The decay of sound in rooms

At each reflection of a sound wave from a surface, unless that surface is infinitely hard, a reduction in amplitude of the incident sound will occur. If the sound source in a room is switched off this causes the sound field in the room to decay. This decay is commonly called the reverberation of the room.

The sound pressure level in a room is measured in decibels which is a logarithmic scale.

It is defined by the expression $L_p = 10 \log 10 \log (P/P_0)^2$ or $20 \log (P/P_0)$

where Lp is the sound pressure level in dB and
P is the sound pressure (Pascals or N/m^2) and
P_0 is the sound pressure at the threshold of hearing at 1000 Hz. which is
taken as 2×10^{-5} Pascals.

Alternatively the intensity level in a room (a measure of energy rather than pressure) is given by the expression

$L_i = 10 \log (I/I_0)$

where L_i is the intensity level in dB
and I is the sound intensity in W/m^2
and I_0 is the reference sound intensity which is chosen as 10^{-12} W/m^2 so that $L_p = L_i$ in a free field (that is without any reflecting surfaces)

Noises sound differently according to the frequency content of the noise and measurements are often made in frequency bands. In building acoustics these are generally in octave or 1/3rd octave bands. These bands follow a geometric progression. An octave band is the group of frequencies between one frequency and twice that frequency e.g. 500 - 1000 Hz. The standard octave bands now used are described by their centre frequencies which are the bottom frequency in the band x 1.414. 1/3rd octaves are octave bands divided into three parts following the same geometric progression.

The standard octave bands are (audible range) 31.5, 63, 125, 250, 500, 1000, 2000, 4000, 8000, 16000 Hz. Examples of the 1/3rd octave bands are 100, 125, 160, 200, 250, 315, 400, 500, 630, 800, 1000 etc. As a comparison with musical toes middle C on a piano keyboard is 256 Hz.

The reverberation in a room is characterised by the reverberation time (RT) defined as the time it takes for the sound level to decay by 60 dB or for the sound energy in the space to decay to one millionth of its original value. It is measured using either an impulsive source such as a starting pistol or by switching off a white or pink noise source and measuring the decay. This decay is usually measured over 20 dB or 30 dB from -5 to -25 dB or -5 to -35 dB but always expressed as an equivalent 60 dB decay. The early decay time (EDT) measured from 0 to -10 dB, though again expressed as the equivalent 60 dB decay, is more closely related to the subjective impression of decay. This is calculated using the 'Schroder reverse integration' technique. In all cases the RT or EDT should be measured in octave bands or 1/3 octave bands as the absorbing properties of the surfaces will vary with frequency.

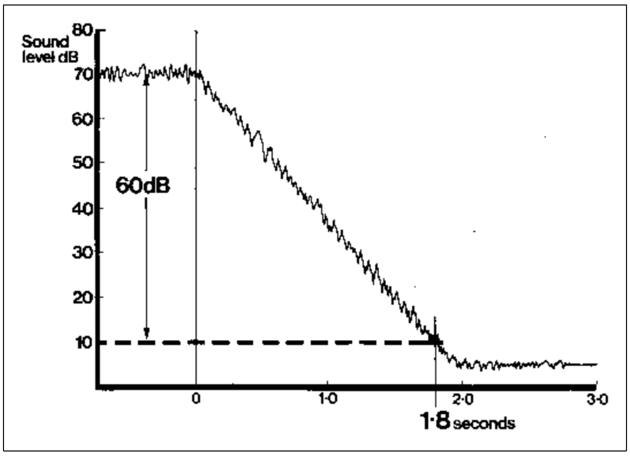

Fig 6
Measurement of Reverberation Time

Rooms for Speech

The structure of speech consists of combinations of vowels and consonants to produce voice tones sometimes called 'formants' which can be varied over a small frequency range (pitch) by the person but are generally characteristic of the way that person speaks. Females have generally a higher pitch region than males in which their formants occur.

Speech is understood mainly by the overtones or harmonics on the consonants. The important frequency range for understanding speech is between 500 - 4000 Hz.

The listener hears a direct sound from the speaker and then the reflected sounds. To reiterate earlier statements, those reflected sounds arriving within 50 ms of the direct sound are not distinguishable by the ear. Effectively the ear has a certain integrating time. These early reflections contribute to the level of the direct sound while those arriving after 50ms contribute to the general reverberation of the space. While the level of the direct sound can be increased by standing closer to the speaker the general reverberation in the space remains constant. Thus where the direct sound and early reflected sound is already at a reasonable level for listening the clarity of the the speech cannot simply be increased by the speaker talking louder, unless the externally created background level is high. A good example of this is the public address system in swimming pools (or underground train stations) where simply increasing the amplification has no effect on speech articulation

In acoustics the Clarity (for speech) is defined as:

C = 10 log E/L where E is the sound energy arriving within the first 50 ms and L the sound energy arriving after the first 50 ms.

Good early reflections and good sight lines to the audience are very important in