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Loudness (Annoyance) Prediction Procedure for Steady Sounds

A method has been devised to predict the loudness level of any steady sound solely from its measured power-spectrum level. For many applications, hand calculations are adequate; however, for applications involving considerable data, a computer program has been written to perform the loudness-level computation when the data consist of a 1/3-octave, power-spectrum-level analysis of the noise (see note 4.). The method is based on the assumption that, with respect to the loudness sensation, the human auditory system acts as an open-loop transmission system with a transmittance function determined from well-known, input-dependent, equal-loudness curves which are obtained by exposure of listeners to pure tones. (This differs from present methods wherein the transmittance function is often assumed to be independent of the stimulus intensity and is based on equal-loudness curves obtained by exposure to imprecisely specified bands of noise.). The transmitted power-spectral density is summed over all frequencies to obtain the overall loudness (annoyance) level. (This differs from most methods wherein loudness, rather than power, in frequency bands is summed over all bands to obtain the overall loudness.)

Because the sensations produced by sound stimuli in human beings are important to human existence and the development of human intellect, it is imperative in many endeavors ranging from sound reproduction (e.g., broadcasting) to transportation (e.g., pollution by noise) that the magnitudes of the sensations be quantified.

Any word which a listener might use to describe the subjective sensation produced by a sound constitutes a description of a psychological sensation which might be quantifiable. Possibly the most widely recognized auditory sensation is "loudness." Loudness is defined as the magnitude of the auditory sensation produced by a sound stimulus. For annoying sounds, loudness is often a good measure of annoyance as well.

The loudness of all sounds is specified relative to that of a 1-kiloHertz tone imposed on a listener from the front, as plane waves at a sound-pressure level of 40 decibels. This reference sound and any other equally loud sound is said to have a loudness of 1 "sone." Like sound pressure, loudness is often expressed in logarithmic form and called loudness "level". The loudness level of any sound in "phons" is defined as being equal to the sound-pressure level of an equally loud, 1-kiloHertz tone. Thus, the loudness $\mathcal{L}$ and loudness level L of any sound are interrelated with the sound-pressure level S_1 of an equally loud, 1-kiloHertz tone according to

$$\mathcal{L} = \text{antiglog}_{10} \quad [\alpha(\mathrm{L} - 40)/10]$$
$$\mathrm{L} = S_1$$

where α is a constant (experimentally $1/3 \leqslant \alpha \leqslant 1/2$).

The proposed method appears to be the only one which has, with good absolute accuracy, predicted the loudness and relative loudness of noises as judged by listeners.

(continued overleaf)

Notes:

1. This method should have application for prediction of loudness for a wide variety of situations such as noise suppression of jet engines, automobiles, trucks, and machinery, and for use in broadcasting, sound reproduction, speech analysis, and hearing aids.
2. The following documentation may be obtained from:
   National Technical Information Service
   Springfield, Virginia 22151
   Single document price $3.00
   (or microfiche $0.95)

   Reference: NASA TM-X-2300, (N71-26993), Loudness Determined by Power Summation
3. Technical questions may be directed to:
   Technology Utilization Officer
   Lewis Research Center
   21000 Brookpark Road
   Cleveland, Ohio 44135
   Reference: B72-10579
4. The computer program for use with this method may be obtained from:
   COSMIC
   112 Barrow Hall
   Univertity of Georgia
   Athens, Georgia 30601
   Reference: LEW-11761

Patent status:

NASA has decided not to apply for a patent.

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