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THE INFLUENCE OF VISCOSITY ON SOUND TRANSMISSION THROUGH SMALL CIRCULAR APERTURES IN WALLS OF FINITE THICKNESS

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Summary

The validity of a formula derived earlier for the transmission of sound through small cylindrical apertures in walls of finite thickness has been confirmed by means of a new measuring method with pure tones.

At the same time the influence of viscosity – ignored in the deduction of our earlier formula – was satisfactorily established.

It has been found that a formula of Ingerslev and Nielsen renders a good account of the viscosity losses in the resonance regions, but only gives a very unsatisfactory description of the further course of the transmission characteristic.

The combination of our earlier formula with the formula of Ingerslev and Nielsen for the resonance peaks now gives a reliable rendering of the complete trend of transmission.

A graph has been constructed from which the minimum transmission loss can be read for a given length and diameter of an aperture.

Zusammenfassung

Die Gültigkeit einer früher abgeleiteten Formel für Schallübertragung durch kleine zylindrische Öffnungen in Wänden endlicher Dicke hat sich mittels eines neuen Meßverfahrens mit reinen Tönen bestätigt.

Gleichzeitig wurde der Einfluß der Viskosität, die bei der Ableitung unserer früheren Formel vernachlässigt wurde, auf zufriedenstellende Weise festgestellt.

Es erwies sich, daß eine Formel von Ingerslev und Nielsen die Viskositätsverluste zwar in den Resonanzgebieten sehr gut berücksichtigte, aber den weiteren Verlauf der Übertragungscharakteristik nur auf sehr ungenügende Weise beschrieb.

Die Kombination unserer früheren Formel mit der Formel von Ingerslev und Nielsen für die Resonanzgipfel ergibt jetzt eine zuverlässige Beschreibung des ganzen Übertragungsverlaufes.

Es wurde eine graphische Darstellung zusammengestellt, auf welcher die minimale „Schalldämmung“ für eine gegebene Länge und einen gegebenen Durchmesser einer Öffnung abgelesen werden kann.

Sommaire

A l'aide d'une nouvelle méthode de mesure avec sons purs, on a confirmé la validité d'une formule obtenue précédemment pour la transmission du son à travers de petites ouvertures cylindriques dans des murs d'épaisseur finie.

De plus, on a tenu compte de façon satisfaisante, de l'influence de la viscosité que l'on avait négligée dans l'établissement de la formule précédente. On a trouvé que si la formule proposée par Ingerslev et Nielsen rend compte de façon satisfaisante des pertes de viscosité dans les régions de résonance, elle ne décrit que très imparfaitement le phénomène de transmission. La combinaison de notre formule antérieure avec celle d'Ingerslev et Nielsen pour les pointes de résonance donne maintenant une description bien fondée de l'évolution totale de la transmission. On a construit un graphique qui donne par simple lecture «l'indice d'isolement acoustique» minimum pour une ouverture de diamètre et longueur donnés.

1. Introduction

The influence of viscosity on sound transmission through small apertures in walls has – as far as we know – never been investigated experimentally. The experimental investigation of sound transmission through apertures has been confined to some unsystematic and often dubious sound transmission measurements [1]. We also consider as being weak in principle the method which was first applied by Schoch [1], later by Ingerslev and Nielsen [2] and recently by Fasold [3]. These investigators determined the sound transmission factor of an aperture from the decrease in transmission loss of a partition wall by making such an aperture in it.

* Publication number 223.

[1] See postscript.

The accuracy of such indirect measurements, however, especially for small apertures, is very low and certainly does not suffice to determine the influence of viscosity (which was not the immediate aim of the investigators mentioned). Moreover the known insulation formula, which is used with this method, is based on the notorious assumption of a diffuse sound field in the transmitting and receiving room, which assumption is incorrect for somewhat larger apertures were it only on account of the aperture in the partition wall.

In this paper we now describe a comparatively simple measuring method by means of which, as opposed to our earlier technique [4], we were able to determine fairly accurately the sound transmission factor also for the resonance regions.

Owing to the fact that we already had at our disposal a formula for calculating the sound transmission factors in the theoretical case where there is no viscosity [4], we were at the same time able to establish the influence of viscosity by means of these simple sound transmission measurements.

As expected, this influence was found to be negligible outside the resonance regions. At the resonance frequencies of the apertures the viscosity losses satisfied a formula of Ingerslev and Nielsen [2] in spite of its somewhat doubtful deduction (see Section 3).

2. Elucidation of the symbols (insofar as they are not defined in the text)

Agreeing as far as possible with our previous article [4], we give the following definitions:

α = end correction of aperture,
ε = radius of the circular cross-section of the cylindrical aperture,
$K = k\,\varepsilon = \frac{2\pi}{\lambda}\,\varepsilon$,
λ = wavelength,
μ = kinematic shear viscosity coefficient in air $\approx 1.56 \times 10^{-5}\,\mathrm{m^2/s}$ (at 20 °C and 0.76 m Hg),
ν = frequency,
π = 3.1415 ....,
ϱ = density of the air,
$\omega = 2\pi\nu$,
c = sound velocity,
$\mathrm{i} = \sqrt{-1}$,
$k = \frac{\omega}{c} = \frac{2\pi}{\lambda}$ = wave number,
l = length of aperture,
p_w = effective value of the sound pressure directly in front of the (closed) aperture,
p_r = effective value of the sound pressure at r cm distance behind the (now open) aperture,
$q_\mathrm{a} = \frac{W_{\mathrm{R_a}}}{W_{\mathrm{S_a}}}$ = sound transmission factor,
$R_\mathrm{a} = -10 \log q_\mathrm{a}$ = transmission loss of aperture,
R_r = resulting transmission loss of wall with aperture,
S_a = area of cross-section of aperture,
S_w = area of the partition wall,
$W_{\mathrm{R_a}}$ = energy on receiving side radiated by aperture,
$W_{\mathrm{S_a}}$ = input energy at the site of the (closed) aperture on the transmitting side.

3. Formula of Ingerslev and Nielsen

According to Ingerslev and Nielsen the sound transmission of a cylindrical aperture in a wall on which a plane wave falls perpendicularly is not essentially different from that of an identical aperture in which massless rigid pistons are moving at both ends. The following equivalent electrical circuit can be drawn for this system (Fig. 1).

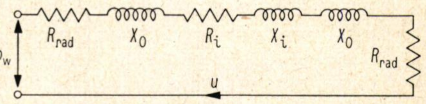

Fig. 1. Equivalent electrical circuit for the sound transmission through a cylindrical aperture according to Ingerslev and Nielsen.

Where:

$R_\mathrm{rad} + \mathrm{i}\,X_0$ = the acoustical (radiation) impedance of each individual piston; this impedance makes due allowance for the reaction forces of the air upon the pistons. According to Rayleigh the following applies:

$$R_\mathrm{rad} + \mathrm{i}\,X_0 = \frac{\varrho\,\omega^2}{2\pi c} + \mathrm{i}\,\frac{8}{3\pi^2}\,\frac{\varrho\,\omega}{\varepsilon}, \tag{1}$$

X_i = the reactance of a pipe which is open at both ends, i. e. without external forces. By analogy with a short-circuited electrical transmission line:

$$X_\mathrm{i} = \frac{\varrho\,c}{\pi\,\varepsilon^2}\tan kl, \tag{2}$$

R_i = the internal friction resistance. According to Crandall [5] and Sivian [6]:

$$R_\mathrm{i} = \frac{l + \frac{\pi}{2}\,\varepsilon}{\pi\,\varepsilon^3}\,\varrho\,\sqrt{2\,\mu\,\omega}, \tag{3}$$

U = volume velocity.

INGERSLEV and NIELSEN have introduced into this circuit the following two refinements:

1) In view of the fact that the particle velocity at the real aperture is not constant over the orifices whereas this is indeed the case with the pistons, INGERSLEV and NIELSEN replace the value

$$X_0 = \frac{8}{3\pi^2}\frac{\varrho}{\varepsilon}\,\omega \approx 0.270\,\frac{\varrho}{\varepsilon}\,\omega$$

by the value

$$X_0 = 0.250\frac{\varrho}{\varepsilon}\,\omega\,. \tag{4}$$

2) Since in the deduction of eq. (3) the average particle velocity is assumed to have the same value in each cross-section of the cylindrical aperture, whereas at resonance this assumption is certainly not fulfilled, INGERSLEV and NIELSEN replace eq. (3) by the following expression which they consider more correct:

$$R_i = \frac{1}{\sqrt{2}}\,\frac{l+\frac{\pi}{2}\varepsilon}{\pi\,\varepsilon^3}\,\varrho\sqrt{2\,\mu\,\omega}\,. \tag{5}$$

The acoustical energy radiated by the aperture can now be easily calculated from the equivalent circuit:

$$W_{R_a} = U^2 R_{rad} = \frac{p_w^2}{(2\,R_{rad}+R_i)^2+)2\,X_0+X_i)^2}R_{rad}\,. \tag{6}$$

The incident energy is (see [4], p. 5)

$$W_{S_a} = \frac{\pi\,\varepsilon^2\,p_w^2}{4\,\varrho\,c}\,. \tag{7}$$

Therefore:

$$q_a = \frac{W_{R_a}}{W_{S_a}} = \frac{4\,\varrho\,c}{\pi\,\varepsilon^2}\,\frac{R_{rad}}{(2\,R_{rad}+R_i)^2+)2\,X_0+X_i)^2} \tag{8}$$

At resonance $2\,X_0+X_i=0$, therefore

$$q_{max} = \frac{\varrho\,c}{\pi\,\varepsilon^2\,R_{rad}}\,\frac{1}{\left(1+\dfrac{R_i}{2\,R_{rad}}\right)^2} = \frac{2}{K^2}\,D\,, \tag{9}$$

where the damping factor

$$D = \frac{1}{\left(1+\dfrac{R_i}{2\,R_{rad}}\right)^2}. \tag{10}$$

By substitution of eq. (1) and eq. (5) in eq. (10) and bearing in mind that $l+2\,\alpha \approx l+\frac{\pi}{2}\varepsilon$ and at resonance $l+2\,\alpha = s\,\lambda/2\,(s=1,2,3,\ldots)$ eq. (10) of INGERSLEV and NIELSEN can also be resolved into the form:

$$D = \left[1+\frac{(L+2\,e)^{5/2}\,W^{1/2}}{(\pi\,s)^{3/2}}\right]^{-2}, \tag{11}$$

where: $L=\frac{l}{\varepsilon}$, $e=\frac{\alpha}{\varepsilon}$, $W=\frac{\mu}{c\,\varepsilon}$ and $s=1,2,3,\ldots$

Outside the resonance regions R_i can be ignored, and by substitution of the given values for R_{rad}, X_0 and X_i, eq. (8) changes into:

$$q_a = \frac{2}{K^2+\left(\dfrac{\pi}{2}+\dfrac{\tan K\,L}{K}\right)^2}\,. \tag{12}$$

For very low frequencies ($l \ll \lambda$) it follows from eq. (12) that:

$$q_{l\ll\lambda} \approx \frac{2}{(L+2\,e)^2}\,. \tag{13}$$

4. Comparison of the results obtained by Ingerslev and Nielsen with those of the authors

In our previous paper [4] we considered three special cases, viz:

1. The case of a very thin wall ($l \ll \lambda$).
2. The case of resonance: $l+2\,\alpha = s\,\lambda/2$ $(s = 1, 2, 3, \ldots)$.
3. The case of antiresonance: $l+2\,\alpha = (2\,s+1)\,\lambda/4$ $(s = 0, 1, 2, 3, \ldots)$.

For the first two cases the results (9) and (13) of INGERSLEV and NIELSEN are identical with our eqs. *(46)* and *(47)*[2] (apart from the damping factor D, which does not occur in our eq. *(47)* because from the outset we have ignored viscosity).

For the case of antiresonance, in contrast to this, eq. (12) gives very sharp "antiresonance peaks", even sharper than the resonance peaks, owing to the fact that in the antiresonance region $\tan K\,L \to \infty$ and hence $q \to 0$. These "antiresonance peaks" were not, however, manifested at all in our measuring results, nor in the results of the aforementioned investigators, which drew from FASOLD the remark that in practice these peaks only occur to a much smaller extent [3].

According to our eq. *(45)* there is, however, no question of peaks in the antiresonance regions. The occurrence of such peaks in eq. (12) must in our opinion be attributed to the incorrectness of the deduction: it has not been shown convincingly beforehand that the "equivalent" circuit will indeed give a good rendering of the transmission trend, for example by proving that both systems lead to the same differential equations.

Eq. (12) is therefore more defective than is perhaps to be expected in view of the good results of

[2] Equations from [4] will henceforth be indicated by *italics*.

the first two special cases: only the transmission factors for very low frequencies and the resonance peak values (not the form of the resonance peaks themselves) are well approximated by the formula.

5. Our measuring method

5.1. The set-up

The measurements were carried out in our new T.N.O. laboratory. Between the large reverberation chamber (400 m^3) and the anechoic chamber covered with wedges of foam plastic (useful volume 7 m $\times$ 5 m $\times$ 5 m) is a measuring aperture of 2.75 m $\times$ 3.65 m for the purpose of examing test walls for their sound radiation. (Also this measuring aperture may be covered over in the anechoic chamber by means of a sliding panel covered with wedges.)

For the present research the test wall consisted of two plaster walls, each 8 cm thick, with an intervening air space of 36.8 cm. A brass tube was passed through the middle of this double wall, which tube had a length equal to the total thickness of the double wall (52.8 cm) and a diameter of 2.94 cm (Fig. 2).

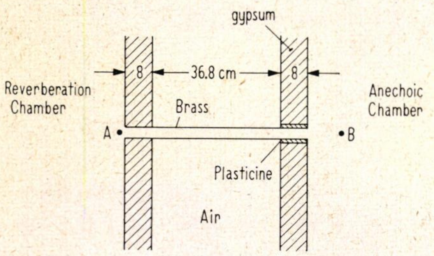

Fig. 2. Fastening of the brass tube into the double wall between reverberation chamber and anechoic chamber.

In order to reduce the transmission loss of the double wall as little as possible the tube was fixed into the plaster wall on one side with plasticine. The other side of the tube was closed temporarily with a plaster plug.

In the reverberation chamber, at site A, directly in front of the now closed tube (at a distance of 0.1 cm) a microphone was placed, which was connected to a dB-recorder. This combination registered automatically the sound level at A, generated by a loudspeaker installed in a corner of the reverberation chamber. The loudspeaker was connected with a beat frequency generator which passed automatically through all the frequencies from 100 Hz to 7000 Hz.

After the so-called transmitting level had been recorded (see registration tape 1, Fig. 3) without further altering the set-up or the adjustment of the apparatus, the microphone of the reverberation chamber was transferred to the anechoic chamber and placed there at a distance of 10 cm from the aperture, in such a way that the axis of the microphone coincided with the axis of the aperture. The dB-recorder now registered the so-called ambient noise level, i.e. the sound that reached the microphone via the closed wall (see registration tape 2).

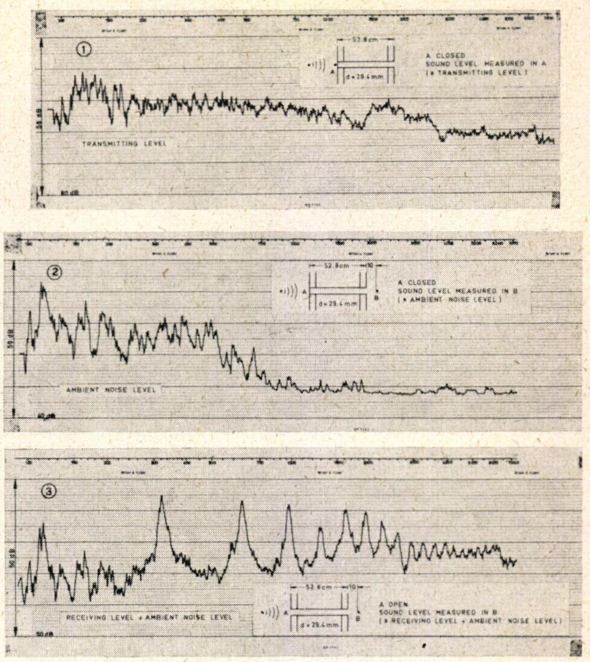

Fig. 3. Transmitting level, ambient noise level and receiving + ambient noise level for an aperture 29.4 mm in diameter.

Finally, the plaster plug was removed from the tube and, again without further altering the set-up of the apparatus, the combined receiving level and the ambient noise level were registered, i.e. the sound which reached the microphone via the open tube and the otherwise closed wall (tape 3).

If the transmitting level had a "smooth" frequency characteristic, then this (considered for a moment apart from the ambient noise level, which, as appears from tapes 2 and 3, had an influence up to only 600 Hz) would also have been the case for the receiving characteristic. But now that the transmitting level as a result of the many normal frequencies in the reverberation chamber has a very erratic trend, the receiving level will have a corresponding trend; the same peaks and valleys of the transmitting characteristic will, though somewhat mutilated, come through on the receiving characteristic.

By very carefully comparing the transmitting characteristic and the receiving characteristic with each other it is possible to trace corresponding peaks, valleys, etc. on the tapes 1 and 3 and in this way to determine fairly accurately the difference in sound level $10 \log (p_w/p_r)^2$ for various frequencies. (This is not possible by simply superimposing the frequency scales at the top of the two tapes upon each other, as might perhaps be expected. These frequency scales only give a rough indication of where, on both tapes, the corresponding regions must be searched for. The determining of the frequencies on the various tapes cannot be effected with sufficient accuracy in view of the elastic coupling between the beat frequency generator and the dB-recorder and the comparatively great variation velocity of the frequencies.)

In a similar manner, viz. by comparing tapes 2 and 3 the ambient noise level can be evaluated.

The same series of measurements was also carried out for tubes with diameters of 2.43 cm; 1.93 cm; 1.53 cm; 0.93 cm and 0.44 cm (see tapes 4 to 7, Fig. 4).

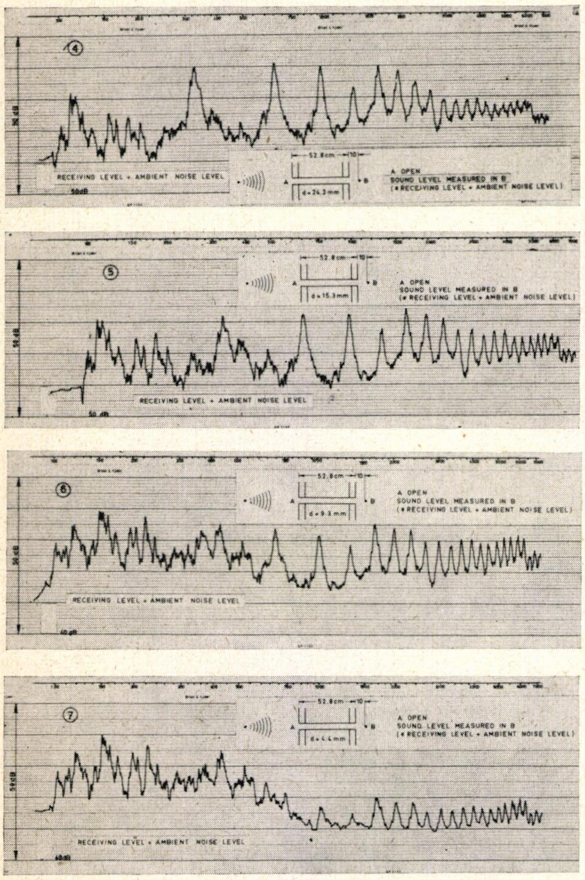

Fig. 4. Receiving level + ambient noise level for apertures with different diameters d.

Except for the Philips loudspeaker the measuring set-up consisted entirely of Brüel and Kjaer apparatus.

5.2. Corrections

As the microphone, when mounted in the reverberation chamber, is situated in a more or less diffuse sound field, whereas when mounted in the anechoic chamber it is in a directional field and equal sound levels are registered somewhat differently under these different conditions, all the values of the calculated magnitude

$$10 \log \left(\frac{p_w}{p_r}\right)^2$$

must be further corrected according to the data in the Brüel and Kjaer catalogue for the type of microphone used. We roughly checked these data (and found them correct) by registering the receiving level under identical conditions with the microphone in the position indicated above (microphone axis parallel to axis of aperture) and in a position in which the microphone axis was perpendicular to the axis of the aperture.

The corrections for the magnitude $10 \log (p_w/p_r)^2$ varied from +0.5 dB at 1000 Hz to +4.5 dB at 7000 Hz.

5.3. Reproducibility

The differences in the case of repeated registration of one and the same frequency characteristic amounted to about 2 dB maximum.

5.4. Check measurements

It is found from the measuring results that especially the resonance peaks at the lower frequencies are greatly reduced as compared with the theoretical values at which viscosity was ignored. As at the start we did not rule out the possibility that a part of these reductions was the result of transmission losses through and resonance of the comparatively thin brass wall of the tube (thickness 1.2 mm), which was in a detached position in the air over 36.8 cm, we moulded a plaster block of 26 cm × 26 cm × 52.8 cm around the brass tube and fixed the tube with the plaster block into the double wall. In order not to lessen the transmission loss of the double wall we carried out this fixing of the tube into the wall elastically by means of rubber supports and a plasticine seal. (The insulation of the wall was found afterwards to have improved somewhat!)

The results of the measurements with the tube in the plaster block did not, however, differ from the measurements with the tube in a detached position in the air. From this we found that the reductions established were caused solely by viscosity losses.

In order to investigate to what extent the viscosity losses depend on the nature of the wall surface, we spread the inner wall of the tube with oil and repeated the measurements. This time also there was no difference as compared with the previous results.

Subsequently we scattered fine dune-sand over the layer of oil, as a result of which the inner surface of the tube became very rough. The small difference in measuring results that could now be observed was presumably caused solely by the naturally somewhat narrowed aperture of the tube.

The nature of the wall surface is therefore seemingly unimportant in the first approximation.

Finally, we investigated whether the transmitting characteristic was sensitive to small variations in the distance of the microphone from the separating wall, which distance was always about 1 mm during our tests.

For this purpose we fixed a microphone to a micrometer permanently mounted near the wall, by which we were able to regulate the distance of the microphone from the wall from 0 to 5 mm. We now registered the sound level at 3000 Hz for distances of 0, 1, 2, 3, 4 and 5 mm. In accordance with our expectations there were no measurable differences.

6. Experimental results

In order to obtain the transmission loss of the aperture from the observed sound level differences $10 \log (p_w/p_r)^2$, the formula to be applied in the case where the aperture is situated in a wall of infinite extent, upon which a plane wave falls perpendicularly is as follows (see [4]):

$$R = -10 \log q = 10 \log \left(\frac{p_w}{p_r}\right)^2 + 10 \log \frac{\varepsilon^2}{8\, r^2} \quad (14)$$

and in the case where the aperture is in the middle of the partition wall between the transmitting chamber and the receiving chamber and there prevails a diffuse field in the transmitting chamber, the formula is:

$$R = -10 \log q = 10 \log \left(\frac{p_w}{p_r}\right)^2 + 10 \log \frac{\varepsilon^2}{16\, r^2}. \quad (15)$$

Here ε is the radius of the aperture and r the distance of the microphone (in the receiving chamber) behind the aperture; in our experiments r was equal to 10 cm. (Remark: the fact that in our measurements we were concerned exclusively with the second case has no bearing on the matter: the same sound pressure p_w which we measured before the (closed) aperture, could just as easily have been generated by a plane wave.)

In Fig. 5 the value R has been plotted as a function of K. The dash line gives the measured curve, which was found to have shifted somewhat with regard to the curve (full line) calculated with eq. (*45*). This shift may very probably be attributed to the comparatively great velocity with which the beat frequency generator passed through the frequencies from 100 Hz to 7000 Hz, as a result of which, as already mentioned above, the frequency corresponding to a certain point of the characteristic

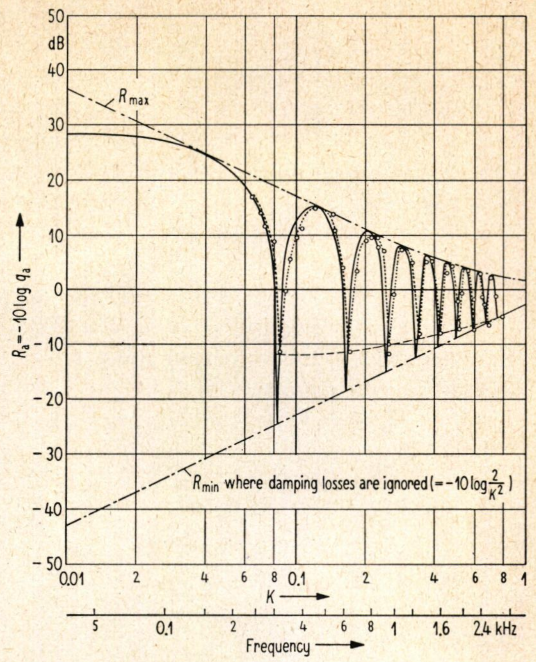

Fig. 5. Measured (–o–o–o–) and calculated (———) transmission loss R of a cylindrical aperture with length $l = 528$ mm and diameter $d = 29.4$ mm, for the case where a plane wave falls perpendicularly on the wall in which the aperture is situated. (For a diffuse sound field instead of a plane wave, all the transmission loss values must be diminished by 3 dB.)

was evidently not read at the correct moment. Indeed when the resonance frequencies were adjusted by hand, they corresponded exactly to the calculated resonance frequencies.

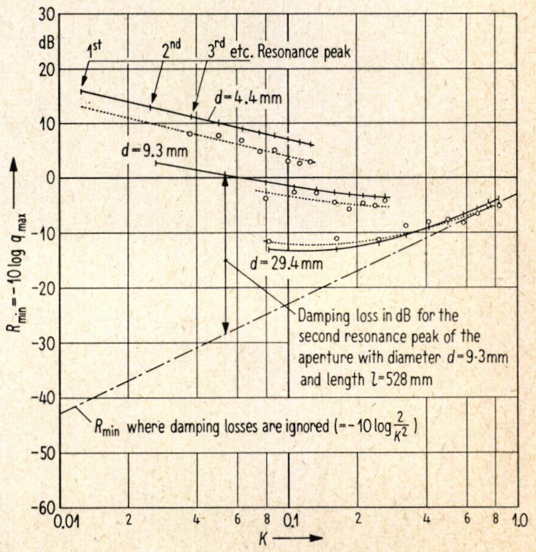

Fig. 6. Calculated (–|–|–) and measured (–o–o–) transmission loss R_{min} at resonance frequencies of equally long cylindrical apertures ($l = 528$ mm) with different diameters d.

That the measured resonance peaks are much less sharp than the theoretical resonance peaks (without viscosity) is, as we observed, very probably due solely to viscosity losses the magnitude of which we now wish to determine.

For this purpose the measured peak values and the calculated peak values, ignoring viscosity have been plotted in Fig. 6 for three different aperture diameters as a function of K (dotted line and dash-and-dot line respectively). At the same time the full lines in this Figure show the peak values calculated by means of eq. (9); on these lines the positions of the first ten resonance peaks are indicated by ten vertical stripes.

The peak values calculated by means of eq. (9) and the measured peak values show satisfactory agreement; the greatest deviations (about 3 dB) are of the same order of magnitude as the inaccuracies in measurement.

7. Application of these results

Eq. (9) was finally used to calculate the minimum transmission loss for various combinations of lengths and diameters of the apertures. Fig. 7 gives the result.

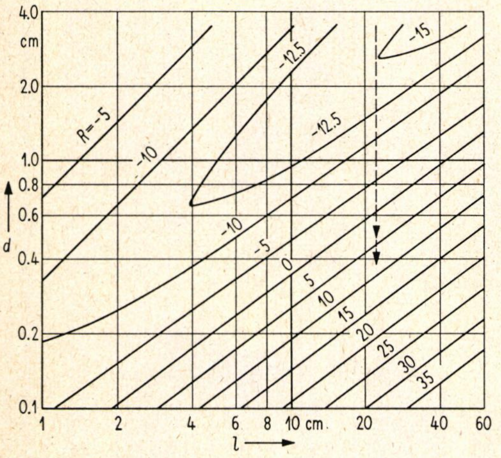

Fig. 7. Transmission loss R of a cylindrical aperture with length l cm and diameter d cm at the first resonance frequency (it is assumed that a plane wave falls on the aperture; for a diffuse field all the values R must be diminished by 3 dB, 6 dB or 9 dB according to whether the aperture is situated in the middle of the partition wall, in the middle of one of its edges or in one of its corners).
Dangerous diameter region for single-brick wall ($\Delta R > 1$ dB):
↓ aperture in the middle of the wall,
↓ aperture in a corner of the wall.

On the basis of this graph it is easy to calculate the resulting minimum transmission loss for the case of a given aperture in a given wall, of which the transmission loss in an intact condition is known. Example: What minimum transmission loss R_r will result if a cylindrical aperture with a diameter of 2.2 cm is made in the middle of a wall, 22 cm thick and 11 m² in area, of which the transmission loss curve in an intact condition coincides exactly with the "Sollkurve"?

Solution: From Fig. 7 we read that the minimum transmission loss of an aperture with length $l = 22$ cm and diameter $d = 2.2$ cm amounts to about -14.5 dB if the field of incidence is a plane wave. For a diffuse field of incidence this value must be diminished by 3 dB, therefore $R_{min} = -17.5$ dB.

By means of eq. (51) we now find the resulting transmission loss:

$$R_r = 10 \log \frac{S_w}{S_a} + R_a = 10 \log \frac{\pi\, 1.1^2}{110000} + \\ + R_{min} = 44.6 - 17.5 = 27.1 \text{ dB}.$$

Remark: The transmission loss of the wall in its intact condition is a rather superfluous datum: it is of importance only for very small apertures or for walls with a very small transmission loss (see [4], p. 9).

In Fig. 8 the entire transmission loss curve has been drawn for the conditions mentioned in the example. In contrast to our earlier procedure (Fig. 3 in [4]), viscosity has now been taken into account: the dash curve in Fig. 6 determines the real positions of the resonance peaks.

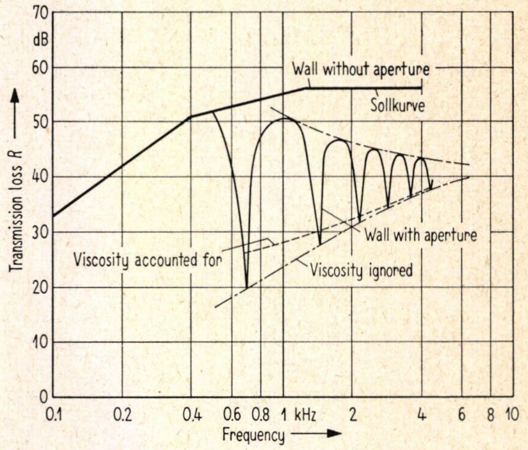

Fig. 8. The transmission loss R of a wall, 22 cm thick and 11 m² in area, with and without a cylindrical aperture 2.2 cm in diameter.

Finally, the arrow in Fig. 7 indicates which aperture diameters in a single-brick wall cause the transmission loss at the resonance frequency of the aperture to drop by more than 1 dB (for only one such aperture). Fig. 7 shows that apertures of less than 4 mm diameter do not appreciably diminish the transmission loss of a single-brick wall, not even for the most unfavourable case where the tone of a whistling kettle possesses exactly the same frequency as the resonance frequency of the aperture in the wall.

Acknowledgement

The author hereby wishes to express his thanks to Mr. J. H. K. Holst for his agreeable cooperation and the commendable manner in which he executed the measurements, and to Mr. A. F. C. v. d. Linden for his interest and most useful comments.

Postscript

During the preparation of this paper the writer received a letter from Prof. W. W. Soroka of California, in which the latter informed him that Dr. Wilson and he himself had also conducted an extensive theoretical and experimental research on sound transmission through small apertures.

After publication of their work they were to send the writer a copy. The contents of this copy are not as yet, however, known to him.

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