Sound Control Manual − Sound Construction
Room Acoustics

Acoustics is usually very broadly defined as "the science of sound." The term "Room Acoustics" can be more narrowly defined as the shaping and equipping of an enclosed space to obtain the best possible conditions for faithful hearing of wanted sound and the direction and the reduction of unwanted sound. It deals primarily with the control of sound which originates within a single enclosure, rather than its transmission between rooms.

In addition to reducing the undesirable background noises that originate withing a room, the acoustical objective often includes preservation of the wanted sounds. For example, any space considered to be speech or music room −− upper grade classrooms, assembly halls, or wherever we are communicating to an audience of some kind, requires faithful reproduction of wanted sound. The techniques are retention and reinforcement of useful sound reflections. In short, we control sounds for communication with reflective surfaces, and we control reverberation and background noise levels with absorptive surfaces.

A combination of techniques is required in some rooms where, for example, the voice of the teacher or supervisor must be heard above fairly high noise levels. Such rooms include lower grade classrooms, gymnasiums and swimming pools. The wanted sound must override the background noise level. The architect will be dealing with a balance between sound reflective and absorptive surfaces.

Planning: Think Sound
The starting point is usually determined by the use of the room −− what kind of acoustical environment is desired? This in turn should dictate the design approach. The designer should anticipate any serious noise problems and have some idea of the amount of noise which must be reduced. For example, if he's designing a kindergarten room, he must remember that a child's conception of his own progress is based on how much noise he can make. Thus, lower grade classrooms usually require more sound absorption.

Such factors must be weighed against the performance cpabilities of available sound control products before the design stage. In some cases, the amound of noise may be actually too great to be corrected by conventional acoustical treatments. Then, further refinement of the plan is necessary. Perhaps room shapes must be changed, or the critical rooms further isolated from the noise source.

If such basic considerations are disregarded until late in the design stage, it may be too late or too costly to correct them. "Acoustical treatment" is all to often just that −− treatment of a fault or weakness which could have been avoided in the planning stages.

In the last analysis, good acoustics usually results from the absence of faults rather than the presence of any particular detail or feature. Thus, considerable emphasis in this chapter is placed on what not to do in order to prevent the need for correction

The best apporach is to "think sound" all through the planning and design stages, and avoid as many potential problems as possible.

Rooms	Typical Requirements	Acoustical Treatment
Live		
Auditoriums, theaters (for music)	Obtain proper reverberation time to enchance musical quality.	Provide reflective surfaces near source to reinforce sound; absorptive surfaces toward rear
Medium Live		
Conference and board rooms	Normal speech must be heard over distances up to about 35 ft.	Allow middle section of ceiling to act as a reinforcing sound−reflector. Apply absorbent to periphery of ceiling or to wall surfaces (not both). Additional treatment will contribute little to noise reduction.
Medium		
Cafeterias (school or office)	Reduce overall noise level.	Use highly sound−absorptive ceiling; also use quiet equipment such as rubberized dish trays.
Gymnasiums	Instructor must be heard over background noise	Use acoustical material over entire ceiling to reduce noise; walls remain untreated to permit some reflected sound.
Private office	Reduce noise and improve speech communication over short distances.	Either an acoustical ceiling or sound absorptive wall treatment (not both).
College & high school classrooms	Normal speech must be intelligible over entire area.	Mechanically suspended acoustical ceiling; large lecture rooms may also require some reflective ceiling surfaces to reinforce sound.
Restaurants	Reduce overall noise level and control reverberation of dish	Use acoustical ceiling.

	clatter and speech.	
Hospital rooms (wards, semi−private & private)	Localize and reduce noise from radios, TV and guests.	Use acoustical ceiling.
Stores	Reduce noise; also provide access to ceiling plenum for changing lighting locations and other service functions.	Suspended acoustical ceiling with lay−in panels.
Home	Localize as much as possible.	Acoustical ceilings in living, play areas, dining room and kitchen.
Medium Dead		
Elementary−grade classrooms	Teacher must be heard distinctly; reduce noise level produced by children.	Acoustical ceiling essential. Supplementary acoustical space units on upper rear and side walls are desirable.
Music rehearsal rooms	Unlike music hall, instructor must hear individual notes distinctly; minimum reverberation desired.	Entire ceiling, sidewalls, and wall facing musicians whould be treated; wall behind musicians may be left sound−reflective for proper hearing. Room should be located away from normal use rooms.
Hospital work spaces	Reduce noise radiation to nearby quiet areas; also provide protection against impacts, fumes and moisture.	Metal or plastic coated acoustical ceiling, and if possible, acoustical space units (plastic coated) on some wall surfaces.
Typing office	Localize and reduce noise.	Highly absorbent acoustical ceiling, preferably suspended; also acoustical space units on upper wall surfaces.
Office/Hospital corridors	Reduce noise and echo−chamber effect radiated through open doors to adjacent rooms.	Acoustical materials on ceiling; if corridor width is less than height, acoustical space units on walls necessary; door locations should be staggered to provide

		sound barriers.
Dead*		
Kindergarten	Maximum noise reduction.	Maximum acoustical treatment on ceiling; space units on available wall surfaces.
Vocational classrooms and shops	Maximum noise reduction.	Acoustical tile or lay−in panel ceiling, plus acoustical treatment of available upper wall areas; locate away from normal use rooms.
Business machine (tabulating) rooms	Maximum noise reduction; localize noise at machines.	Acoustical ceiling and space units on walls.
Factory areas	Maximum noise reduction.	Overhead equipment may not permit acoustical ceiling; use suspended acoustical baffles in rows across accessible ceiling areas.
Sports arenas	Maximum noise reduction; reduce reverberation time.	Multi−purpose arenas for speech and music will require some reflective surfaces to reinforce sound; use functional sound absorbers where structure prevents use of acoustical ceiling.
* Rooms classified as "dead" require maximum noise control treatment. Acoustically dead rooms actually include spaces such as radio, TC, recording and movie studios, where distinct sounds must be capture for reproduction purposes.		

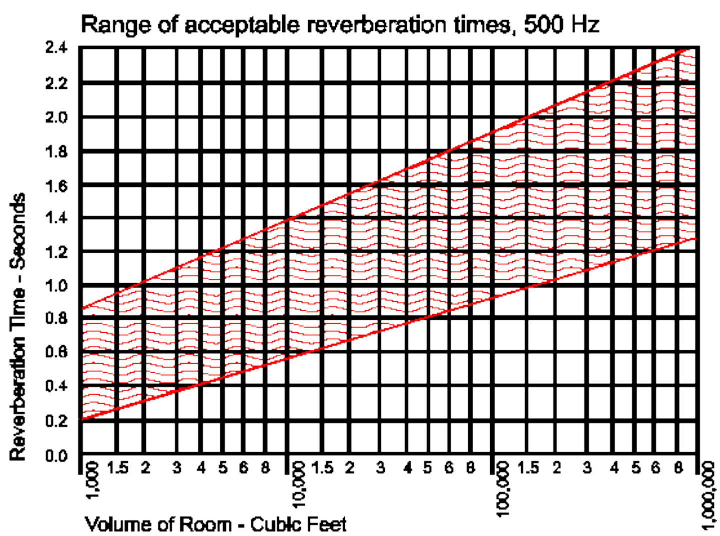
The Acoustical Environment: "Dead" or "Live"
Since the use of the room dictates the acoustical goals, a general guide is provided in Figure 12 (above). It classifies some typical rooms by acoustical environments −− ranging from highly reflective or "live" to very absorptive or "dead." These are qualitative terms applied to certain aspects of the acoustical properties of a room. Technically, "liveness" depends on the ratio between relfected and direct sound. The larger the ratio, the greater the "liveness."

In rooms containing a large amount of absorption, there will be little reflected sound −− resulting in a minimum reverberation. Thus, the sound will die out very quickly, and the room is considered "dead." In a room lacking adequate absorptive surfaces, the sound will keep "bouncing" and die out very slowly. This would be considered a "live" room. The requirements of most rooms will fall somewhere between these two extremes.

Reverberation: Friend or Foe
A closer look at reverberation will be helpful because it is a basic consideration in sound control. If the time interval between the original sound and its reflections is short, instead of creating echoes the reflections reinforce the loudness and clarity of the original sound, or , the reflections may persist audibly for a considerable time after teh source sound has stopped. For example, a lecturer may find that some of his words can't be understood because the reflections of one syllable overlap the next syllable.

Reverberation is a basic acoustic property of a room. It can enrich speech and music in all areas −− or it can slur speech and generate higher noise levels throughout a room, depending upon the room volume, timing, and absorption.

In rooms used for speech or music, reverberation time should be long enought to enhance the blending of sounds, but short enough so there is no excessive overlapping and confusion. In general, the larger the room, the longer the reverberation time because sound waves must travel farther between absorptive surfaces. Figure 13 shows the ranges of acceptable reverberation times at 500 Hz. The lower part of the band is best for rooms intended primarily for speech, the upper part is better for music rooms, and the middle portion is recommended for general purpose rooms.



Reverberation time can be approximated accurately enough for preliminary study in advance of construction, and acceptable times for rooms of given size and function have been determined with a high degree of certainty.

Since reverberation time varies inversely with room absorption, acoustical absorbers are the designer's primary contril tools.

Absorption: Controlling Reverberation and Loudness
In a room the ear will always hear direct sound before it hears reflected sound. The basic function of absorptive materials is to control the reflected part of the sound. Absorption of reflected sound energy enables us to obtain desired reverberation time and loudness.

Sound absorption is basically a loss of energy (loudness) of sound as it is reflected. Each reflection absorbs some sound and converts the energy into heat.

The boundaries of a room generate individual reflections which may number in the hundreds. And each one will lose energy in varying amounts depending upon the total travel distance between reflections and amount of energy absorbed by each room surface.

The energy of the total reflected sound throughout a room varies inversely with room absorption. Thus, if we can measure how much absorption already exists in a room (due to carpets, furniture, people, etc.), we can then determine how much additional absorption is require to reach specific acoustical objectives, such as loudness reduction or a desirable reverberation time.

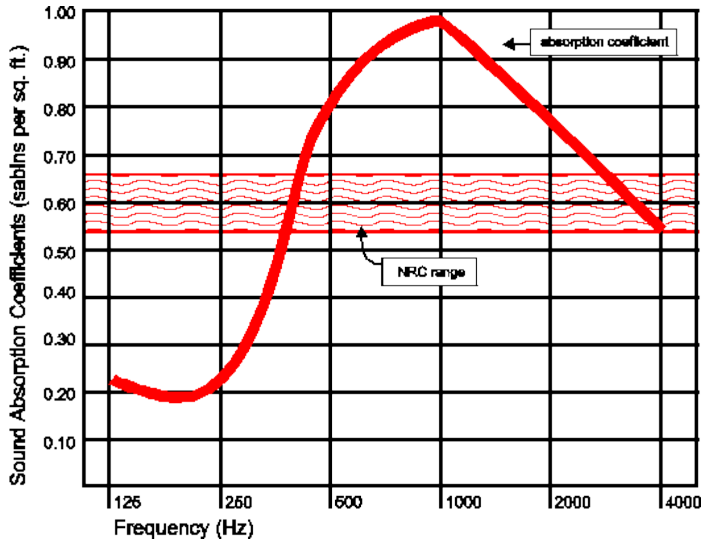
Measuring Absorption
The fraction of the energy absorbed (at a specific frequency) during each reflection is represented by the sound absorption coefficient of the reflecting/absorbing surface. In the building industry, this is a meaningful and widely accepted quatitative measuring of sound absorption, and applies to all surfaces −− whether they be of reflective or absorptive materials.

Surfaces which ouls be considered primarily reflective include plaster masonry, glass, wood and concrete. These are hard, massive, nonporous surfaces which will absorb probably less than 5% of the sound energy and reflect the rest. Such materials therefore have absorption coefficients of 0.05 or less.

On the other hand, porous materials such as acoustical time, carpets, draperies and furniture are primarily absorptive. They permit the penetration of sound waves and are capable of absorbing most of the sound energy. These materials may have absorption coefficients approaching 1.00 (one sabin per sq. ft.).

As mentioned, even objects like furniture and carpeting have specific absorption values per square foot. However, the absorption of people is oftern measured in terms of total absorption per person, for convenience.

Measuring Average Absorption
Sound absorption coefficients represent absorption at individual sound frequencies. Since most sounds contain a range of frequencies, it is necessary to consider absorption at several frequencies or use an average of the absorption coefficients. A method of comparison has been developed for noise that is predominantly in the middle frequencies. Called the Noise Reduction Coefficient (NRC), it represents the average amount of sound energy absorbed over a range of frequencies betweeen 250 Hz and 2,000 Hz.



As shown in Figure 14 (above), an acoustical product which absorbs sound will at one frequency may be very inefficient at other frequencies. In short, absorption coefficients represent maximum performance at each frequency while an NRC value represents an average of the absorption at four frequencies.

To determine the NRC figure, acoustical tile is measured over 1/3−octave bands centered at 250, 500, 1000, 2000 Hz. The arithmetic average of the absorption coefficients at these frequencies is the NRC value. For example, if four coefficients in these frequencies total 3.05, this figure is simply divided by four and the result is the NRC value of .75. This is usually represented as an NRC range, because a difference of less than 10 points usually cannot be detected by the ear. In general, large office areas and shool rooms usually require NRC of .60 to .80; the noisier lower grade schools normally require more absorption than the higher grades.

If the noise level is predominantly at a single low or high frequency, selection of acoustical material should be based on absorptive performance at the critical frequecies. In such cases, individual absorption coefficients are used and the performance at each frequency is evaluated. In conert auditoriums, and other critical acoustical situations, an acoustical engineer should be consulted.