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THE MOISTURE LOAD IN DWELLINGS AS A FUNCTION OF THE LAYOUT OF THE ROOMS SHOWN BY GROUND PLANS

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SYNOPSIS

Measurements in some dwellings show differences of the absolute humidity as a function of the kind of ventilation (only natural or mechanical exhaust air or balanced ventilation) and the position of the single rooms, especially of the bedrooms. Therefore is investigated into the expected moisture transport in two different ground plans.

The main humidity production is in the kitchen and bathroom. If kitchen and bathroom are on the outer side, the dwelling is loaded with this moisture through the main wind direction. This counts especially for bedrooms, because through this moisture load on the day there can appear peaks in the night.

By the right layout of these rooms in the ground plan you can relieve the dwelling of moisture load as far as possible.

If kitchen and bathroom are in the interior of the dwelling, only the effectiveness of the natural or mechanical exhaust air counts for the transport of moisture. By the right construction of the exhaust air, this air can reduce the moisture even in the living- and bedrooms.

1. INTRODUCTION

The National German building code only say that a dwelling`s ventilation has at least to be guaranteed by natural cross ventilation. In fact, also before this code was set up, there has always been a regard for dwelling ventilation in the way that every room of an apartment could be provided with supply air coming through opened or not airtight closed windows or out of other rooms in the dwelling, respectively.

The last two decades show a development in building construction favorizing smaller dwellings, especially apartments of a size of 30 - 40 m². Additionally those apartment buildings were economically constructed as blocks with ground plans of depth up to 15 m. In the interior of the dwelling windowless sanitary rooms like bathroom and W.C. are situated. Consequently, first we had to accept bathroom and toilet as interior and windowless rooms; finally - with the late edition of the building code - we have come to kitchens, situated in the dwelling`s centre and without windows, too.

However, these rooms now being windowless an additional ventilation according to the building code becomes necessary. This code, written down in DIN 18 017, describes a shaft ventilation with natural air draught or an additional supporting ventilator.

The efficiency of this system for the interior rooms depends on:

- a sufficient natural air draught trough the shaft
- the operation time of the possibly installed ventilator in the day`s course
- the amount of air which is additionally provided as supply air out of these rooms which still have natural cross ventilation

Experience shows that those shaft ventilation systems - in possible combination with ventilator - for the interior rooms have also improved the ventilation of the whole dwelling in general.

In case of a greater amount of exhaust air load arousing from many visitors to the user, people smoking or an exagerated heating up of the rooms a sporadic ventilation by a wide opening of the windows for a short time is still absolutely necessary, though.

The basic ventilation by the exhaust system reaches an air change rate of 0,3 - 0,5 per hour. A ventilation by window opening comes up with an air change rate of 1,5 - 3,0 per hour depending on the wind (direction and velocity) and the opening time of the windows.

In the last 10 years the function of the ventilation systems for the interior sanitary rooms turns more bad, because the construction of new windows becomes more airtight as well in new buildings as in older buildings through reconstruction. Therefore there are only little possibilities for the air to come through the envelope and the cross ventilation doesn`t exist in a adequate proportion.

2. PROBLEMS OF VENTILATION CONCERNING A THREE ROOM DWELLING, PARTIALLY FINANCED WITH GOVERNMENT SUBVENTION

The apartment consists of three rooms, dining place and kitchen and interior bathroom and toilet.

Figure 1 shows a ground plan with cross ventilation according to west - east direction. With the wind coming most often from southwest till northwest one can expect that the stream of natural air will take its way from dining place, kitchen and living room over the floor into parents` and children`s room. The points of exhaust ventilation in kitchen, bathroom and toilet will be even more efficient, if during periods of high load of exhaust air this air is drawn off additionally by a mechanical system. Even if this mechanical aid is used just temporarily, an air stream from the bedrooms to the ventilation points as a sort of supply air for the interior rooms can arouse.

In case of changing wind direction or an insufficient or even missing ventilation in bathroom, W.C. and kitchen, it can happen - as shown by the turned around arrows in figure 1 - that the supply air stream is led from bedrooms to the living area.

The figure 2, a) - c), presents a cut through the ground plan of figure 1, showing the possible air streams through the rooms. The minimum demand of the national building code is a shaft ventilation system with natural air draught in bathroom and W.C. There is no definite rule for the kitchen as long as being provided with windows - here through the dining place - but experience recommends at least the same treatment for the kitchen as for the interior sanitary rooms.

The function of exhaust ventilation with only natural air draught mainly depends on the length of the shaft and the difference in density between inside and outside air.

The stream of supply air as well as the stream going through the dwelling, which implies also the continous stream of exhaust air to the ventilation points, is in the meantime ruled by wind direction, wind intensity and by the pressure difference as described in figure 2 for the cross ventilation. The consequence of wind calm is stagnation of the streams.

The figures 3 and 4 show in addition to the possible air streams the corresponding humidity streams. As long as cross ventilation reached the level of the air change rate 1,0 - 2,0 per hour, humidity was just regarded secondarily. With air change rates now being 0.3 - 0.5 per hour only, we have to concentrate our special regard on humidity streams, though, since there load has increased through new windows. Wrong behaviour of the users may influence a possible damage to the building by condensation of humidity with a final development of mould growth.

So far, in figures 1 - 4, we saw today`s technical possibilities concerning exhaust ventilation for those cases in which one wants to fulfill just the minimum demand of our building code.

The exhaust ventilation guarantees a constant standard of hygienics in the rooms without influence on or consideration of the building`s heating. Exhaust air will be drawn off with its complete heat capacity depending on the room temperature respectively. This means that all the time a certain amount of heat will get lost to the atmosphere. Consequently we always have to substitute the infiltration heat loss arousing from this type of ventilation system.

2.1 Order of natural exhaust shaft ventilation

The figure 5 presents in a cut through a building the function of a natural exhaust shaft ventilation. The shafts having the heights h_1 = 5,00 m and h_2 = 8,00 m.

The tables of figure 6 present values of the supply air stream by window rabbets as a function of several a-values.

In figure 7 values of air volume transport through shafts are plotted as a function of outdoor temperature range from - 10 °C up to + 20 °C and of wind velocity at 4 m/s in the diagram and are given in the table.

The values of the tables in figure 6 and 7 show that, for instance, the stream of supply air in the line with wind velocity of 4 m/s will be with an a-value of 1,0 = 1,24 m^3/h,m. Presuming a total length of 15 m for the window rabbets of the apartment, considered in the ground plan of figure 1, and furthermore presuming the outside air stream coming from one side with positive pressure only, an amount of 19 m^3/h of outside air as supply air for the dwelling will result.

The ground plan in figure 1 comprehends for kitchen and for bathroom and toilet one shaft each. For a sufficient exhaust ventilation of the dwelling an air change of 2 x 60 m^3/h = 120 m^3/h is necessary.

2.2 Summary

The outdoor temperature ranging at + 5 °C and below and the wind velocity reaching 4 m/s those two shafts described in figure 5 cannot guarantee the necessary air change.

Our experience proved that in such a constellation either additional window opening or support by a ventilator, which has to be operated at least temporarily, are necessary to keep up the minimum conditions.

2.3 Streams of air and humidity in a dwelling with kitchen and bathroom on the outside

In figure 1 kitchen, bathroom and toilet were arranged as interior rooms. The kitchen, however, designed as kitchen-dining room can receive window air and light from the dining place with the need of a shaft ventilation system.

Now in figure 8 we see a ground plan in which both kitchen and bathroom are lying on the outside, so they have windows. Therefore the necessary air change can be provided by opening the window only.

Values concerning the ground plan in figure 8 of supply air stream, which depends on the wind conditions, and values of humidity streams are given in figure 9.

Supply air finds its way into kitchen, bathroom, parents` bedroom and then loaded with humidity and wasted air it streams as exhaust air through living room and children`s room to the envelope of the building with the negative pressure.

Figure 10 shows the change in wind direction and followingly in pressure a situation results, in which exhaust air stream and humidity stream as well have changed, too, according to the new direction.

Both figures 9 and 10 prove that in this dwelling there will always be a certain disturbing load of humidity and several odours. Figure 9 reveals the somewhat inconvenient situation, especially for the users of living- and children`s room as far as the air conditions are concerned.

2.4 Streams of air and humidity in a dwelling with mechanical ventilation

Considering the haft ventilation above, it was mentioned that in case of an insufficient function of natural draught an additional ventilator becomes necessary.

The shafts in the ground plan of figure 1 being equipped with exhaust ventilators one can reach, presuming a sufficient arousel of negative pressure, a supply air stream through the window rabbets on all sides and not only on the side of the building with the positive pressure.

Looking back to the figures 3 and 4, 9 and 10, we realize that there we had an effective stream of supply air on the side with positive pressure, only.

Completing the ground plan of figure 1 by installation of ventilators we find the air and humidity streams presented in figure 11.

The supply air streaming into the apartment takes the exhaust and humidity load out of the living-, parents`- and children`s room over to the ventilation points in the kitchen and in the bathroom and toilet, where it is drawn off.

There is no possibility that - as with the natural shaft ventilation system - exhaust air may stream from the sanitary rooms back over to the living area. However, we cannot exclude the eventual necessarity of an additional window ventilation in terms of sporadic ventilation in those cases of an overflow of exhaust air, for instance many visitors or smokers being in the rooms. If it is made use of this sporadic ventilation, there again we have to cope with the disadvantage of exhaust air being exchanged between the rooms.

So far we have proved that the mechanical exhaust ventilation compared to just natural air draught leads to a considerable improvement of air and humidity values in a dwelling.

That situation of a mechanical exhaust ventilation can be improved even more by installation of a balanced ventilation.

The figure 12 presents, refering to the ground plan of figure 1, the arrangement of a balanced ventilation system, comprehending a mechanical exhaust and a mechanical supply ventilation as well. Air and humidity streams shown in figure 12.

The whole volume of air stream is 180 m^3/h for supply and exhaust air respectively. This means an air change rate of 0,8 per hour for the dwelling.

rooms	supply air normally m^3/h	supply air switch over day m^3/h	supply air switch over night m^3/h	exhaust air m^3/h
living room	60	80	40	--
dining room	40	60	20	--
kitchen	--	--	--	100
children`s room	40	20	60	--
parent`s room	40	20	60	--
bathroom	--	--	--	50
toilet	--	--	--	30
amount	180	180	180	180

The table shows the volumes of the streams related to the several rooms.

A reduction of the volumes of air stream during the night period may be performed by appropriate mechanical or electrical connections.

In the summer month the mechanical supply ventilation can be switched off also during day time while it is then substituted by window ventilation.

Besides the fact that balanced ventilation will guarantee a continuous drawing off of humidity and exhaust load, there is the possibility to combine it with a heat recovery.

2.5 Values of humidity measured in dwellings with different ventilation systems

The diagrams of figure 13 present values of absolute humidity in the course of four consecutive days in January. The values were measured in two dwellings with the type of ground plan shown in figure 1, both having shaft ventilation in bathroom and toilet, however, no one in the kitchen.

One can well perceive the different behaviours of the users concerning the window opening. The apartment 3. floor left has the highest values of absolute humidity, so one may conclude that there had been little window ventilation by the users.

The living room has relatively low values of humidity. Users affirmed our presumption that the room most likely had been used rather seldom.

The curves of figure 14 show values of absolute humidity measured in two dwellings, one of which was equipped with mechanical exhaust ventilation - 1. floor left - the other one with balanced ventilation - 2. floor right.

Since these measurements have been taken at the same time as those shown in the diagram before we can compare them under the aspect of absolute humidity values.

All rooms being provided with balanced ventilation obviously showed the lowest values of absolute humidity.

The dwelling with mechanical exhaust ventilation only has higher values than the one mentioned before with the balanced ventilation; however, its values in the bedrooms are still found to be lower than those given in diagram of figure 13, where we had natural shaft ventilation only.

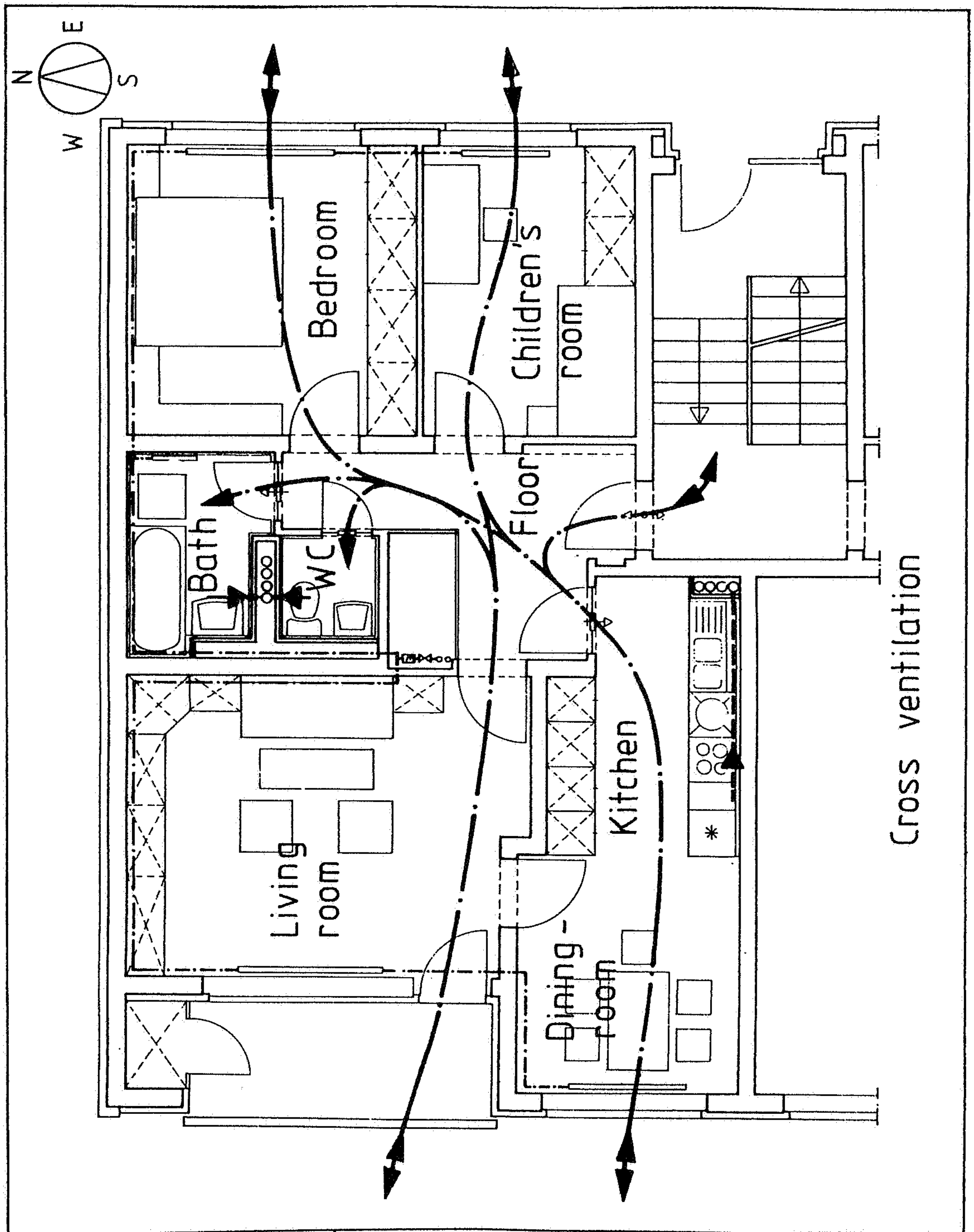
3. CONCLUSION

The previous pictures and diagrams proved that values of air and humidity streams can obviously be looked upon as a function of the different ventilation systems the dwellings are equipped with.

Furthermore user`s behaviour has a certain influence on the curves of absolute humidity in the different rooms within the same apartment as well to be perceived from the example shown in figure 13.

We should emphasize that especially in those bedrooms which were ventilated rather and therefore showing high values of absolute humidity in consequence, there was in spite of double glassed windows a condensation and mould growth to be seen.

The balanced ventilation as described in figure 12 should be installed in buildings because of hygienic and energetic reasons as well as to avoid humidity problems.



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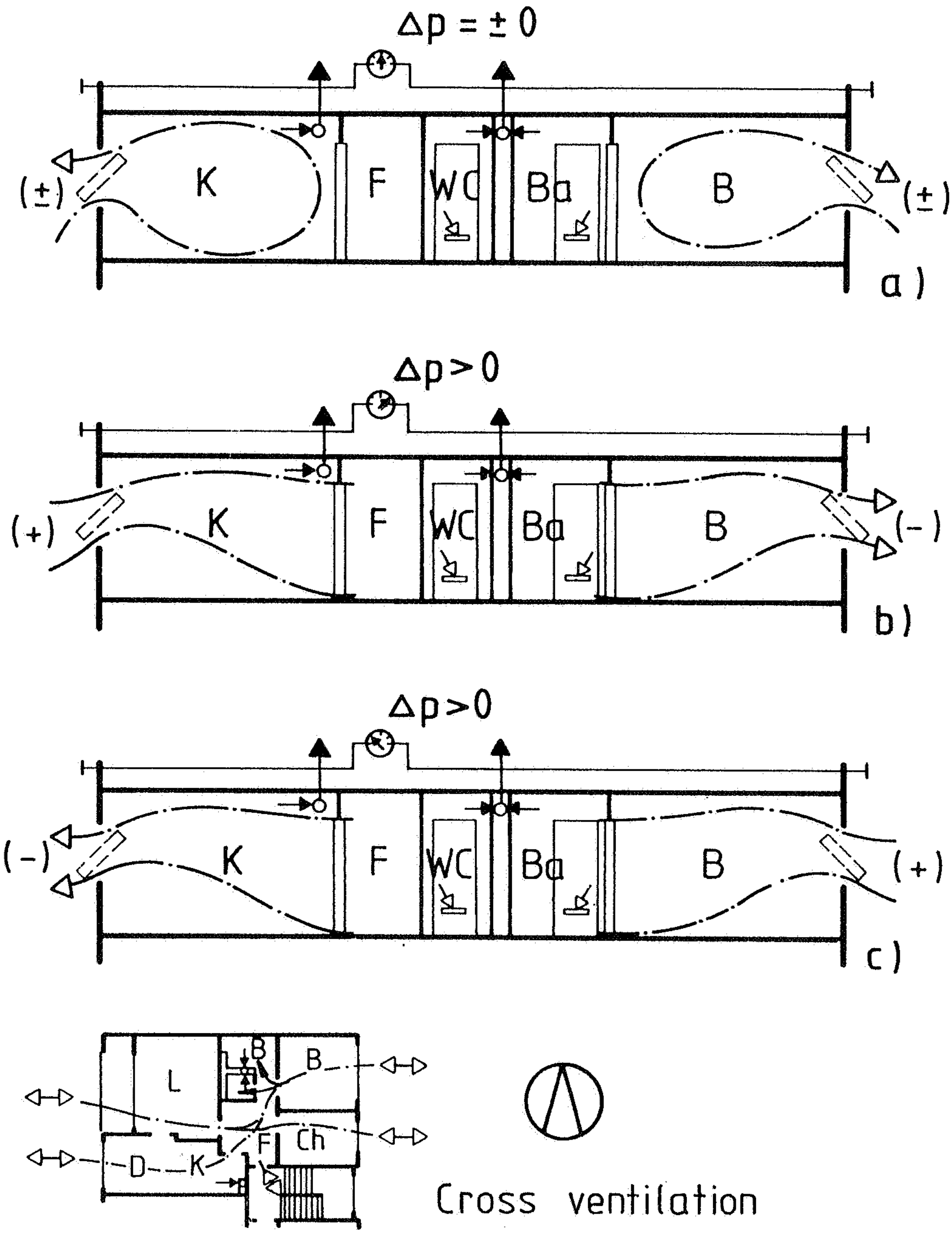

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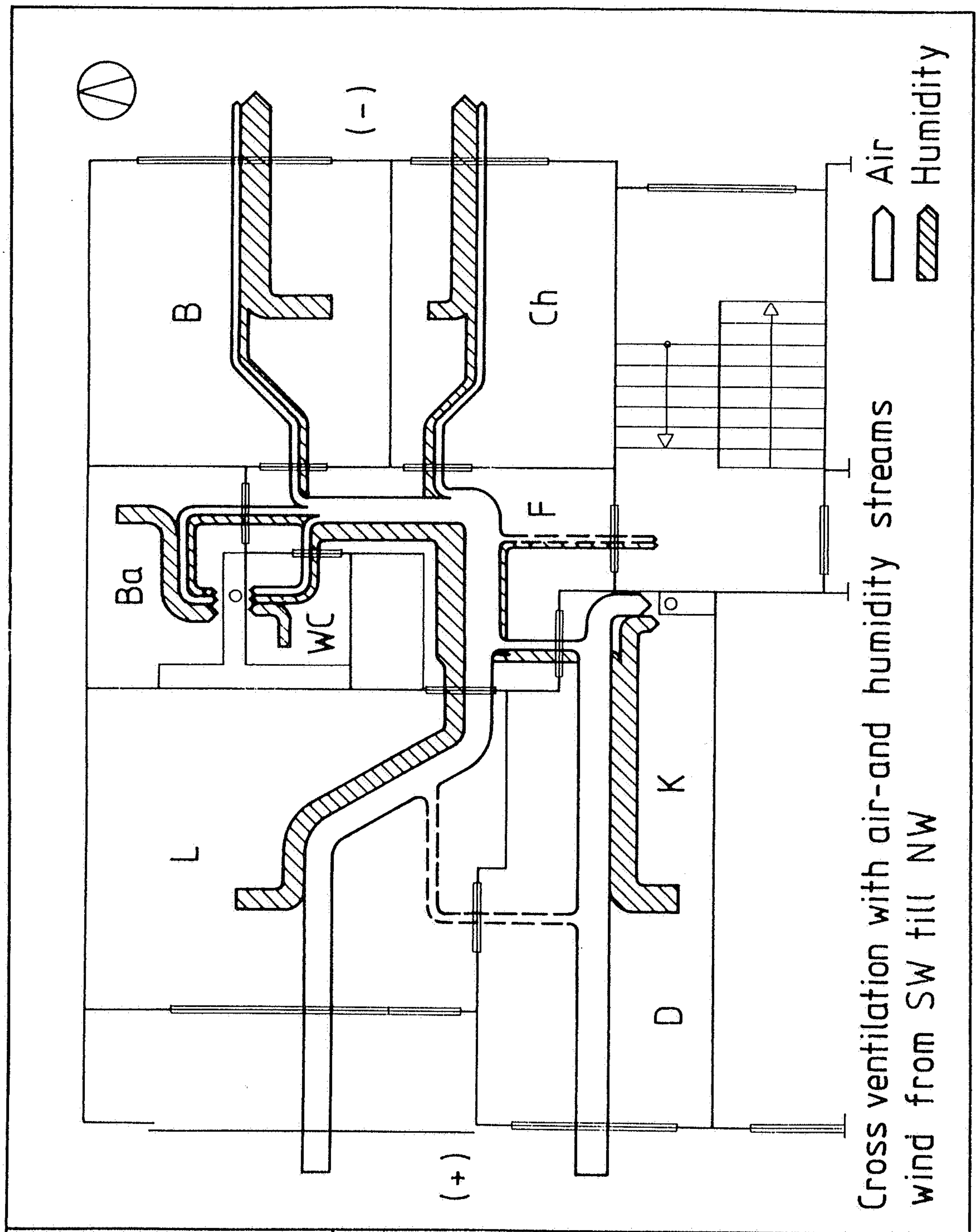

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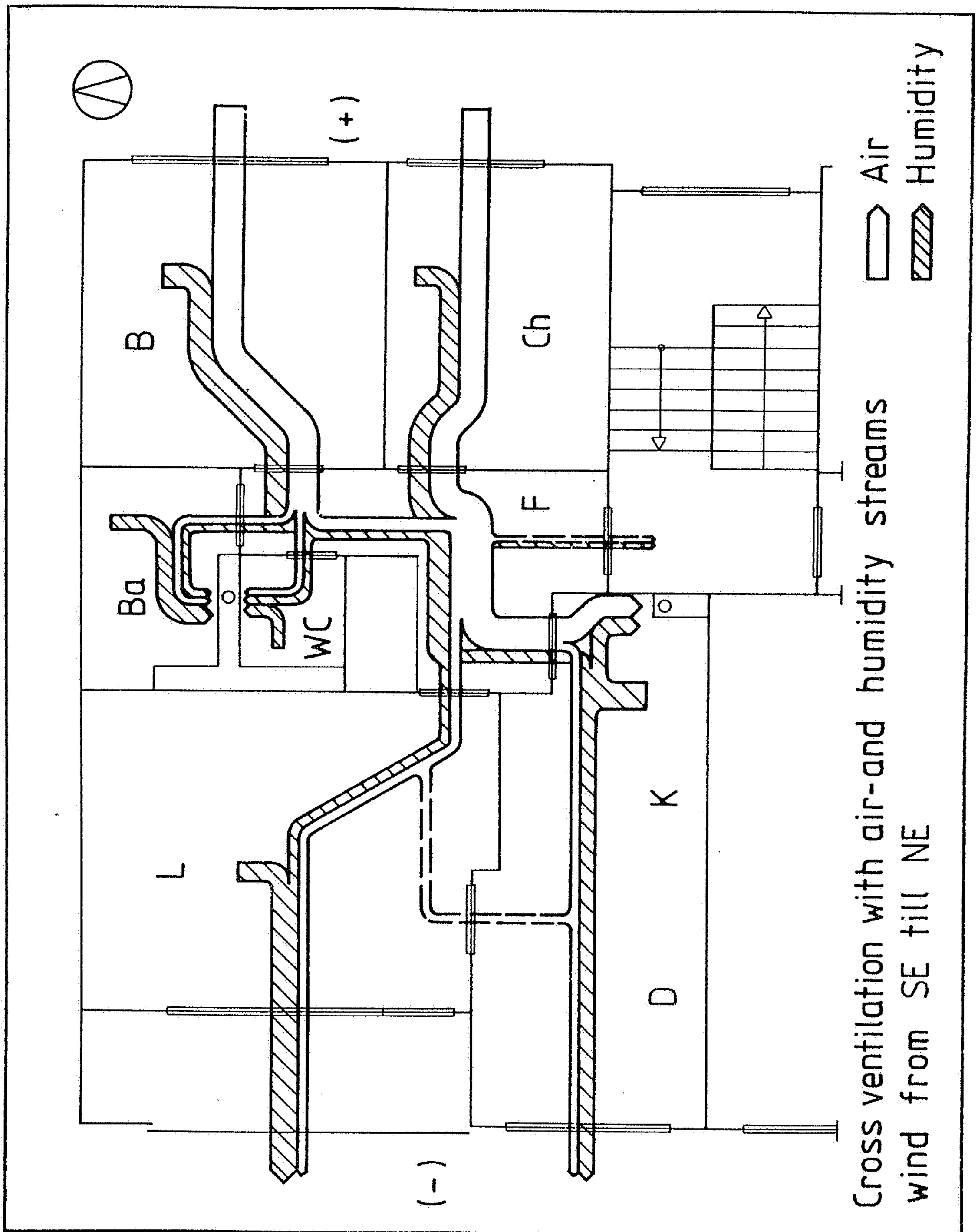

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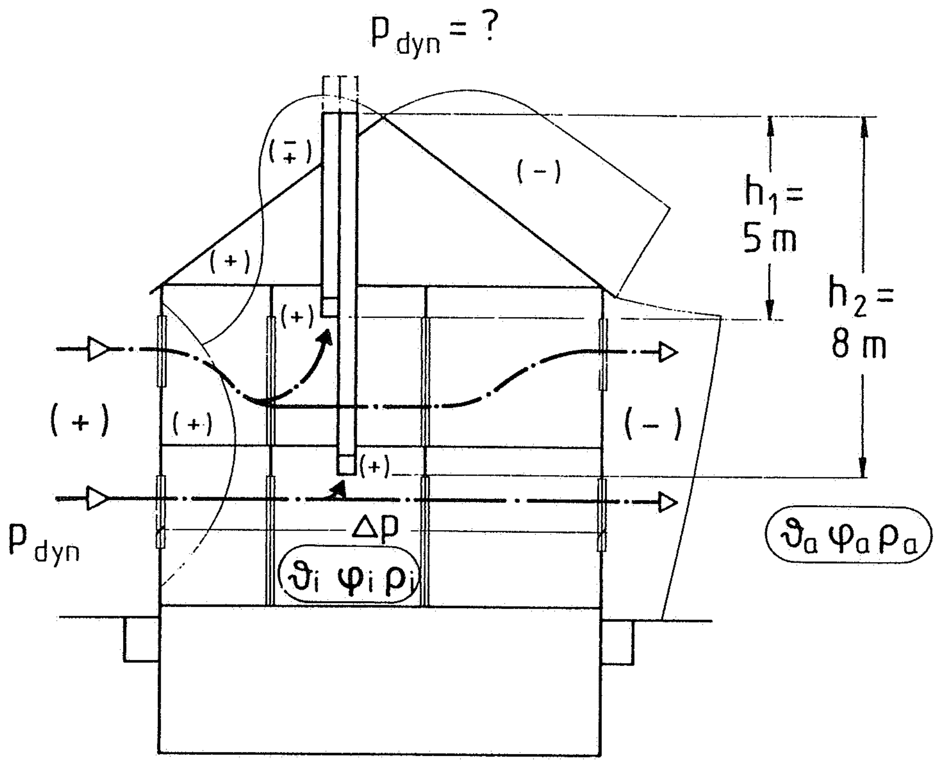

$v = 4\ m/s\ ;\quad \rho_{0°C} = 1{,}29\ kg/m^3$

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$$H = h \cdot g\ (\rho_a - \rho_i) \text{ in Pa}$$

ϑ_o °C	ϑ_i °C	φ_a %	φ_i %	ρ_a kg/m³	ρ_i kg/m³	H_1 Pa	H_2 Pa
−10	22	90	50	1,34	1,19	7,36	11,77
±0	22	90	50	1,29	1,19	4,91	7,85
+15	22	70	50	1,22	1,19	1,47	2,35

$$p_{dyn} = \frac{v^2 \cdot \rho}{2}; \quad \Delta p = \frac{4}{3} p_{dyn} \quad \text{in Pa}$$

v m/s	p_{dyn} Pa	Δp Pa	$\dot{V}/l$ m³/mh a=1,0*	$\dot{V}/l$ m³/mh a=2,0*
1	0,65	0,87	0,20	0,39
2	2,58	3,44	0,49	0,98
3	5,81	7,75	0,84	1,69
4	10,32	13,76	1,24	2,47
5	16,13	21,51	1,67	3,33
6	23,22	30,96	2,12	4,25

* : in $\frac{m^3}{h \cdot m \cdot (daPa)^{2/3}}$

nach DIN 18 055 Ausgabe 10.81

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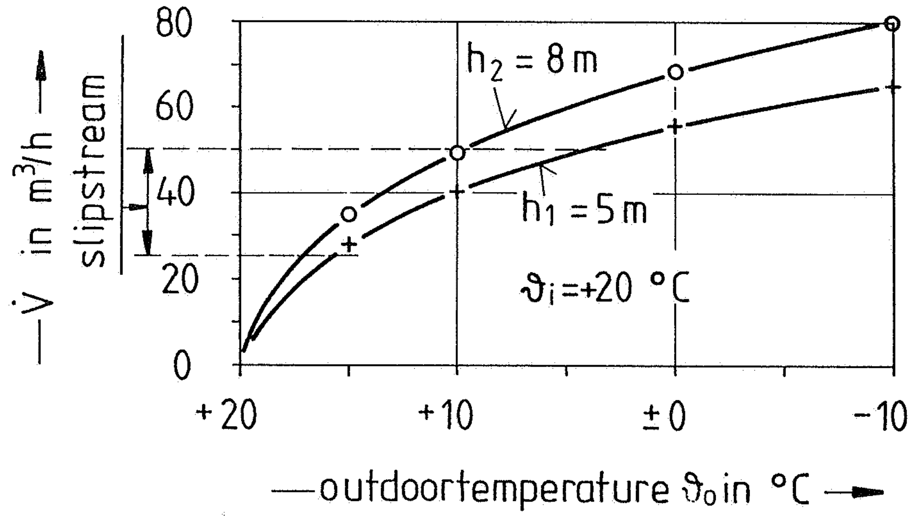
ϑ_o °C	H_1 Pa	v_1 m/s	$\dot{V}_1$ m³/h	H_2 Pa	v_2 m/s	$\dot{V}_2$ m³/h
−10	6,72	1,28	64,5	10,75	1,62	81,6
±0	4,32	1,09	54,9	6,90	1,35	68,1
+10	2,11	0,78	39,3	3,38	0,97	48,9
+15	1,30	0,55	27,7	1,65	0,69	34,8



p_{dyn} ≈ 10 Pa ; Δp ≈ 13,3 Pa

□ = 0,014 m² = 100 / 140

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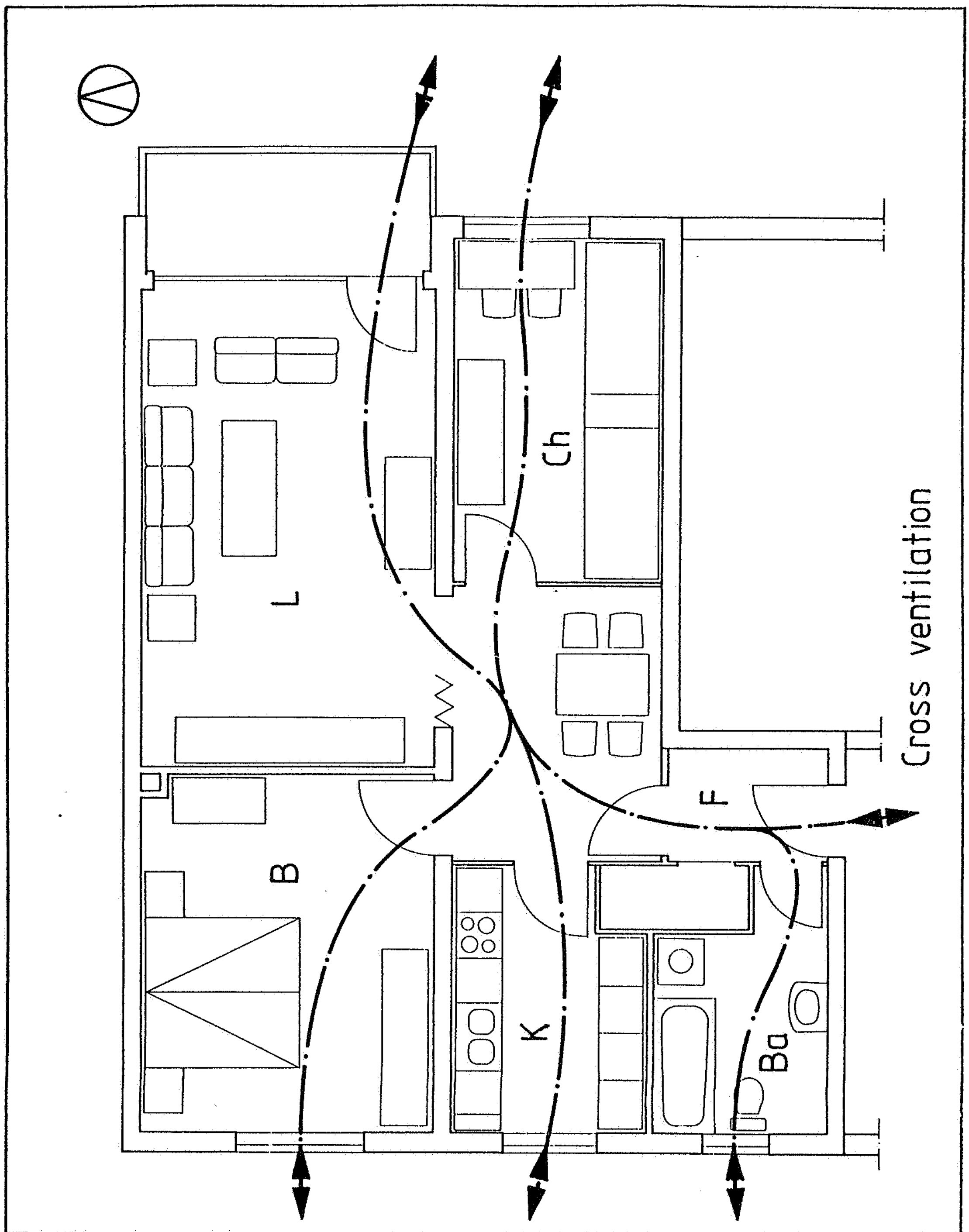

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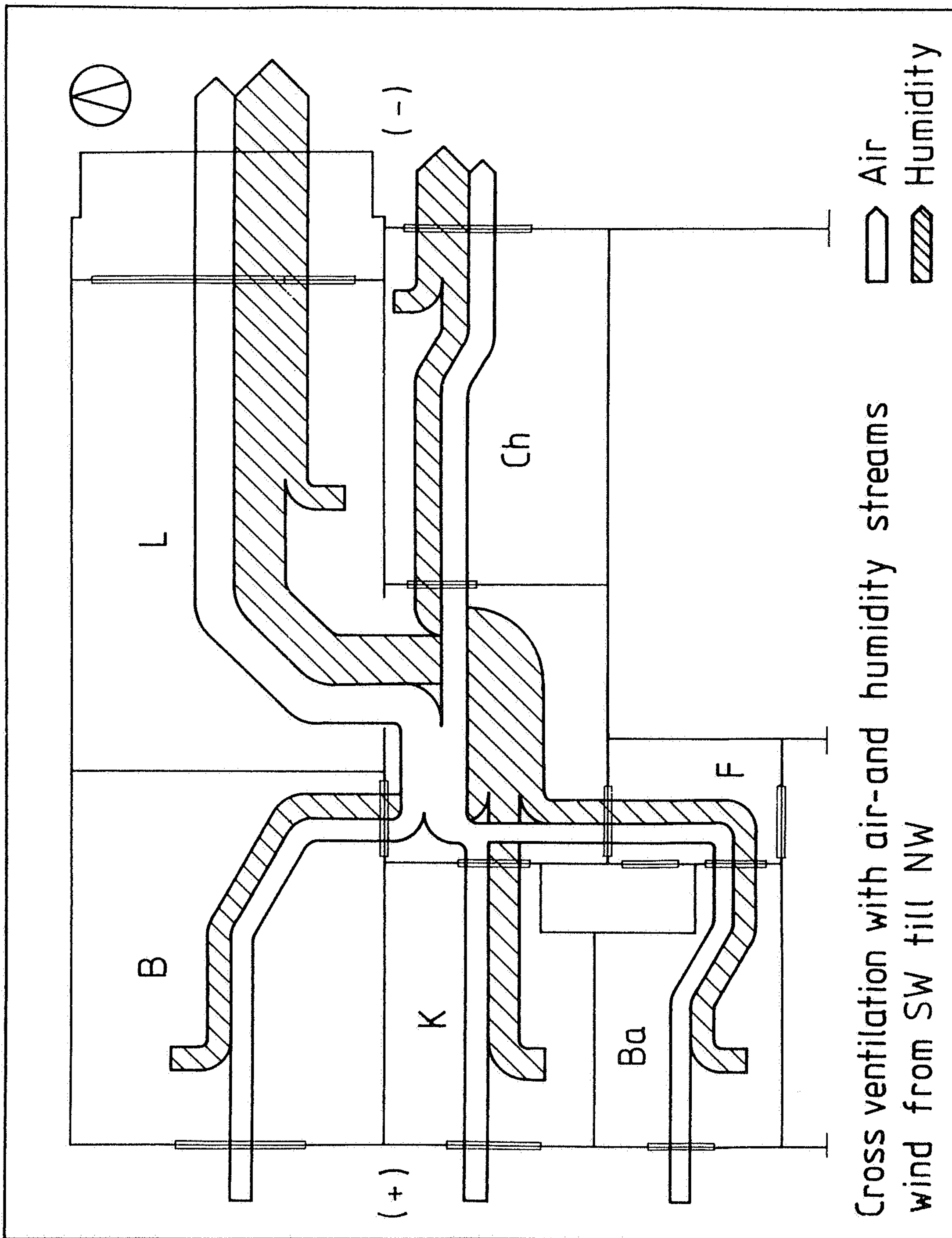

Cross ventilation with air-and humidity streams
wind from SW till NW

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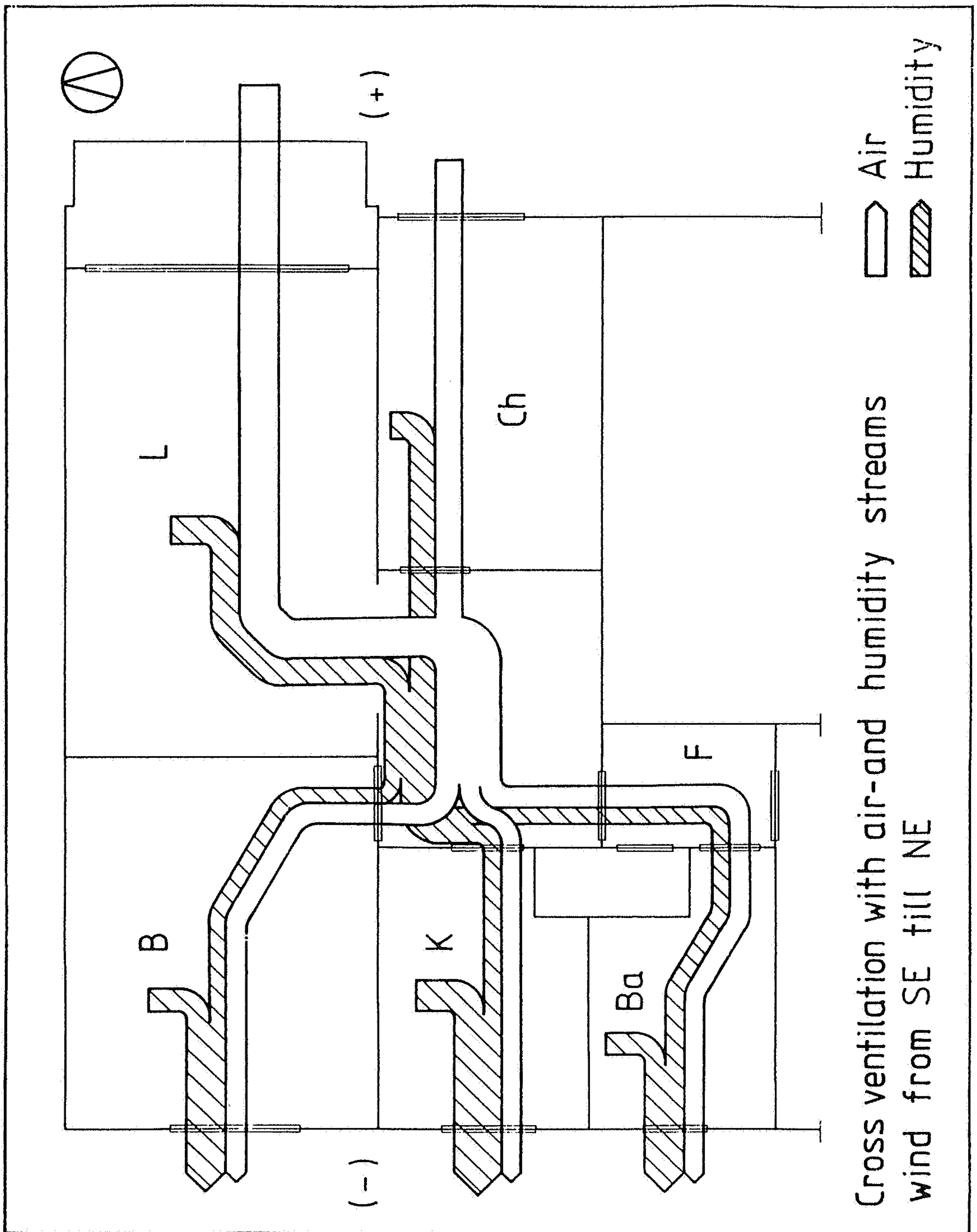

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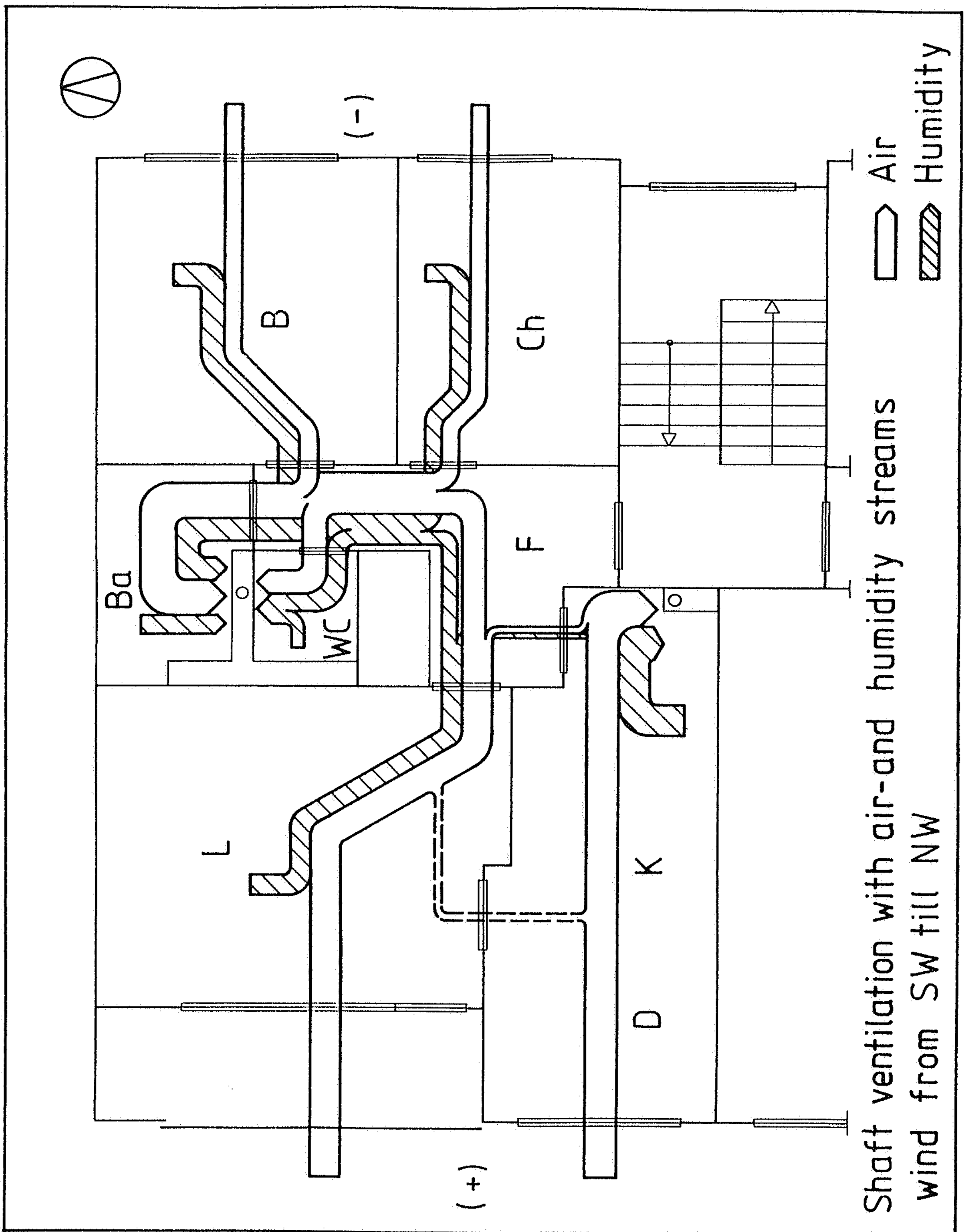

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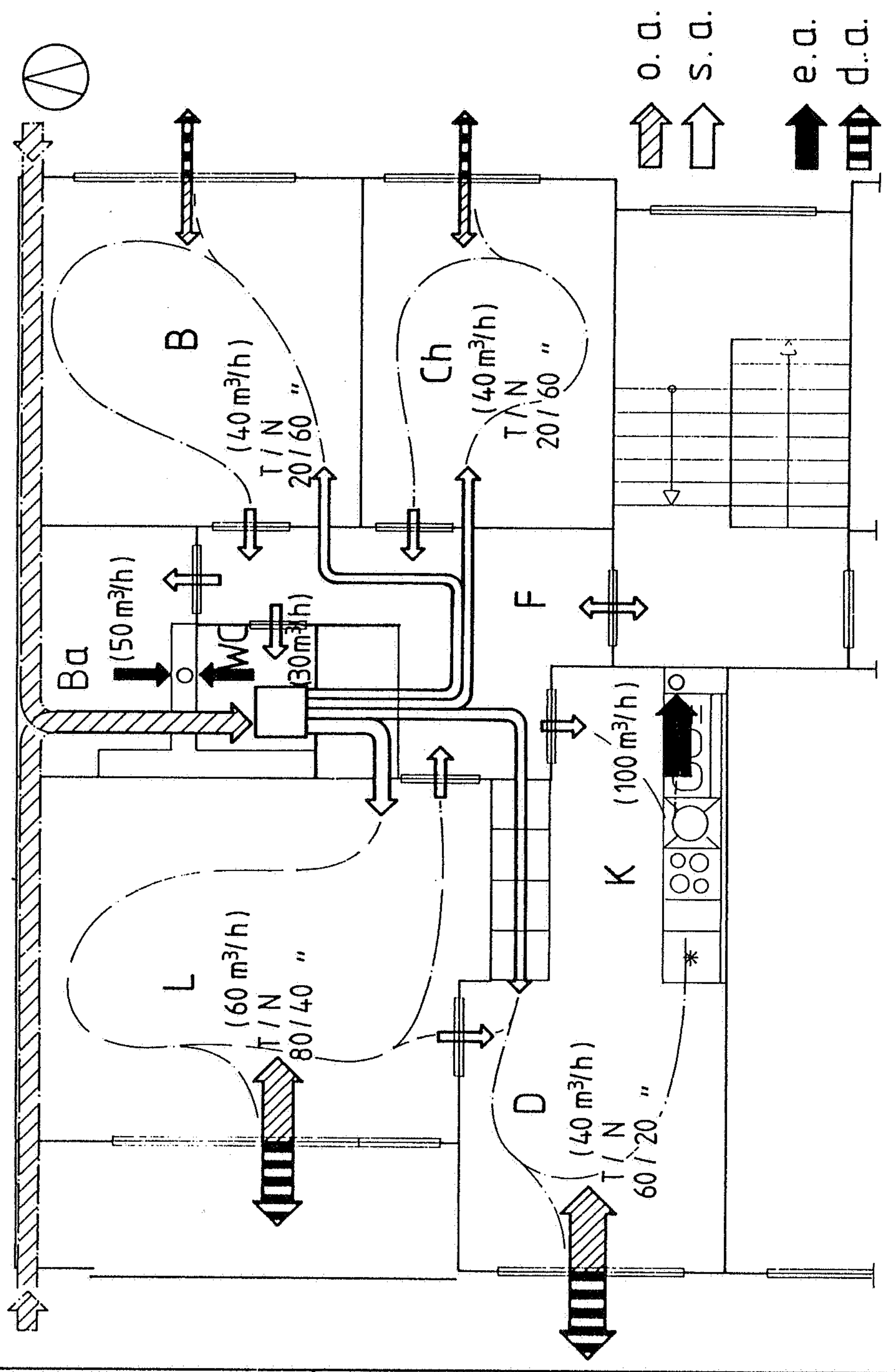

Balanced ventilation

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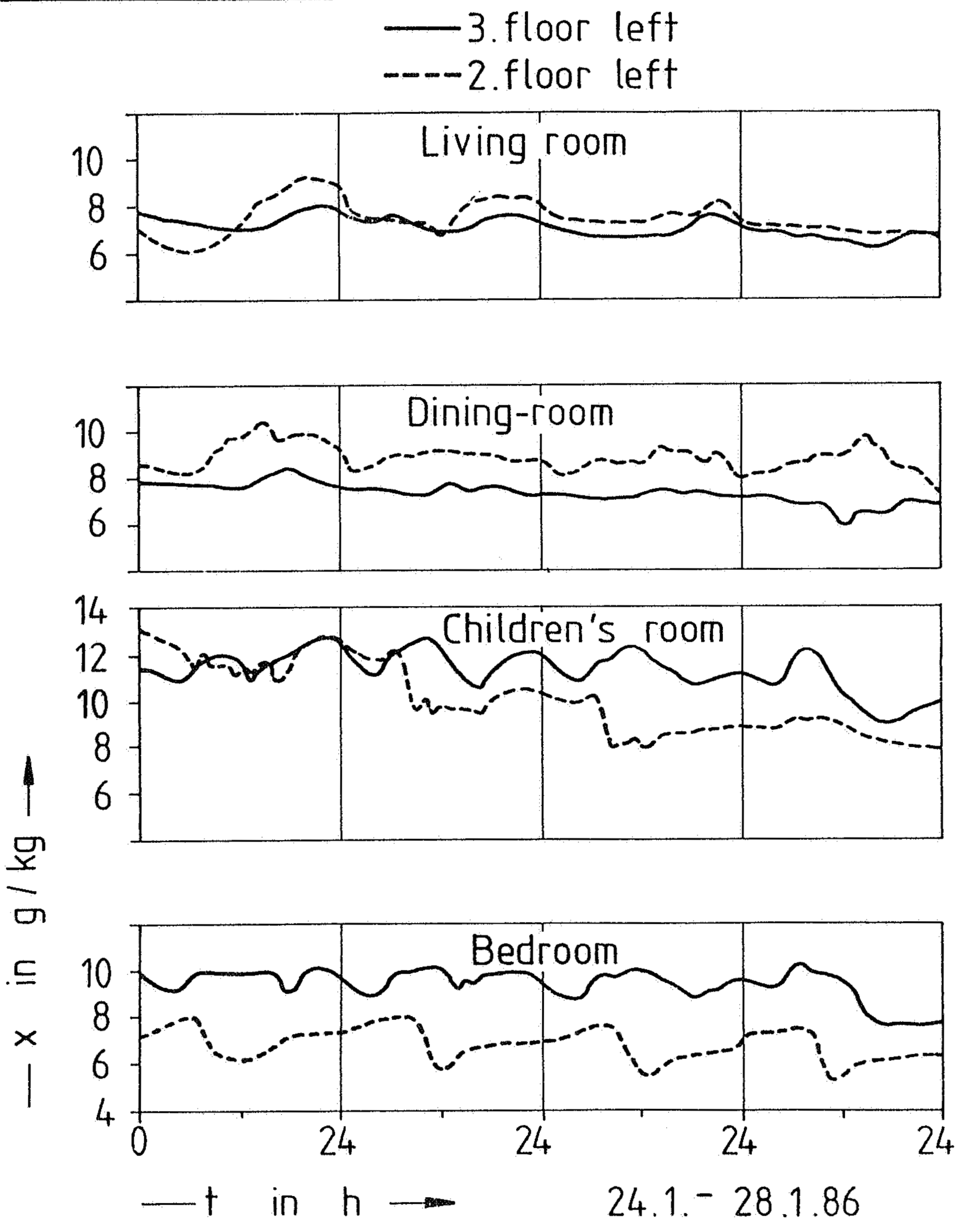
Dwelling Ventilation

8.4

Bild 12

Absolute Humidity   Residential building "B"



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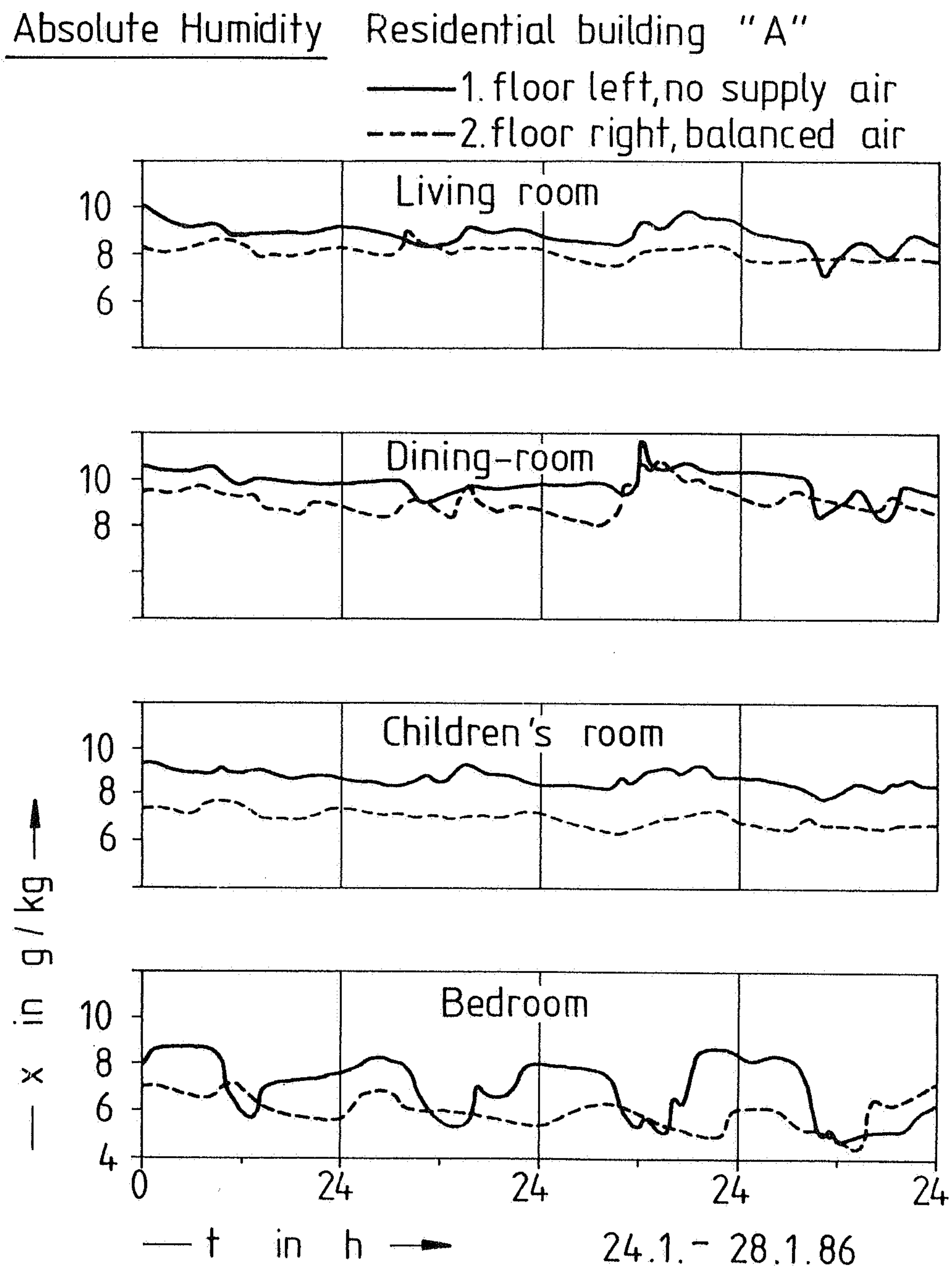

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