+	0 x	0.33
37	6.1	1.7x	+	0.22	0.75
38	2.0x	3.0x	+	0.14	0.26
39		3.8x	+	2.5	
40	1.2x	3.6x	+	0.32	5.3
				0.4	
41	4.7x	6.1	+	0.16	1.5
	3.3x		+		
42	0.8x		+	0.3	1.0
43	1.7x		+	0.18	4.2
				11	9.7

x meets NEN 3661

Table 5

Air transfer per m with Δp = 150 Pa in 1/sec for bedrooms

dwelling	chinks			joints	
no.	window	door	draught-proofing	glass/window frame	window frame/ wall
12	4.2x		+	1.4	9.1
22	4.3x		+	0.8	3.6
32	4.6	19.8	-	0.2	0.5
42	14.6		-	0.2	0.7
52		3.2x	+	0.3	1.0
62		0.7x	+	0.2	0.7
72	0.8x		+	0.4	2.3
43	6.8		+	0 x	0.6
53	7.1		+	0.2	0.7
	13.8	roof monitor	+	0 x	4.7
63	5.5		+	0 x	0.5
73	2.0x		+	0 x	0.3
93	12.6		+	1.3	1.5
	2.7x		+	4.3	13.8
04	3.2x		+	1.0	4.6
14	4.6x		+	0 x	14.0
24	4.3x		+	0 x	7.2
34	8.5	attic	+	0.2	6.9
44	0.5x		+		
54	21.1		-	0 x	1.0
64	15.3		+	0.2	2.7

x meets NEN 3661

7. Testing air transfer to NEN 1087

NEN 1087 (Ref. 7) states, as regards the quantity of ventilation air (outside air) for the various spaces, minimum values with the lowest values of wind speed and the difference between the outside and room temperature at which that quantity must still be reached.

The measurements indicate that in the majority of cases the air transfer solely through the chinks does not meet the minimum requirements for living rooms nor in a large number of cases is it met even by the chinks and joints taken together. Uncontrollable transfer through the chinks and joints must be reduced to a minimum; this necessitates the use of self-regulating grills or regulatable ventilation facilities in accordance with the instructions set forth in NPR 1088 (Ref. 8).

8. Residual value of air transfer

Even if all the cracks observable are sealed, nevertheless air transfer occurs (residual value). Since building materials are not air-tight, it must be assumed that transfer will take place through them. The measured values are compared with the values given in the Literature.

The details given in the Literature can be sub-divided into:

a air transfer through the outer wall, the chinks and joints together, referred to 1 m^2 of frontage surface (outer wall + windows) and occurring with a pressure difference of 200 Pa

b air transfer through the outer wall alone, referred to 1 m^2 of outer wall surface (i.e. excluding the windows) with a number of pressure differences. These apply to individual kinds of materials.

Ad. a Column 2 of Table 6 shows the air transfer, excluding transfer via wall-mounted contact plugs, ventilating grills and the like, for the living rooms with a pressure difference of 1 Pa and expressed in 10^3.Cℓ m^3/sec. Column 3 gives these values per m^2 of front surface (including window surface).

The Literature (Ref. 9) states that with a pressure difference of 200 Pa, this air transfer, referred to the total frontage (including windows), lies between 0.8 and 7.5 x $10^{-3} m^3/m^2$/sec. The air transfers discovered from the measurements (Column 3) are converted to those for a pressure difference of 200 Pa by using the appropriate n values (Column 1) and included in Column 4. This shows that only 7 cases (33% of all cases) fall within the stated limits.

Table 6 - see page 16

Table 6

Air transfer in living rooms

			10^3.C.1				
		for the frontage including windows				for all walls, floors and ceilings excluding windows	
		per m^2 of frontage surface			residual value	per m^2 of wall surface	
apartment no	n (1)	Δp = Pa (2)	Δp=1 Pa (3)	Δp=200 Pa (4)	Δp=1 Pa (5)	Δp=1 Pa (6)	Δp=100 Pa (7)
21	1.29	15.219	2.153	130.9	3.546		
22	1.44	15.443	2.184	86.5	4.886		
23	1.56	7.609	0.236	7.05	4.001	0.038	0.728
24	1.52	5.632	0.575	18.77	1.583	0.026	0.538
25	1.62	6.484	0.675	17.77	4.056	0.030	0.515
26	1.80	5.142	0.381	7.23	1.274	0.014	0.181
27	1.48	10.105	0.632	22.67	2.251	0.031	0.696
31	1.49	10.862	0.597	20.91	3.708	0.040	0.880
32	1.73	4.856	0.382	8.17	1.777	0.026	0.372
33	1.66	25.483	1.722	41.90	18.347		
34	1.23	2.322	0.084	6.24	0.718		
35	1.33	1.299	0.059	3.17	0.785		
36	1.91	9.253	0.436	6.99	5.566	0.034	0.379
37	1.57	4.961	0.234	6.84	2.310	0.014	0.263
38	1.76	6.550	0.289	5.87	4.217	0.026	0.356
39	1.36	10.487	0.400	19.68	6.215	0.040	1.182
40	1.36	11.464	0.210	10.33	6.974	0.035	1.034
41	1.54	9.523	0.526	16.41	5.826		
42	1.53	4.894	0.295	9.41	3.917		
43	1.55	10.814	0.315	9.61	5.836		

However, it must also be expected that, when the measurements were taken, air transfer also took place through the inside walls, the floor and the ceiling. For this reason, when considering the air transfer through the outer wall per unit of surface, account has been taken of the surface of the inside walls, floor and ceiling in the following manner. The air transfer in Situation 1, in which all the cracks observed are sealed (Column 5), that is, the residual value, converted into values per m^2 of wall surface by dividing by the sum of surfaces of the outer wall, inner walls, floor and ceiling. This gives the values shown in Column 6. They apply to a pressure difference of 1 Pa. These values, plus the air transfer through chinks and joints calculated per m^2 of frontage surface, are reconverted to transfers with a pressure difference of 200 Pa. Now it is found that 10 cases (50% of the total) lie within the limits. (The values are not included in the Table).

ad. b The air transfer discussed under ad. a is partly caused by the transfer through chinks and joints. Due to the traditional methods of building in the Netherlands, the latter may be higher than abroad; this is known to be the fact in comparison with German windows. Transfer through the outer walls must therefore also be considered separately for the purpose of better comparison with foreign values. Ref. 10 gives values of air transfers through masonry. With a pressure difference of 100 Pa, the following values apply per m^2 of outside wall surface:

for bare masonry

$2.37 \times 10^{-3} m^3/m^2.sec$

for masonry with a layer of plaster

$0.022 \times 10^{-3} m^3/m^2.sec.$

The values calculated from Column 6 (1 Pa) with $\Delta p = 100$ Pa (Column 7) lie between these values.

9. Conclusions

1 The proportion of air transfer through chinks forms a relatively small part of the total air transfer.

Investigations carried out in Belgium (Ref. 11) produce a similar result (maximum proportion about 40% of the total). If in future there is a considerable improvement in the finishing of chinks, joints and other cracks in the frontage, it will be necessary to use controllable ventilation facilities to meet the requirements of NEN 1087.

2 The measured air transfers apply to an excess pressure in the room in relation to the outside atmosphere. Other investigations have shown that the difference in transfer as between excess pressure and negative pressure respectively is negligible in practice.

3 The investigation shows that no appreciable difference can be observed in air transfers in the living rooms of apartments on the oneehand and single-family houses on the other. This also applies to the bedrooms investigated, in cases in which there was no attic.

The investigation included no rooms in which air transfer was partly determined by the sealing-tightness at the place where the roof joined the frontage. It is known from practice that this connection shows considerable air leakages. An attempt must be made to produce standardised elements for this connection which can be very simply incorporated in the building to produce a satisfactory seal.

4 In certain buildings provision is made to reduce the penetration of rain water along the window frames and/or air transfer through the joints between the window frames and the frontage construction.

In nos. 33 and 34 the window frames have hard plastic flaps attached to the masonry in the crack; this produces satisfactory results as regards air transfer. Otherwise only the joints in the case of no 34 meet the requirements of NEN 3661.

In the case of nos. 36, 37 and 38 the laths with cracks are furnished with draught-proofing strip. The results are not as satisfactory as with the flaps, but they are a considerable improvement over constructions without any provision. However, the constructions with the provision stated do not yet meet the requirements of NEN 3661.

Table 7

C and n values of chinks observed

Values of $10^3.C$	
Construction: wood/plastic	
Individual windows and doors	0.45
Ditto with draught-proofing strip	0.20
Sliding windows	0.18
Double-glazed windows	0.24
Ditto with draught-proofing strip	0.12

Table 7 (cont)

C and n values of chinks observed	
Values of 10^3.C	
Construction: steel/non-ferrous	
Individual windows and doors	0.20
Ditto with draught-proofing strip	0.12
Sliding windows with draught-proofing strip	0.05
Double-glazed windows	0.15
Ditto with draught-proofing strip	0.09

In all cases a n value of 1.5

10. Values to be adopted

Air transfer through a frontage is made up of 3 components, namely air transfer through

a chinks

b joints between glass and window frame and between window frame and frontage construction

c the outside wall

On the basis of the investigation described, the Standards Commission has decided to include the following in the Standard:

ad. a The C values given in Table 7 should be used for the chinks

ad. b C values of 0.05 x 10^{-3} m^3/m.sec $Pa^{1/n}$ should be taken for joints between glass and window frame and of 0.04 x 10^{-3} for joints between window frame and frontage construction. Despite the low C values of the joints between glass and window frame due to the considerable joint lengths, air transfer through such joints may amount to 25 - 50% of that through the joints between window frame and frontage construction and must, therefore, not be ignored. Consideration may be given, for example, to "glass rods".

ad.c For the outside wall construction it is assumed that $C\ell = 0.04 \times 10^{-3} m^3/m^2.sec$ (per m^2 of outside wall surface, excluding window surface).

In all cases n = 1.5 can be taken as axiomatic. The Standards Commission is to give further consideration to the pressure difference to be used in calculations.

11. Bibliography

(1) SBR report B2-17. Meetmethode voor de luchdoorlatendheid van woningen, toepassing en consequenties. (Method of measuring the air penetration of apartments; application and consequences). Stichting Bouwresearch Rotterdam 1981.

(2) NEN 3660. Ramen. Luchtdoorlatendheid, waterdichtheid, stijfheid en sterkte. (Air penetration, water-tightness, rigidity and strength). Testing methods 1975.

(3) ISSO research report No. 2. Metingen ten aanzien van luchttransporten in woningen. (Measurements of air transfer in apartments). ISSO Rotterdam 1981.

(4) ISSO Publication 4. Ontwerptechnische kwaliteitseisen voor warmwaterverwarminginstallaties. (Draft of technical quality requirements for water heating installations).

(5) Becque. Berekening transmissieverlies. (Calculation of transmission losses). Verwarming en Ventilatie 1972, No. 8, pp 512 et seq.

(6) NEN 3661. Ramen. Luchtdoorlatendheid, waterdichtheid, stijfheid en sterkte. (Air penetration, water-tightness, rigidity and strength). Requirements.

(7) NEN 1087. Ventilatie van woongebouwen. (Ventilation of residential buildings). Requirements 1975.

(8) NPR 1088. Ventilatie van woongebouwen. (Ventilation of residential buildings). Practical directives 1975.

(9) BREI Paper IP 14/79. Thorogood. Resistance to air flow through external walls. July 1979.

(10) ASHRAE. Handbook of fundamentals 1977, chapter 21.

(11) Nusgens, Guillaume. Natuurlijke ventilatie van eengezinswoningen. (Natural ventilation of single-family dwellings). WTCB Journal, No. 1, March 1980.

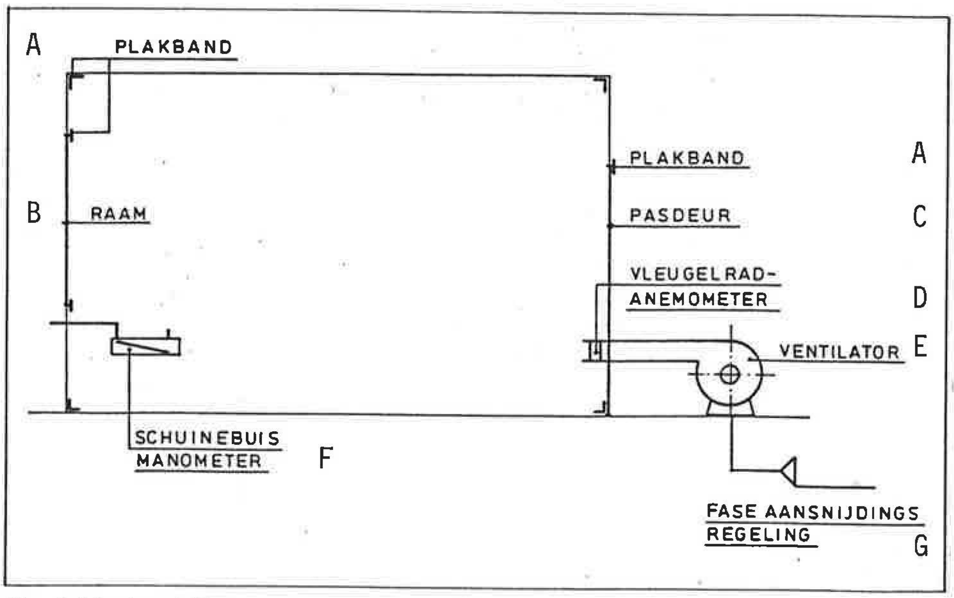

Fig. 1 Meetopstelling

Caption of Fig. 1 Measuring arrangement

Wording: A = adhesive tape; B = window; C = adjustable door; D = fan-wheel anemometer; E = fan; F = inclined tube manometer; G = gate adjustment phase.

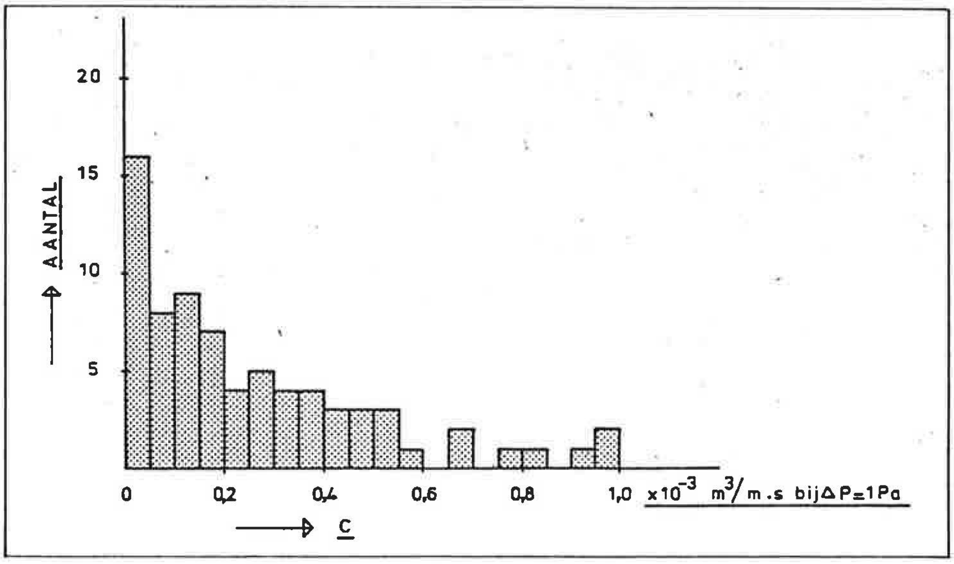

Fig. 2 Histogram voor C-waarden van de onderzochte kieren

Caption of Fig. 2: Histogram of C values of the chinks investigated.

Ordinate: = quantity; abscissa = (1.0) x $10^{-3} m^3$/m.sec. at $\Delta P = 1$ Pa.