ROOM ACOUSTICS

SIMPLIFIED ACOUSTICS
The following simplification of acoustical principles will enable you to evaluate how much acoustical material is required.

LOUDNESS OF DIRECT SOUND
The loudness of direct sound waves to a listener is determined by: (1) the loudness of the original source, and (2) the listener distance from the source.

The loudness of the direct sound decreases with the square of the distance from the source so that the loudness decreases very rapidly close to the source, but as the distance from the source increases, a change in the distance has little effect.

REFLECTED SOUND
When a sound wave strikes a surface such as a floor, wall, or ceiling, the direction of travel is changed by reflection. Reflection of sound waves follow the same physical law as light reflection. The angle of the incidence equals the angle or reflection.

MULTUPLE REFLECTIONS
Sound travels about 768 miles per hour in all directions. Quickly the original sound is reflecting from all of the surfaces again & again. At any given moment a listener will not only hear the current direct sound, but portions of earlier sounds that are reflected one or more times. Soon sounds are traveling in every possible direction. The multiple reflection of sound waves has two effects on acoustics: (1) loudness is increased, and (2) it causes reverberation.

LOUDNESS OF COMBINED DIRECT & REFLECTED SOUND
The loudness of reflected sound is always less than direct sound because (1) reflected sound travels further & loudness diminishes with distance, and (2) reflected sound loses some energy by absorption at each reflection. The combination of direct sound & reflected sound results in loudness that is greater than direct sound alone.

Loudness of reflected sound depends in room absorption while direct sound depends only on the distance from the source.

The overall effect on loudness is determined by absorption present within the room.

REVERBERATION
Reflected waves will continue ricocheting between room surfaces losing only a fraction of power by absorption at each reflection. The prolongation of sound is called reverberation. The sound will gradually diminish.

REVERBERATION TIME
Reverberation time is the time measured in seconds that a sound average loudness can be heard before it becomes completely inaudible under quiet conditions. The time may vary from 1/2 second in a very "dead" room to 5-10 seconds in an excessively "live" reverberant room.

SPEECH & COMMUNICATION
"The maximum reverberation time for clear speech is about 2 seconds". When reverberation time exceeds 2 seconds and moves upward, speech becomes increasingly more difficult to understand. Speech finally becomes unintelligible at reverberation times of 4-10 seconds. Speech intelligibility improves as reverberation time decreases below 2 seconds. The ideal time for classrooms or lecture spaces is actually lower than 1 second.

MUSIC
Optimum reverberation time for orchestral, choral and church music generally ranges between 1.5-2 seconds; large organs: 2 seconds or more and chamber music: 1-1.5 seconds.

REVERBERATION EFFECT ON HEARING

0.5 TO 1 SECOND	Speech = Good
	Music = Too Dead
1 TO 1.5 SECONDS	Speech = Good
	Music = Fair
1.5 TO 2 SECONDS	Speech = Fair
	Music = Good
OVER 2 SECONDS	Speech = Poor
	Music = Fair to Poor

ECHO
A distinct repetition of direct sound is an echo. In a highly reverberant room, an echo gets lost in the general reverberation. An echo is easily distinguished if the interval is greater than 1/2 second in a room with low reverberation time.

Sounds reflected from flat surfaces will be less intense than the original direct sound. Sound reflected from concave surfaces has a focusing action that produces very annoying echoes.

SOUND ABSORPTION & COEFFICIENTS
Hard, reflective, nonporous interior building surfaces such as glass, wood, plaster, brick and concrete absorb 2% to 5% of the sounds striking the surface to reflect 95% or more of the sound. Absorption coefficients are expressed as a percentage of the sound absorbed. A perfect sound absorber is an open window since it permits 100% of the sound to escape and not return.

Absorption coefficients are usually measured at 63, 125, 250, 500, 1000, 2000, 4000 & 8000 cycles (Hz).

COEFFICIENTS OF GENERAL BUILDING MATERIALS & FURNISHINGS

Complete tables of coefficients of the various materials that normally constitute the interior finish of rooms may be found in various books on architectural acoustics. The following short list will be useful in making simple calculations of the reverberation in rooms.

MATERIALS	COEFFICIENTS					
	125 CPS	250 CPS	500 CPS	1000 CPS	2000 CPS	4000 CPS
Bricks	.03	.03	.03	.04	.05	.07
Carpet heavy on concrete Carpet with impermeable backing	.02	.06	.14	.37	.60	.65
Concrete block, course	.08	.24	.57	.69	.71	.73
Concrete block, painted	.08	.27	.39	.34	.48	.63
Light fabric	.03	.04	.06	.07	.09	.08
Medium fabric	.07	.31	.49	.75	.70	.60
Concrete, terrazzo, marble or glazed tile	.01	.01	.02	.02	.02	.02
Wood	.15	.11	.10	.07	.06	.07
Heavy glass	.18	.06	.04	.03	.02	.02
Ordinary glass	.35	.25	.18	.12	.07	.04
Gypsum board, 1/2"	.29	.10	.05	.04	.07	.05
Plaster	.01	.02	.02	.03	.04	.05
Water surface	.01	.01	.01	.02	.02	.03
Air, sabins 1000 cubic feet	–	–	–	–	2.3	7.2
People	4 sabins					

N.R.C. NOISE REDUCTION COEFFICIENT

When acoustical materials are tested in a laboratory, they are tested at 125, 250, 500, 1000, 2000 and 4000 CPS. An average of the middle four frequencies (250, 500, 1000, 2000) is known as the N.R.C. (Noise Reduction Coefficient). This permits rapid value comparisons of various acoustical materials.

SABIN

A sabin is a unit of sound absorption equivalent to one square foot having a coefficient of absorption of 1.00. A concrete floor 10,000 square feet in size and having an absorption coefficient of .015 at 500 CPS (Hz) will yield: 10,000 x .015 = 150 sabins. 200 square feet of acoustical wall panels with an absorption coefficient of 0.95 at 500 CPS will yield: 200 x 0.95 = 190 sabins.

FREQUENCY & REVERBERATION TIME

Quick and easy calculations can be made on the spot by doing the calculation at 500 CPS. This is usually sufficiently accurate for most conditions, but it is not infallible.

SABIN FORMULA

Named after Wallace C. Sabine, generally accepted as the

A) Determine existing reverberation (just how bad it is):

$$T = \frac{V}{20\,S}$$

T = Reverberation time in seconds
V = Cubic Volume in Cubic Feet in the room
20 = The Constant
S = Sabins (units of absorption) present in the room. This quantity is obtained by multiplying the area of each surface by its absorption coefficient and arriving at a total.

B) Determine acoustical absorption required:

$$S = \frac{V}{20\,T}$$

S = Sabins (units of absorption) required in the room
V = Cubic Volume in Cubic Feet in the room
20 = The Constant
S = Desired (design) reverberation time in the room (see Reverberation Effect on Hearing)

C) To calculate acoustical absorption needed:

required sabins (part "B")
– existing sabins (part "A")
= sabins we need to add to the space

D) Determine how many square feet of acoustical material needed:

$$\frac{\text{sabins we need to add (part "C")}}{\text{material absorption coefficient}} = \text{sq. ft. required}$$

OR

$$\frac{\text{sabins we need to add (part "C")}}{\text{sabins/panel}} = \text{panels required}$$

Father of Acoustics.

This information has been provided compliments of MBI Products Company, Inc.MBI strongly recommends that there is no substitute for actual sound level measurements done by a competent acoustician with the proper equipment. A thorough professional analysis and evaluation often has better results and a lower overall cost. A list of professional acoustical consulting firms is available at no charge upon request.

Innovation for the Sound Experience

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