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Transmission Parameters of Porous Sound Absorbers (with Particular Reference to the Flow Resistance)

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FLOW resistance, being relatively easy to measure, is commonly used as a rough guide in choosing sound-absorbing materials for specific purposes. This practice is based on the tacit assumption that, when there is an alternating air-flow through the sample, the resistance encountered is identical with the flow resistance. It can be shown, however, that in the case of several materials this assumption is false, and that the acoustical resistance under alternating conditions is substantially greater than the flow resistance.

To establish the variation of effective resistance with frequency the characteristic impedance (Z_0) and the specific transmission constant ($\gamma = \alpha + j\beta$) of a number of commonly used porous sound-absorbing materials have been measured over the range 100–1,300 c/s using samples 1 in.–3 in. thick inserted into a rigid tube 3·47 in. in diameter. At each frequency sound is passed into the sample under two conditions in succession: first, when the sample is terminated by an impedance effectively infinite, and second when the terminal load is purely capacitive. By adopting an electroacoustic artifice the effect of the input impedance of the probe microphones, which measure the sound pressure, is completely eliminated, and by using an a.c. potentiometer to measure microphone voltages, the pressure ratio is derived as a complex number. Assuming that conventional transmission theory is applicable, this ratio is $\cosh(\gamma l)$ (l = sample thickness); whence γl. Knowing γl, the second test yields Z_0 in terms of the terminal capacitance.

After analysing the variation with frequency of these two parameters, it is found that in all the materials examined the series arms of the equivalent-tee network which represents the performance of the acoustical structure contain resistance and inductance in series, the shunt arm being a capacitance in series with a small resistance. Where the test samples have been sufficiently stable to yield very precise data it has been possible to investigate the series arms of the tee network in detail; it is then found that each branch consists of two series combinations of R and L in parallel which have impedances $(R_1 + j\omega L_1)$ and $(R_2 + j\omega L_2)$, L_2, say, being greater than L_1. Re-analysis of the data published in ref. 1 confirms this curious disposition. The same data also confirm the series arrangement of the shunt branch of the tee-network, a fact apparently unrecognized by the authors. It is to be noticed that a later publication[2] discusses the possibility of a rather similar disposition, using arguments of quite a different kind. Yet another publication[3] presents data which on re-analysis confirm the series combination of R and C, in the shunt arm, mentioned here.

If then we assume that the series arm of the equivalent tee-network has the dual form described, with $L_2 > L_1$, it is clear that flow resistance measures the value of R_1 in parallel with R_2, whereas when frequency rises from zero the effective resistance rises towards R_1—a quantity which in various materials has been found to be of the order of 1·5 up to 3 or more times the flow resistance. Moreover, as L_2 may be many times greater than L_1, the frequency at which the transition from the lower to the higher effective resistance is substantially complete may be as low as 150 c/s; usually it is in the region of 200–300 c/s.

Knowing both Z_0 and γ it has been possible to go a stage further and to build electrical artificial lines, the input impedance of which imitates the acoustical impedance, at normal incidence, which sheets of any thickness of the tested materials would present when mounted on the walls of a room as sound absorbers. The real part of the electrical input impedance is—subject to the usual corrections—a measure of the acoustical resistance in which the sound would be absorbed. By modifying the length of the artificial line and its terminal impedance it becomes possible to predict the effect of altering the thickness of the absorber and of its method of mounting.

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