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Atmospheric absorption of sound: Update

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Best current expressions for the vibrational relaxation times of oxygen and nitrogen in the atmosphere are used to compute total absorption. The resulting graphs of total absorption as a function of frequency for different humidities should be used in lieu of the graph published earlier by Evans *et al.* [*J. Acoust. Soc. Am.* **51**, 1565–1575 (1972)].

PACS numbers: 43.35.Ae, 43.35.Fj

In 1972, Evans *et al.* published a family of curves for absorption of sound in a still atmosphere.¹ Since that time, Fig. 8 of that paper for total amplitude absorption has appeared in a number of publications. Now that improved analytical expressions are available, we want to present these expressions as well as updated total amplitude absorption curves.

Reference 2 gives the absorption of sound in still air in nepers per meter as

$$\alpha = f^2 \left[1.84 \times 10^{-11} \left(\frac{p_s}{p_{so}} \right)^{-1} \left(\frac{T}{T_0} \right)^{1/2} + \left(\frac{T}{T_0} \right)^{-5/2} \right. \\ \times \{ 1.278 \times 10^{-2} [\exp(-2239.1/T)] / \\ [f_{r,O} + (f^2/f_{r,O})] + 1.068 \times 10^{-1} \\ \times [\exp(-3352/T)] / [f_{r,N} + (f^2/f_{r,N})] \} \}, \quad (1)$$

where f is the acoustic frequency in Hz, p_s is the atmospheric pressure, p_{so} is the reference atmospheric pressure (1 atm), T is the atmospheric temperature in K, T_0 is the reference atmospheric temperature (293.15 K), $f_{r,O}$ is the relaxation frequency of molecular oxygen and $f_{r,N}$ is the relaxation frequency of molecular nitrogen.

Since publication of Ref. 2, additional experimental

measurements³ have given better estimates for $f_{r,O}$ and $f_{r,N}$. The best estimates are now

$$f_{r,N} = \frac{p_s}{p_{so}} \left(\frac{T_0}{T} \right)^{1/2} \left(9 + 280h \exp \left\{ -4.17 \left[\left(\frac{T_0}{T} \right)^{1/3} - 1 \right] \right\} \right) \quad (2)$$

and

$$f_{r,O} = (p_s/p_{so}) [24 + 4.04 \times 10^4 h(0.02 + h) \\ \times (0.391 + h)^{-1}], \quad (3)$$

where h is the molar concentration of water vapor in percent. Equations for calculating h from the relative humidity h_r follow

$$h = h_r (p_{\text{sat}}/p_{so}) / (p_s/p_{so}) \text{ in } \%, \quad (4)$$

where the saturated vapor pressure p_{sat} divided by the ambient pressure p_{so} is given by

$$\log_{10} \frac{p_{\text{sat}}}{p_{so}} = 10.79584 \left(1 - \frac{T_{01}}{T} \right) - 5.02808 \log_{10} \\ \times (T/T_{01}) + 1.50474 \times 10^{-4} \{ 1 - 10^{-8.29692} \\ \times [(T/T_{01}) - 1] \} + 0.42873 \times 10^{-3} \{ 10^{-4.76955} \\ \times [1 - (T/T_{01})] - 1 \} - 2.2195983, \quad (5)$$

and $T_{01} = 273.16$ K.

Figures 1 and 2 present updated absorption curves based upon Eqs. (1)–(3).

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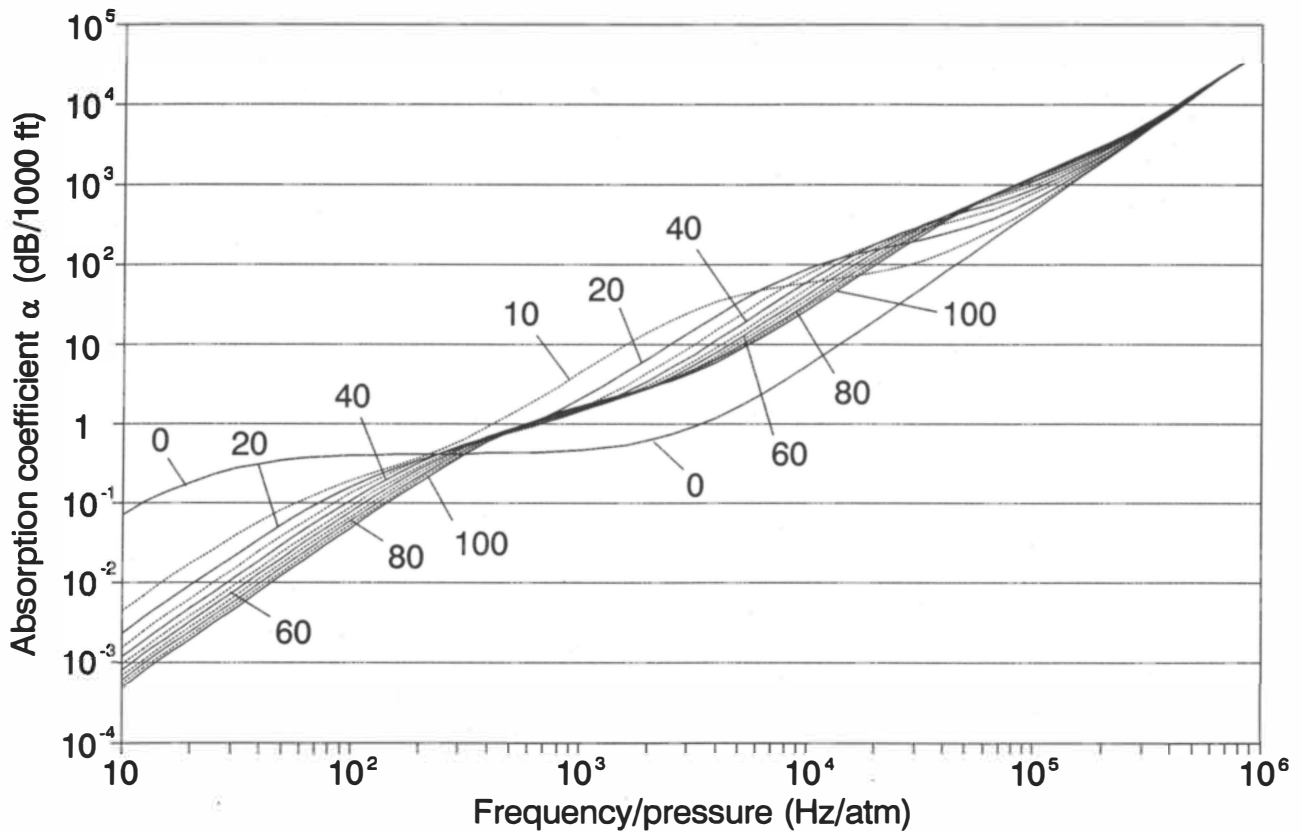


FIG. 1. Sound absorption coefficient in air (dB/1000 ft) versus frequency/pressure ratio for various percent relative humidities at 20 °C.

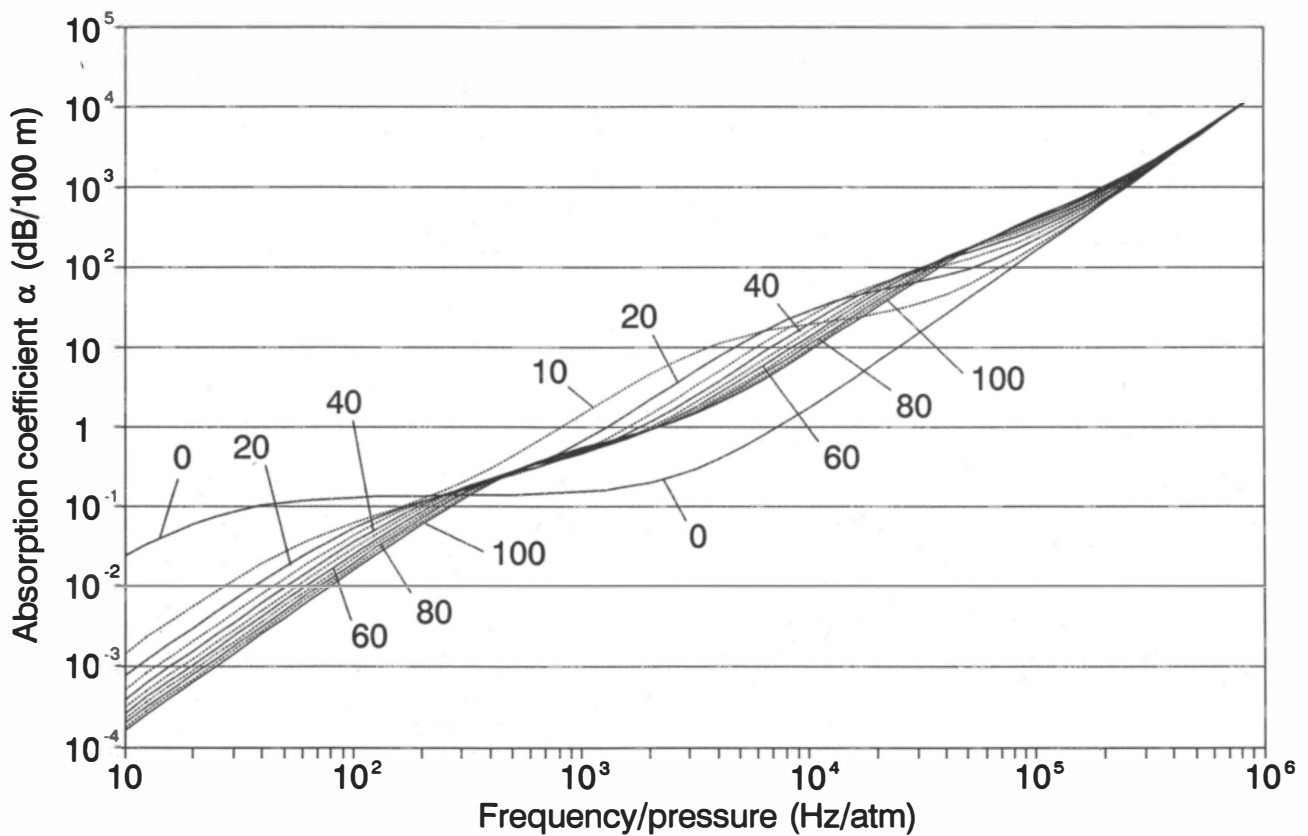


FIG. 2. Sound absorption coefficient in air (dB/100 m) versus frequency/pressure ratio for various percent relative humidities at 20 °C.

Reflection and scatter of acoustic waves from a thin, rough elastic plate on the surface of a fluid: Theory and experiment

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When the wavelength of an incident plane wave is greater than the plate thickness h and the scale a of the roughness ($kh < 1$, $ka < 1$), one may combine the generalized smoothed boundary condition technique with the classic Germain thin plate equation to obtain a simple and compact theory of scatter. The predictions of the theory are in substantial agreement with recently reported model experiments.

PACS numbers: 43.30.Hw, 43.30.Ma, 43.20.Fn

INTRODUCTION

A recent paper by McClanahan and Diachok,¹ based upon McClanahan's thesis work,² has described the effects of small-scale corrugations (half-cylinders) on the scatter of acoustic waves from a thin lucite plate on the surface of a fluid. These results were obtained by measuring the coherent reflection coefficient as a function of grazing angle with a matched pair of transducers. Measurements were made over many realizations of thin plates with parallel, randomly spaced half-cylinders, and thus represent an ensemble average of many reflections. The relevant parameters for the problem are defined in Fig. 1. The experimentally significant results are shown here in Figs. 2 and 3.

As shown elsewhere,³ the problem may be modeled with the use of generalized Biot smoothed boundary conditions with Germain's thin plate equation, to write a set of boundary conditions describing the scatter at wave number k , for low frequencies:

$$D \frac{\partial^4 w}{\partial x^4} + \rho_p h \frac{\partial^2 w}{\partial t^2} = \lambda_1 \nabla^2 \Phi_1, \quad kh < 1, \quad z = 0 \quad (1)$$

$$\frac{\partial \Phi_1}{\partial z} - w = \eta \Phi_1, \quad z = 0, \quad (2)$$

wherein, it is assumed that

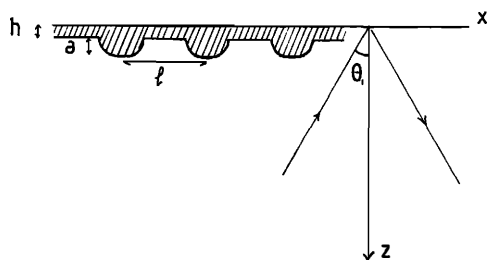


FIG. 1. Parameters of the scattering model.

$$ka < 1, \quad (3)$$

and w is the vertical displacement, Φ_1 is the acoustic displacement potential, h is the plate thickness, ρ_p its density, D an elastic constant related to Young's modulus E , and Poisson's ratio ν : $D = Eh^3/12(1 - \nu^2)$, λ_1 is the fluid bulk modulus. Here, η is, in general, complex

$$\eta = \eta_r + i\eta_i, \quad (4)$$

and can be calculated from first principles, with the following results.

(1) Corresponding to the coherent plane-wave solution, generalization of Biot's boundary condition⁴⁻⁶ always yields the *real part* of η in the form,

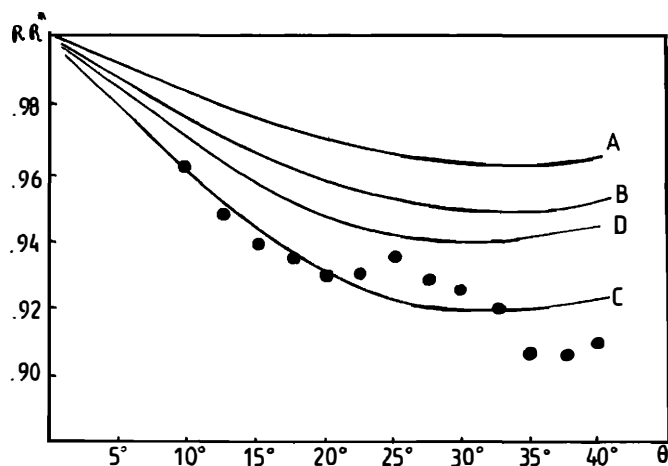


FIG. 2. Observed reflectivity of a lucite plate versus angle of incidence for a plane wave of frequency 100 kHz, for the four sets of plate constants shown in Table I. This suggests that the mass-loading factor given by Eq. (34) is necessary and that, furthermore, the ribbing (corrugations) acts as a plate stiffener although, in view of the uncertainties mentioned in the text, it is not possible to estimate this effect quantitatively.

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