AIC Translation No. 11

"Development of an acoustic method of determining air flow through building elements in situ"

Translated from the original German:
"Entwicklung einer akustichen Messmethode zur ermittlung der Luftdurchlässigkeit von Bauelementen im eingebauten zustand"
D.E. Esdorn
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DEVELOPMENT OF ACOUSTIC METHOD OF DETERMINING AIR FLOW THROUGH BUILDING ELEMENTS IN SITU

Client: Federal Ministry of Building and Planning, Bonn-Bad Godesberg
Work carried out by the Technical University of Berlin, Institute for Heating and Air Conditioning.
Research worker: Esdorn
Work completed: November 1977

a) Acoustic work

It is well known that the transmission of sound through slits, such as are inevitably found around doors and windows, depends essentially on the effective width of the slits, which also determines the rate of air flow through the slits. The aim of the work was to determine whether a simple relation exists between noise penetration, i.e. sound damping and slit width, and therefore air flow.

To answer this question, some analysis was carried out which mainly consisted of extending Gompert's calculation to sound incident from all directions and to find simple formulae for transmission in the main region of interest. This was possible using the method of statistical energy analysis, which also showed that with a slit which included a 90^0 change in direction, the noise transfer was the same as for a slit of equal length without a change in direction. The calculation also showed that, even with straight slits, there is a simple relation between sound damping and slit width only for relatively wide slits. Applied to windows, this means that the slit width can only be calculated from the degree of sound damping at high frequencies if the slit is larger than about 0.3% of the window area, and there are fewer than three changes of direction.

In addition to these theoretical considerations, some sound damping measurements were made. The apparatus was the same as that used to measure air flow through slits. An interesting side effect was that the sound damping became a little less when the air flowed through the slit in the same direction as the sound. However, the effect is too small (3 to 4 dB) to serve as a method of measuring the air penetrability (crack coefficient) at a known pressure difference across the slit. Most of the measurements were therefore carried out without air flow. It was found that, for relatively large slits, the slit width

$$\Delta p_{gas} = \left[\zeta_e + \lambda\left(\frac{t}{2h}\right)^{0.84} \cdot f_\varepsilon + \zeta_o + \zeta_\alpha\right] \frac{\rho}{2} \overline{W}^2 \qquad (1)$$

where the parameters have the following meanings:

Δp_{gas}	total pressure drop at the slit
λ	friction factor (4f)
ρ	density
$\overline{W}$	mean flow velocity
f_ε	relative roughness of the sides of the slit (?)
ζ_e	K factor on entry
ζ_o	K factor on exit
ζ_α	additional equivalent coefficient of resistance for the region of the flow out of the slit

The following values remained constant throughout

$\zeta_e = 0.3$ $\qquad$ $\zeta_o = 1.0$ $\qquad$ $f_\varepsilon = 1.0$

For λ and ζ_α under laminar conditions we found:

$$\lambda = 97/Re \quad \text{and} \quad \zeta_\alpha = 0.05 \qquad (2)$$

$$\lambda = \left[2 \lg (Re\sqrt{\lambda}) - 0.8\right]^{-2} \quad \text{and} \quad \zeta_\alpha = -0.1 \qquad (3)$$

The scatter of the results, in relation to the empirical function (1) were 4.1% in the laminar range and 6.2% in the turbulent range. Figure 3 shows the results for the slit depth of 10mm, chosen as example together with the curves corresponding to theory, and function (1).

The equation used in Building Science,

$$\dot{V} = a \cdot l \cdot \Delta p^n \qquad (4)$$

in which a is the crack coefficient
l is the crack length
n is the exponent
and $\dot{V}$ is the volume of flow rate

could easily be determined from the average sound damping at high frequencies. This relation only changes a little if there are one or two 90^0 changes in direction. It was, however, also found that with very narrow slits, and with slits having more than two 90^0 changes in direction, the degree of sound damping depends markedly on other parameters as well. Unfortunately, these are parameters which have no influence on the flow of air through slots, such as the absorption of sound on the sides of the slit and sound reflection at changes in cross section. It follows that, for narrow slits with several changes in direction, an area of particular interest, it is unlikely that a relation between sound damping and air flow can be established.

b) Flow measurements

Measurements were made of flow through uniform slits of little depth and compared with theoretical predictions. Measurements were confined to regions of pressure difference (up to 100 kgf/m^2, 980 Pa), slit widths (up to 7 mm) and slit depths (from 1 to 100 mm) of interest to the building industry. The aim of the work was to be able to calculate the crack co-efficient and the corresponding exponent, which related the volume flow through the crack and the pressure difference across it, to the dimensions of the slit.

Analysis started with the laws for fluid flow in pipes using the equivalent hydraulic diameters of the slits. For laminar flow (Re<2320) two values for the friction factor*, λ=64/Re as for laminar flow in pipes and λ=96/Re, as obtained analytically for infinitely deep uniform slits, were used.

Measurements were made on models of slits made of drawn aluminium, put into a wind tunnel. Flow volumes were determined using orifice plates and floating anemometers (?) or electronic transducers. 34 different combinations of slit width h and depth t were examined, corresponding to a change in the controlling dimensionless number $t/2h$ from 0.1 to 125. The roughness of the aluminium profile was so little that the walls of the slit could be considered as hydraulically smooth, so that the effect of any roughness of the slits was not examined experimentally. It may, however, be assumed that this effect is equal to that in fluid flow through pipes, so that the results obtained can be extended to slits with rough surfaces. The results can be represented by the following empirical function:

was applied to the results for all the combinations of t and h, and the crack coefficients determined and tabulated (Table 1) and the relations $a = f(t,h)$ and $n = f(t.h)$ were shown graphically in Figures 1 and 2.

The complete report has 58 pages and costs 11.60 DM, obtainable from:

The Information Centre of the Frauhofer Gesellschaft
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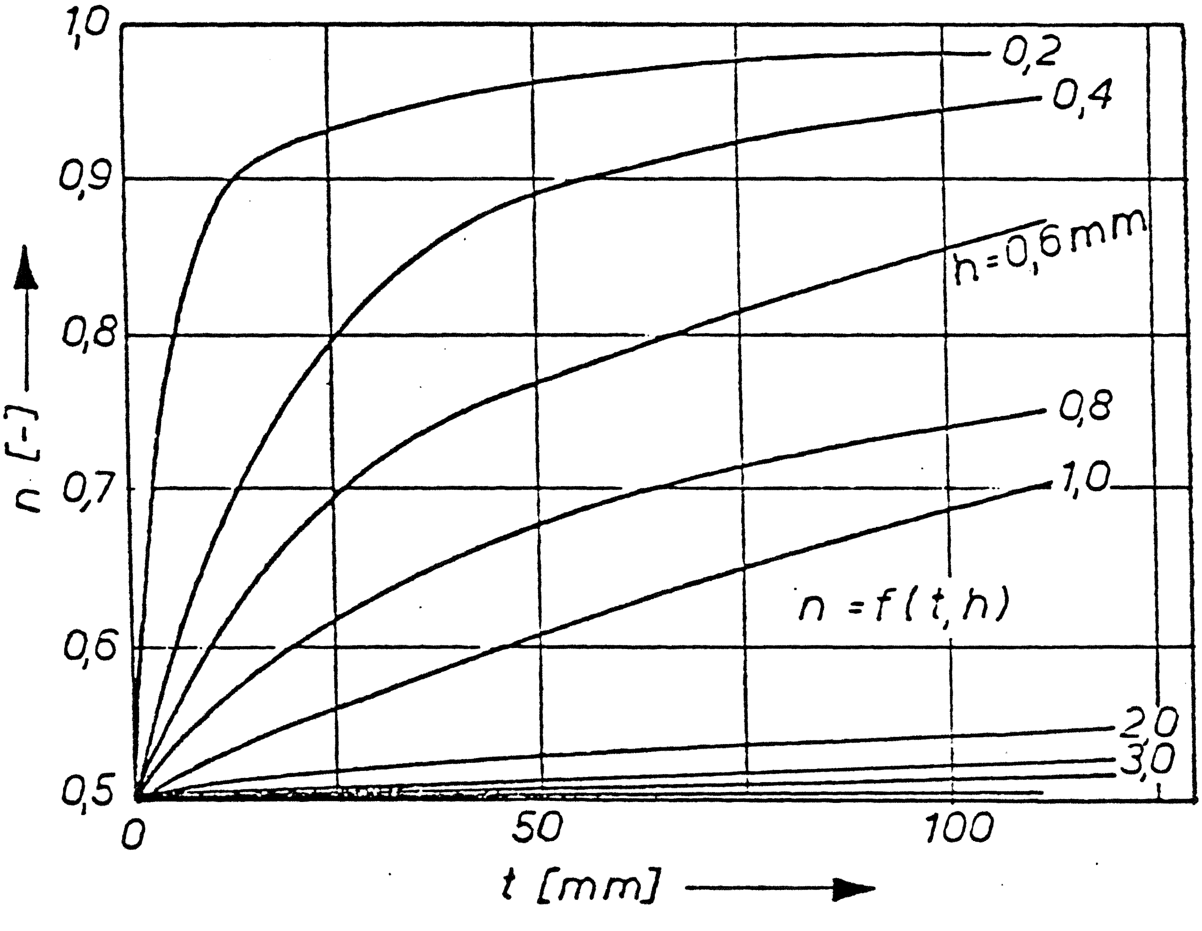
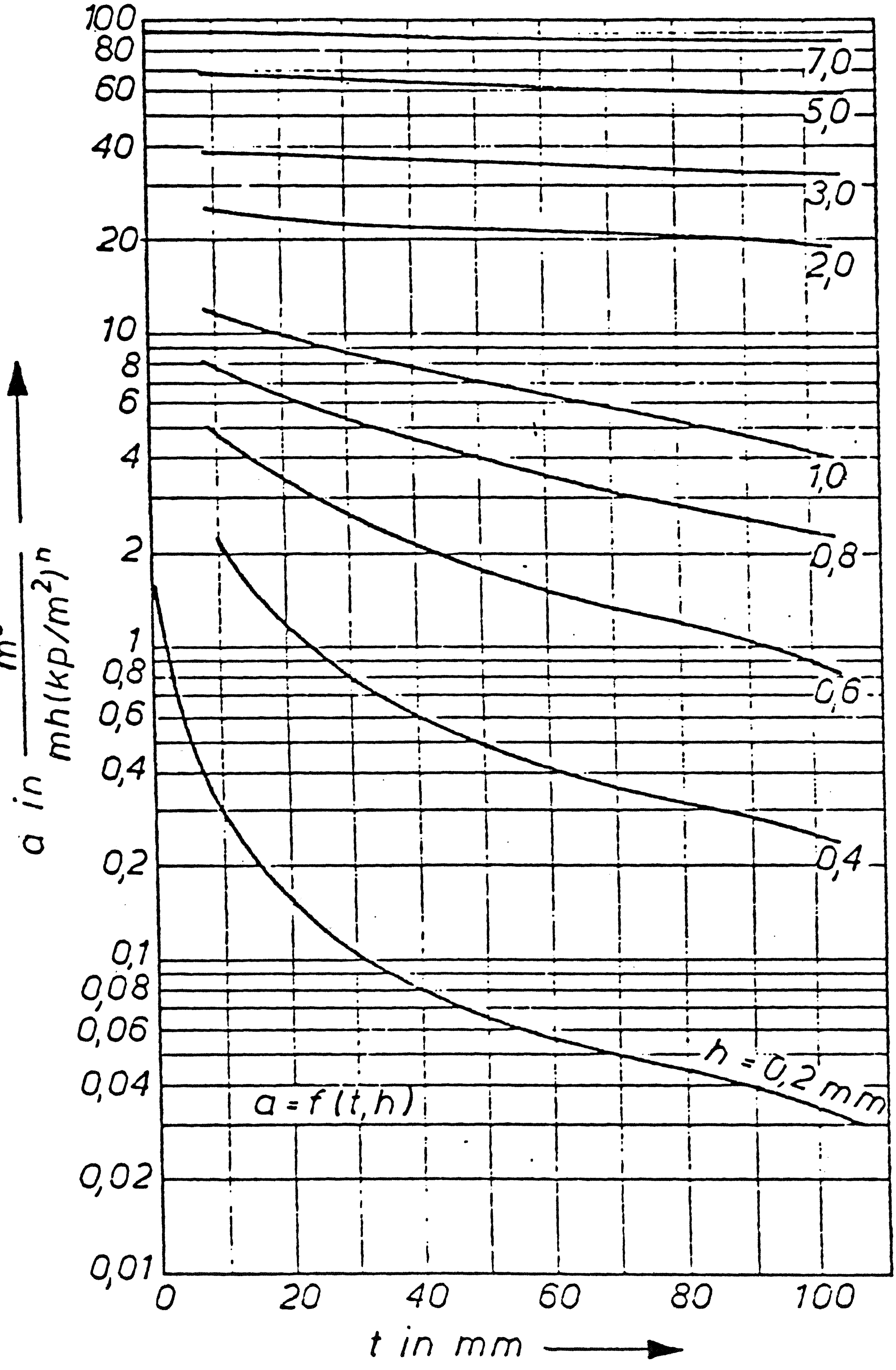


Figure 1



(kp = kilopound = kgf = 9.8 N)

Figure 2

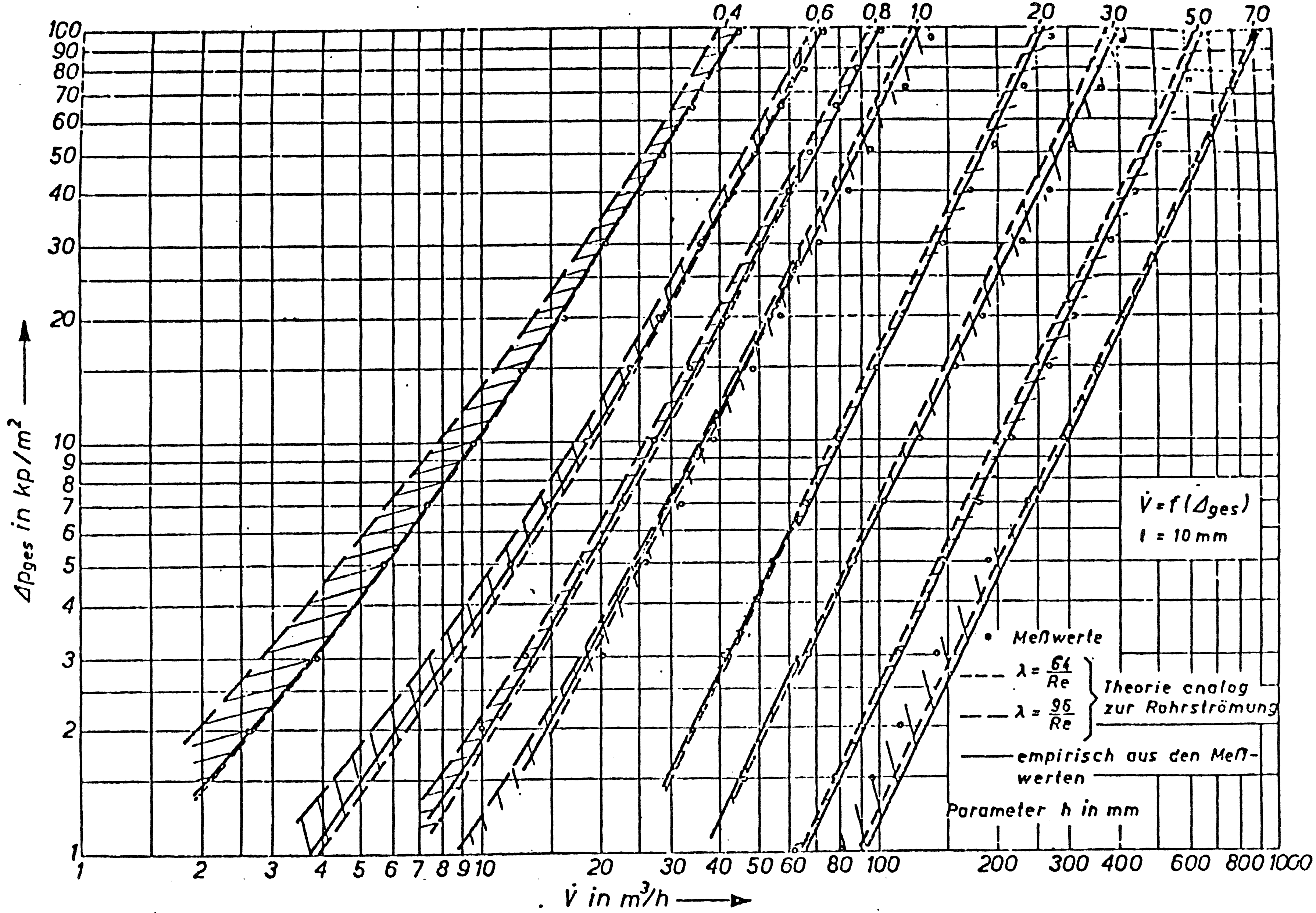

0,4
0,6
0,8
10
20
30
50
70
Δp_{ges} in kp/m²
$\dot{V}$ in m³/h
$\dot{V} = f(\Delta_{ges})$
l = 10 mm
• Meßwerte
$\lambda = \frac{64}{Re}$
$\lambda = \frac{96}{Re}$
Theorie analog zur Rohrströmung
empirisch aus den Meßwerten
Parameter h in mm

Figure 3

h mm	t mm									
	1 mm		10 mm		50 mm		82 mm		100 mm	
	a	n	a	n	a	n	a	n	a	n
0,2	1,55	0,59	0,28	0,87	0,064	0,96	0,043	0,96	0,033	0,98
0,4	-	-	2,14	0,66	0,48	0,89	0,31	0,93	0,245	0,95
0,6	-	-	4,67	0,60	1,75	0,77	1,14	0,82	0,88	0,87
0,8	-	-	7,57	0,56	3,98	0,67	2,72	0,73	2,31	0,75
1,0	-	-	11,21	0,53	7,0	0,60	5,15	0,65	4,19	0,70
2,0	-	-	25,0	0,51	21,8	0,53	20,8	0,52	19,8	0,53
3,0	-	-	38,0	0,51	35,8	0,51	33,5	0,52	32,6	0,52
5,0	-	-	66	0,50	60,3	0,51	60,6	0,51	58	0,52
7,0	95	0,50	93	0,50	87	0,51	88,5	0,50	86	0,51

TABLE 1 Empirically determined crack coefficient a $\left[\frac{m^3}{mh(kp/m^2)^n}\right]$ and

and exponent n $[-]$