ENERGY EFFICIENT DOMESTIC VENTILATION SYSTEMS FOR ACHIEVING ACCEPTABLE INDOOR AIR QUALITY

3rd AIC Conference, September 20-23 1982, London, UK

PAPER 23

ON FLOW IN NARROW SLOTS APPLIED TO INFILTRATION

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SYNOPSIS

The normally used equation for calculation of infiltration flow rates into a house, is

$$q' = \text{const} \cdot \Delta p^{n}$$

where Δp is the pressure drop over the walls and n a constant. The constant n is normally assumed to 2/3 but sometimes also values as 0,5 or even 1 can be seen in the litterature.

In the paper is the constant n calculated assuming a *non fully developed* infiltration flow. The constant n will for this asumption take values beetween 0,67 and 0,77 if the slots where the flow take place are long enough to get a flow close to a developed one.

ON FLOW IN NARROW SLOTS APPLIED TO INFILTRATION

1. Introduction

Flow through cracks around windows, doors etc are to a large extent the cause for the leakage into a house. Normally the flowrate, q, through such cracks estimated by

$$q' = c\Delta p^{n} \tag{1}$$

where Δp is the pressure difference in Pa over the crack

c a coefficient with a physical meaning (the flowrate at Δp = 1 Pa) and

n an exponent with a numerical value near 2/3

The coefficient c in equation (1) is proportional to the lenght, L, of the crack.

Equation (1) has been discussed in a lot of papers. Nylund (1979) gives n to 1 for laminar flow and 1/2 for turbulent flow. Normally - according to Nylund - there are some cracks with laminar flow and some with turbulent. Therefore, for practical cases

$$1/2 \lesssim n \lesssim 1 \tag{2}$$

Etheridge (1977) compared experimental results for q', with a discharge coefficient.

$$c = \frac{q'}{A}\sqrt{\frac{8}{2\Delta p}} \tag{3}$$

where A is the cross section area of the air flow ρ in the density of the air.

He found that the discharge coefficient could be written as

$$c = \sqrt{\frac{1}{c_1 + B\frac{z}{d_n}Re}} \tag{4}$$

Where c_1 and B are constants

R_e = Reynolds number $\left(= \frac{(q'/A) \cdot d_n}{\nu}\right)$

ν = the kinematic viscosity

d_n = the hydraulic diameter, i.e. for a long slot = 2 s where s is the width of the slot, and

z = the distance the air flows within the slot

Etheridge also finds that this form for the discharge coefficient corresponds to that for a laminar flow with a singular loss (at the end of the crack).

Honma (1975) suggested that the exponent n in equation (1) is dependent on the pressure loss Δp.

2. Flow in a crack

The flow in a crack is seldom a so called *developed flow*. The crack is normally short and the flow changes direction. In neither of those cases the flows will be developed. The lenght of undisturbed flow in a channel to get a fully developed flow is

$$L_l > \phi \; d_h Re \tag{5}$$

where ϕ depends on the aspect ration for the crack, see picture 1, after Han (1960).

For a tall slot $L \gg s$ the value ϕ = 0,075 will be used for estimating the entrance lenght.

In a "normal crack" an old window (s = 0,0015 m, L = 1 m, $q' \approx$ 1 m^3/hm) we will then have

$$L_l = 0{,}075 \cdot 2 \cdot 0{,}0015 \; \frac{1 \cdot 2}{3600 \cdot 15 \cdot 10^{-6}} = 8 \cdot 10^{-3} \text{ m}$$

The flow is therefore normally not developed. In some constructions the crack is so long so that a developed flow will occur just at the end of the crack.

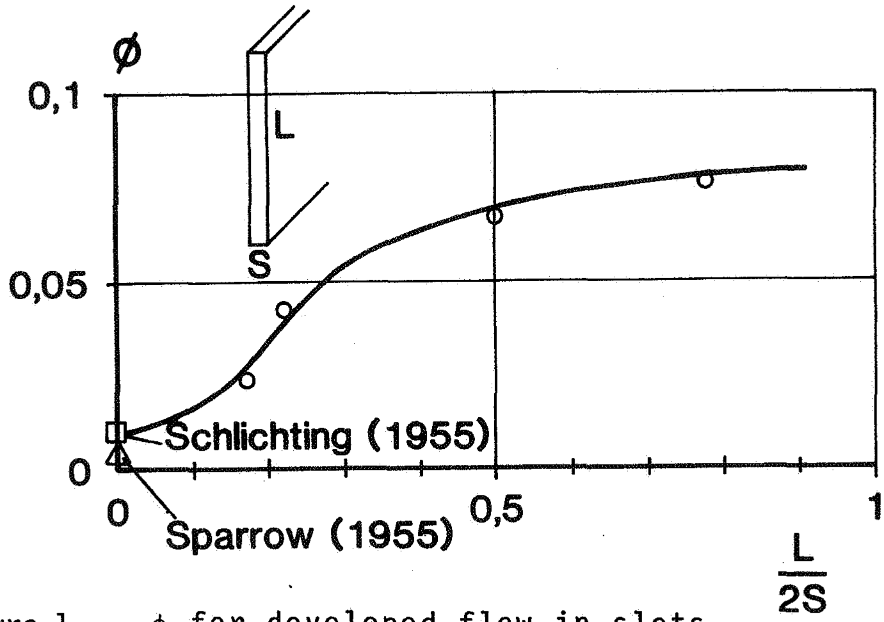

Figure 1. ϕ for developed flow in slots.

The pressure drop in such a flow has been calculated by a lot of researcher. Schiller (1922) showed that the pressure drop could be regarded as composed by two parts:

- o one part depending on the (increased) value for the friction coefficient λ in the slot
- o one part caused by the change in kinematic energy

To these is of course to add the losses at the end of the slot.

The pressure drop can be calculated as

$$\Delta p = \frac{1}{2} \rho \left(\frac{q}{A}\right)^2 \left(\frac{\psi}{R_e}\right)\left(\frac{L_s}{d_h}\right) + K \tag{6}$$

(for the case of $L_s = L_e$). Here are ψ and K coefficients as in table 1.

Equation (6) can also be written

$$\Delta p = \frac{1}{2}\rho \left(\frac{q}{A}\right)^2 \left(\frac{\psi_1}{R_e}\right) \tag{7}$$

where ψ_1 is another coefficient, see picture 2. Equations similar to (6) and (7) have also been given by Kreith (1957) but for tubes.

Table 1. Values for ψ and K according to Han (1960)

$\frac{L}{2sRe}$	ψ	K
1,00	56,9	3,02
0,75	57,8	3,00
0,50	62,1	2,80
0,25	72,8	2,56
0,125	82,3	2,16
0	96,0	1,85

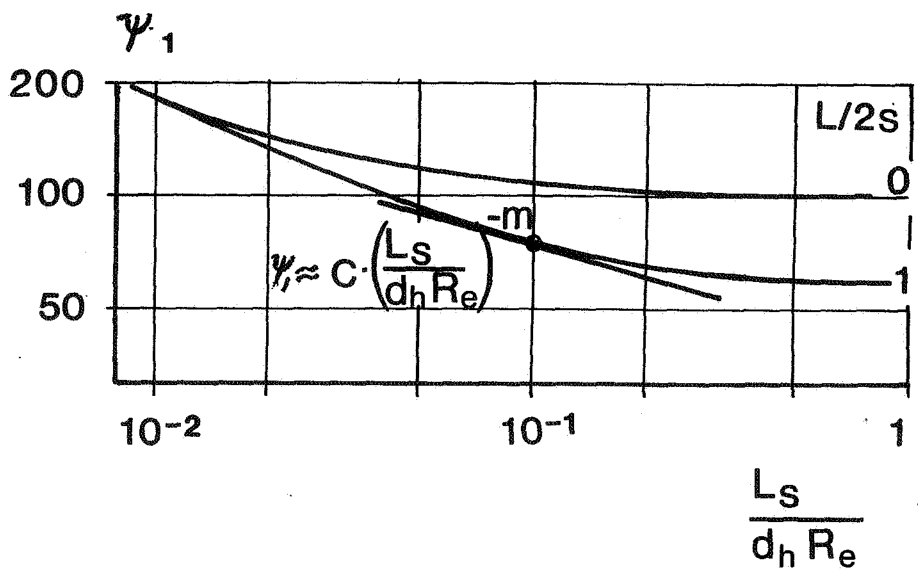

Figure 2. The coefficient ψ_1 in eq (7).

Using the values in the example above we will get

$$\frac{L_s}{d_h R_e} = \frac{8 \cdot 10^{-3}}{2 \cdot 10^{-3} \cdot \left(\frac{1 \cdot 2}{3600 \cdot 15 \cdot 10^{-6}}\right)} = 0,1$$

For this value we can estimate ψ_1 from picture 2 as

$$\psi_1 \approx \text{const.} \cdot R_e^{\,m} \tag{8}$$

see also Kreith (1957) which introduced in (7) will give

$$\Delta p = \text{const } q^{1+m} \qquad (7a)$$

for a given configuration. As can be found from picture 2

$$m \approx 0{,}3 \qquad (9)$$

a value that will be slightly higher for $\frac{L_s}{d_h R_e} < 0{,}1$.

For a "tight" window (or similar) the value of d_h will be smaller than in the example above and so the flow rate q.

This means that $\frac{L_s}{d_h R_e}$ will decrease and so m will increase.

For $\frac{L_s}{d_h R_e} = 0{,}01$ a value of

$$m \approx 0{,}5 \qquad (10)$$

is resonable. It can be used for most cases concerning "tight" constructions. The pressure drop as given by equation (7) will therefore (again for a given geometry) give the (flow-) equation (1) and the value $n = 2/3$. For houses with larger leakage the value will be

$$q = \text{const} \cdot \Delta p^{0{,}77}$$

if $m = 0{,}3$ is used.

For the case of more komplex configuration of the slot similar equations will be useful.

3. Conclusions

The pressure drop in a crack - for instance such as those aroud doors, windows etc - can be calculated using an eq. $\Delta p = \text{const} \cdot q^n$,where q is the flowrate and $n \approx 1,3 - 1,5$. The reason why n differs from 1 or 2 , as for laminar and turbulent flow is that the latter applies for developed flow. Developed flow occurs very seldom in the slots under consideration.

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