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O.A. Trans. Nº ~~4791~~ 1761

May doors in hospitals remain open ?

- by -

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- from -

Publication Nº 437, Instituut voor Milieuhygiene en Gezond-heidstechniek TNO, read at TVVL - TNO Conference, 26th Oct 1972. "Mogen deuren in een ziekenhuis open blijven staan ?.

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1. Introduction

In hospitals without air conditioning or mechanical ventilation there may be two reasons for keeping the doors shut:

a] The desire to prevent draughts and protect patients and staff from catching cold;

b] The desire to prevent germ contaminated air being transmitted from one room to another.

In hospitals with air conditioning or mechanical ventilation ~~only~~, the situation can differ in so far that the danger of catching cold is considerably less. Moreover it may be felt that mechanical ventilation would also prevent undesirable air flow in undesirable directions with the doors open ~~also~~.

Investigations ~~of this matter~~ indicate~~s~~ that, in general, it is ~~must be considered~~ an illusion to suppose that, even with a closed façade~~, and with~~, open doors internally, and ~~with~~ mechanical ventilation, that the direction of movement of the air could be controlled throughout the building. We wish to subject these matters to a thorough investigation.

The air movement from room to room is controlled by the pressure difference. In general pressure differences take place as the result of air flow to and from the rooms. Moreover the magnitude of the pressure difference between rooms is dependent on the mean temperature difference between the rooms, on the form of the temperature variation over the height of the rooms [temperature gradient] and on the height in the room at which the pressure difference is considered.

2. Detailed consideration of a number of theoretical situations & situations possible in practice

Case 1: Two rooms are contiguous, no air is supplied to or extracted from them, there is no temperature difference between the rooms at any height, [there may therefore be two identical gradients over the height of both rooms]. Under these conditions there will be no flow through the doorway with the door open.

Case 2: If the vertical temperature gradient in both rooms is identical, and if air is supplied to one room A and it flows to the other room B through the doorway, there will be a reasonably uniform velocity distribution throughout the whole doorway [Fig.1]. This uniformity can easily be disturbed in room A by residual air velocities resulting from the air blown in room A. Under unfavourable conditions local backflow may occur in the

Case 3: If the vertical temperature gradients are such that at every height in the one room [B] is 1°C warmer than the other room [A], as shewn in Fig.2, and no air is supplied to or extracted from the two rooms, then thermal flow will take place through the doorway after opening the door between the two rooms. In so doing the colder air will flow across the floor to the warm room while warm air will flow through the top part of the doorway to the colder room. The amount of air which flows at floor level from room A to room B must of course be equal to the amount of air which flows through the top of the doorway from B to A.

On the basis of considerations of symmetry, a point will be found about halfway up the door opening where no air change between A and B takes place. This we call the neutral height h_n. At this height therefore the pressure between rooms A and B will be in equilibrium. From this situation it is clear that we can not just speak of the "pressure difference between room A and room B" but that for a better comprehension it is essential to speak of the "pressure difference between room A and room B at a height of h m [h to be specified more precisely] above the floor".

Due to the flow the temperature gradient over the height alters in addition, so that after a time the symmetry of the pressure distribution and of the flow through the doorway will be lost.

If the temperature difference between the rooms is not equal at every height [Fig.3], the pressure distribution will be asymmetric. The non-linear pressure distribution over the height introduces many complications for the theoretical assessment and for further consideration of the matter,without our insight into it being notably increased thereby. Therefore we have limited ourselves to cases with linear variation of the pressure over the height.

Case 4: If the temperature difference between the two rooms at every height is the same and if there is supply to the colder room A and extraction from the other warmer room B, then the following situation will arise in accordance with Figs 4a or 4b.

In fig. 4a the colder air flows along the floor through the doorway of room A to room B. The warmer air flows through the top of the doorway from room B to room A. The air flow from room A to room B, less the air flow from room B to room A must be equal to the quantity of air supplied to room A per unit of time.

This means that the velocity distribution over the doorway is no longer symmetrical. The point where there is no air flow between A and B is now clearly above the half height of the doorway.

If the temperature in room A is higher than in room B [fig.4b] the neutral height h_n is lower and the warm air from room A flows to room B through the top of the doorway while the colder air from room B flows across the floor to room A.

Case 5:

It may be asked how large the air supply q_x to a room must be so that no back flow takes place anywhere in the doorway, if at all heights there is a given temperature between the rooms. The pressure distribution with the door open must obviously be wholly on one side for the air to flow at all heights from A to B as shown in Fig.5.

Case 6:

If more air is supplied than in the limiting case [case 5] is necessary, the situation shewn in Fig.6 occurs.

3. Numerical examples

The conditions in cases 2 to 5 are given below in figures for a room 7m long x 5m wide x 3m high. The temperature difference between the rooms is 1°C and 420m^3/h or more of air is supplied to room A. The doorway in this example is 2m high x 0,8m wide. The air supplied to room A, viz. 420 ^{3}/h corresponds to 4 air changes/h. How the figures given vary for other door sizes and other air quantities is discussed in paragraph 4.

Case 1, para. 2 does not need to be discussed.

Case 2, Here we have the situation depicted in Fig.7. The pressure difference at the doorway is particularly low, viz. of the order of 0,0064 N/m^2 [about 0,00064 mm head of water]. The speed in the doorway is only 7,3 cm/s. It is clear that this speed distribution can easily be disturbed.

Case 3, Here no air is supplied but there is a temperature difference of 1°C [t_B is greater than t_A]. This situation is as depicted in Fig.8. The greatest pressure difference across the doorway occurs along the floor and at the top of the doorway. This greatest pressure difference is only 0,04 N/m^2 [about 0,004 mm head of water]. Also in the case of a closed door leaking uniformly over its height, the pressure of room A with respect to room B, 2m above the floor should be increased by blowing in air by at least 0,04 N/m^2 to prevent air from room B leaking into room A through the chink round the door.

Case 4, The figures are given in Fig. 9. It would appear that an air supply of 420 m^3/h - in this case 4 air changes per hour for room A - is definitely insufficient to prevent back flow through the doorway. If we compare the maximum pressure difference in figures 7 and 9 we see that, solely as a result of the temperature difference of 1°c, ~~is~~ the maximum pressure difference over the doorway, locally, is nine times as high!

Case 5, The figures are given in Fig. 10. To prevent back flow in the doorway, almost 1000m^3/h air supply appears to be necessary, viz. nine air changes/h. This value applies with a temperature difference between the rooms of only 1°C. If the temperature difference is greater, the amount of air necessary to prevent back flow is even greater.

General remarks

It should be clear to the reader that the horizontally hatched portions of the velocity distributions are undesirable because room A must be protected against germs from room B.

4. Numerical values for other situations

The numerical examples for cases 2 to 5 are given for:

- height of door [h = 2m]
- width of door [b = 0,8m]
- temperature difference [Δt = 1°C]
- air supply [q = 420m^3/h]
- volume of room [I = 105 m^3]

By altering these values we wil find other values for:

- the pressure difference across the doorway
- the velocity in the doorway
- the air passing through the doorway
- the number of air changes per hour

Case 2, The velocity in the doorway is $v = q/3600.h.b$, and the pressure difference is proportional to the square of this velocity.

Case 3, The maximum pressure difference Δp is proportional to the temperature difference $\Delta t°$. Air movement directed in one sense through the doorway is proportional to:

$$[h]^{3/2}.b.[\Delta t]^{1/2}$$

Case 4, No simple relationships can be given because the results depend of the solution of a cubic equation.

Case 5, The required maximum air pressure difference throughout the doorway, to prevent back flow of the air is proportional to $\Delta t.h$. The airflow required to ensure this is proportional to

$$[h]^{3/2}.b.[\Delta t]^{1/2}$$

The number of air changes/h can be determined in all cases as the quotient of the air supplied q and the volume of the room I.

5. Consequences of the results obtained.

It would appear from the calculations that temperature difference between the rooms has an important, even a dominating influence on the local back flow of air in the doorway, particularly with the door open. This influence is so great that the air supply required to prevent back flow in the doorway of an open door is so great that it can not be considered in most situations which occur apart from very special cases. If, with the door shut, there are temperature differences, there will also be a pressure difference gradient over the height of the door. If we want to be certain that with the door shut there is no back flow through the chink 2m high, the pressure on the door up to 1m above the floor per 1°C temperature difference must be at least 0,04 N/m^2 [about 0,004 mm head of water]. If there are openings of still greater heights in the walls between the rooms, the pressure difference must be still higher.

Proceeding on the basis that the temperature differences between the rooms are often of the order of 1° to 2°C and also that there must be some certainty of no back flow occurring, we recommend, with closed doors, a pressure difference between rooms at half height of the door, of at least 0,2 N/m^2 [about 0,02 mm water gauge] at temperature differences of from 0 to 2°C.

Because of the, ~~mostly~~ generally unknown, leakage in the structure of buildings, it is not really possible ~~that~~ after design, building and commissioning the installation, that this pressure difference will be attained precisely. With easily handled measuring instruments the accuracy is not much better than 0,1 N/m^2. Therefore it is practical to permit even higher pressure differences. In so doing we must endeavour ~~as far as possible~~, to avoid the pressure difference being much in excess of three times the minimum given.

With much higher pressures the difficulty arises that the uncontrollable leakage currents due to unsealed parts of the structure of the building [pipe passages, unsealed junctions of walls with other walls and of floors and ceilings] increase and this is undesirable.

These recommendations are summarised in Fig. 11.

6. Conclusions

6.1 Even with mechanical ventilation [or air conditioning] in a hospital, the doors of rooms should be kept shut as much as possible in cases where the carriage of germs with the air through the doorways is undesirable.

6.2 For general use, in practice, it is not economically justifiable to choose such a large number of air changes/h so that no undesired back flow occurs with the doors open.

6.3 For all the rooms referred to above, with the doors already shut, one must try to attain pressure differences above the limit line given in Fig. 11.

7. Bibliography

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Figures: See original.

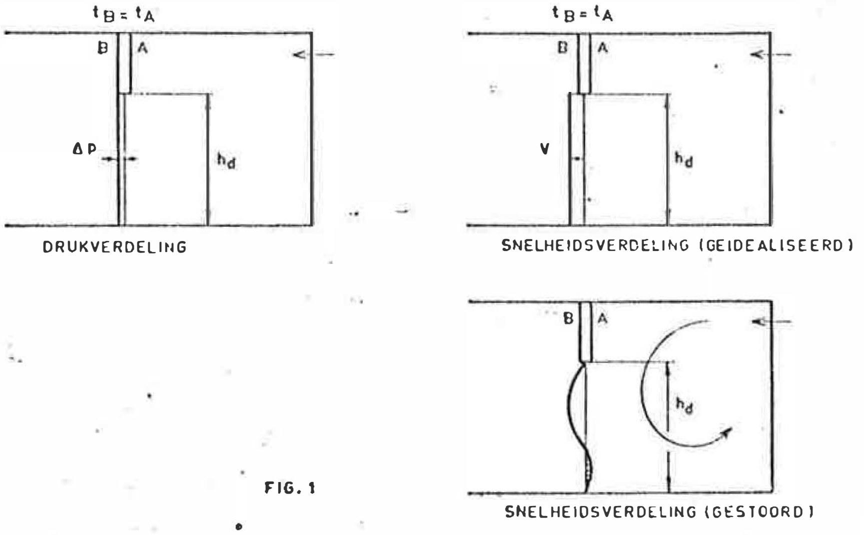
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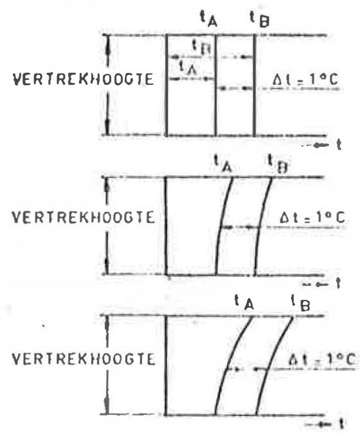
FIG. 1



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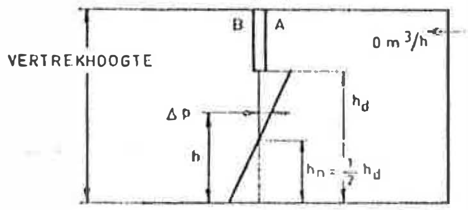

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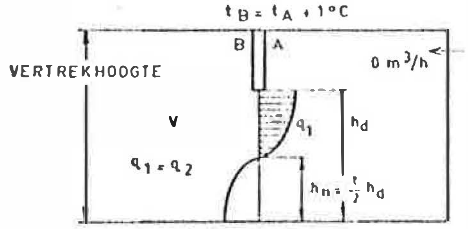

FIG. 2

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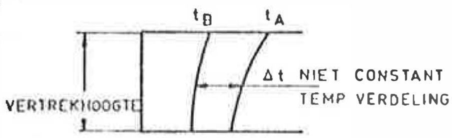


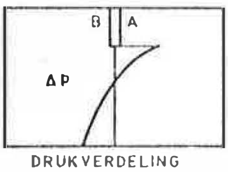


FIG. 3

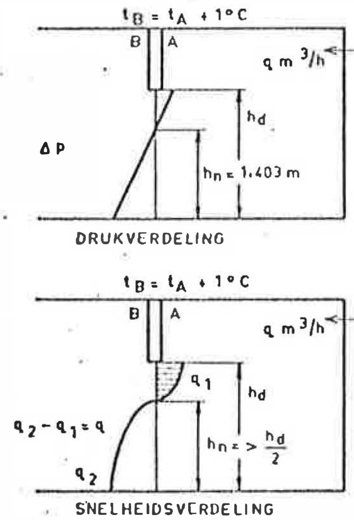


FIG. 4a

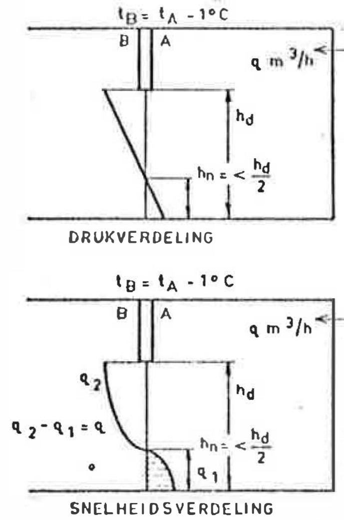


FIG. 4b

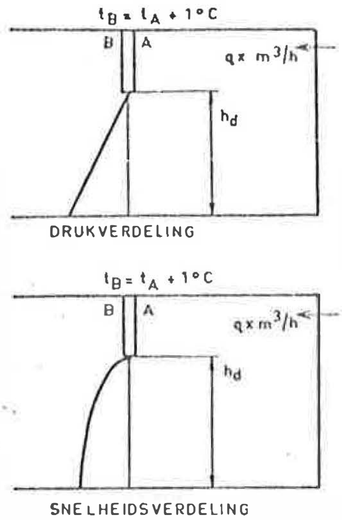


FIG. 5

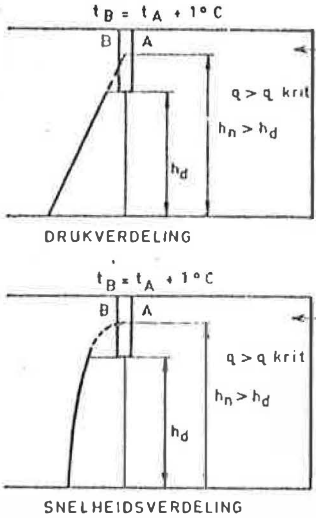


FIG. 6

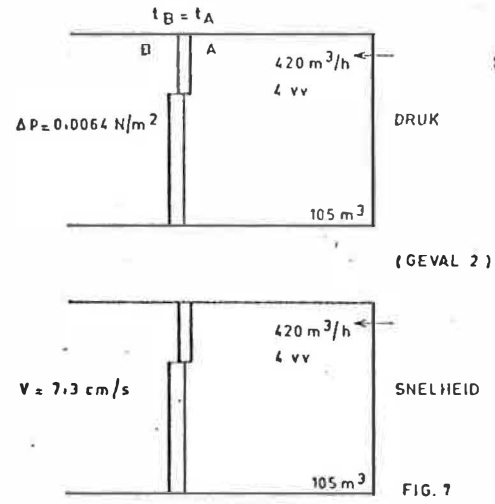


FIG. 7

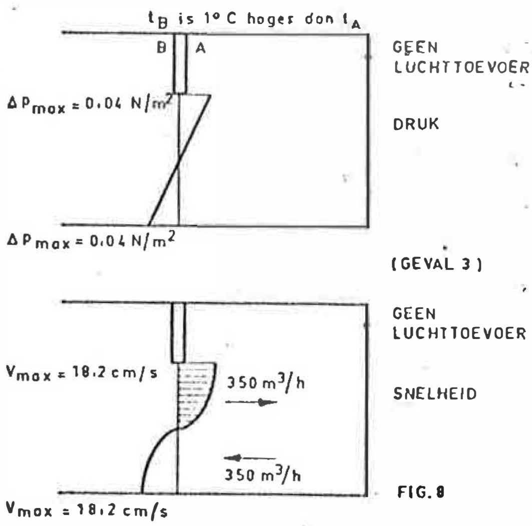
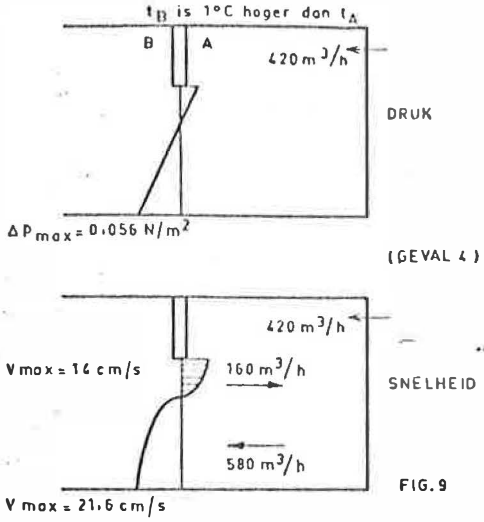


FIG. 8


t_B is 1°C hoger dan t_A
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A
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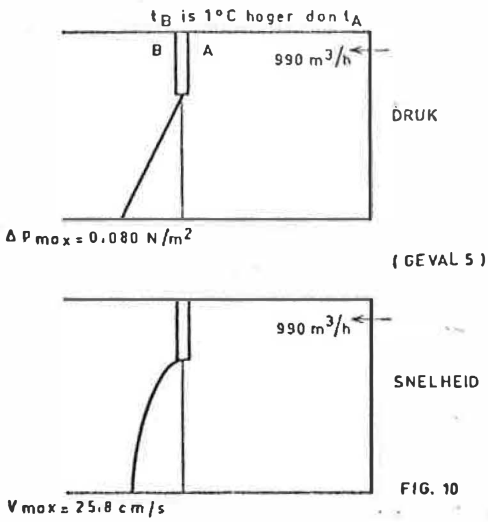
(GEVAL 4)
$420\ m^3/h$
$V_{max} = 14\ cm/s$
$160\ m^3/h$
SNELHEID
$580\ m^3/h$
$V_{max} = 21{,}6\ cm/s$

FIG. 9


t_B is 1°C hoger dan t_A
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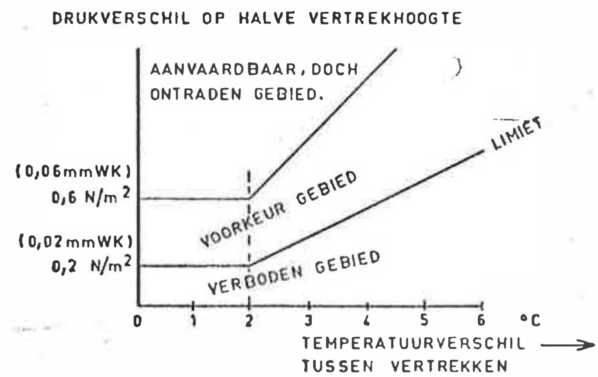
$\Delta P_{max} = 0{,}080\ N/m^2$
(GEVAL 5)
$990\ m^3/h$
SNELHEID
$V_{max} = 25{,}8\ cm/s$

FIG. 10

FIG. 11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