Table 4 . . . . Range of Design Goals for Air Conditioning System Sound Control

Type of Area	A-Sound Level Decibels			NC Level Decibels		
	Low	Average	High	Low	Average	High
RESIDENCES						
Private homes (rural and suburban)	25	30	35	20	25	30
Private homes (urban)	30	35	40	25	30	35
Apartment houses, 2- and 3-family units	35	40	45	30	35	40
HOTELS						
Individual rooms or suites	35	40	45	30	35	40
Ball rooms, Banquet rooms	35	40	45	30	35	40
Halls and corridors, Lobbies	40	45	50	35	40	45
Garages	45	50	55	40	45	50
Kitchens and laundries	45	50	55	40	45	50
HOSPITALS AND CLINICS						
Private rooms	30	35	40	25	30	35
Operating rooms, Wards	35	40	45	30	35	40
Laboratories, Halls and corridors	40	45	50	35	40	45
Lobbies and waiting rooms						
Washrooms and toilets	45	50	55	40	45	50
OFFICES						
Board room	25	30	35	20	25	30
Conference rooms	30	35	40	25	30	35
Executive office	35	40	45	30	35	40
Supervisor Office, Reception room	35	40	50	30	35	45
General open offices, Drafting rooms	40	45	55	35	40	50
Halls and corridors	40	50	55	35	45	55
Tabulation and computation	45	55	65	40	50	60
AUDITORIUMS AND MUSIC HALLS						
Concert and opera halls						
Studios for sound reproduction	25	30	35	20	22	25
Legitimate theaters, Multi-purpose halls	30	35	40	25	27	30
Movie theaters, TV audience studios						
Semi-outdoor amphitheaters	35	40	45	30	32	35
Lecture halls, planetarium						
Lobbies	40	45	50	35	40	45
CHURCHES AND SCHOOLS						
Sanctuaries	25	30	35	20	25	30
Libraries	35	40	45	30	35	40
Schools and classrooms	35	40	45	30	35	40
Laboratories	40	45	50	35	40	45
Recreation halls	40	45	55	35	40	50
Corridors and halls	40	50	55	35	45	50
Kitchens	45	50	55	40	45	50
PUBLIC BUILDINGS						
Public libraries, Museums, court rooms	35	40	45	30	35	40
Post offices, General banking areas, Lobbies	40	45	50	35	40	45
Washrooms and toilets	45	50	55	40	45	50
RESTAURANTS, CAFETERIAS, LOUNGES						
Restaurants	40	45	50	35	40	45
Cocktail lounges	40	50	55	35	45	50
Night clubs	40	45	50	35	40	45
Cafeterias	45	50	55	40	45	50
STORES RETAIL						
Clothing stores	40	45	50	35	40	45
Department stores (upper floors)						
Department stores (main floor)	45	50	55	40	45	50
Small retail stores						
Supermarkets	45	50	55	40	45	50
SPORTS ACTIVITIES INDOOR						
Coliseums	35	40	45	30	35	40
Bowling alleys, gymnasiums	40	45	50	35	40	45
Swimming pools	45	55	60	40	50	55
TRANSPORTATION (RAIL, BUS, PLANE)						
Ticket sales offices	35	40	45	30	35	40
Lounges and Waiting rooms	40	50	55	35	45	50
MANUFACTURING AREAS						
Foreman's office	45	50	55	40	45	50
Assembly lines, Light machinery	50	60	70	45	60	70
Foundries, heavy machinery	60	70	80	55	65	75

How to Determine Design Goals

After a suitable method for expressing the design goal has been selected, it is necessary to assign, for each room in the building, a numerical value which will provide the *proper balance* between the air-conditioning sound and all other sounds in these rooms. It should be emphasized that the acceptability of the air-conditioning sound does not depend upon its *absolute* level or loudness, but on its *relationship* to *the other* sounds involved. Proper design goals for the air-conditioning system must therefore be based on a thorough analysis of the acoustics and architecture of the entire building.

The other sounds which dictate the design goal can be classified as:

1. *Communication* sounds, including speech or music, which it is necessary to hear.
2. *Background* sounds, including traffic and other outside noises as well as indistinguishable inside sounds.
3. *Intruding* sounds, which should *not* be heard, including typing, etc., and speech from adjacent rooms.

The level of sound from the air-conditioning system must, of course, be low enough so that it will not interfere with the communications sounds, but there is no point in reducing it much below the normal background level. In fact, it is often desirable to have sufficient sound from air outlets to mask speech intruding from adjacent rooms, to assure privacy. However, it is necessary that the quality of the sound is such that it will not be annoying, even though the level is not substantially above the background.

In view of the variables involved in the three classes of other sounds listed above, it is impossible to tabulate design goals for various spaces with sufficient accuracy. Even as detailed a table as Table 4 can only provide a very broad range into which the design goal may be expected to fall. This broad range does not mean that any level within the range will be satisfactory. On the contrary, it means that what is right for one conference room, for instance, may not be right for a different conference room.

Conference rooms are typical of rooms in which all occupants must be able to clearly understand what any one person says. The sound *power* output of the human voice for a given speech effort does not vary much from one speaker to the next, but the corresponding sound *pressure* level at the critical position of the listener may vary from one room to the next by more than 10 db, depending upon the size of the room and the amount of sound absorption. The effect of these variables can be eliminated by specifying the design goal in terms of sound power, using Table 5.[39] If desired, the corresponding pressure level can be determined by following the procedure of Step 2 in reverse.

A somewhat different approach may be taken for rooms in which a number of separate discussions are carried on simultaneously by small groups of people. Here it is not necessary, and often undesirable, to have full speech intelligibility beyond the range of about 4 ft at normal voice level. Thus, the design goal can quite simply be specified in terms of sound pressure levels. The proper levels often depend largely upon the level of the background noise, both that with sources within the room and that coming in through the walls.

In some rooms, such as restaurants or banquet halls, close range conversation may prevail most of the time, but total audience listening will prevail during announcements or speeches. Here, the proper design goal will largely depend on whether or not there is a public address system available.

An entirely different condition exists in spaces such as halls and corridors not meant for speech communication. The major acoustic concern for these spaces might well be that conversations in adjacent rooms can be too readily overheard. In order to provide acoustic privacy, a *minimum* level is therefore often specified for the sound from the air-conditioning system. A detailed discussion of the procedures and considerations involved in providing acoustic privacy is found in References 23 and 24.

Table 5 . . . . Maximum Acceptable Power Level[a] of Equipment Sound for Various Speech Communication Conditions, in DB re 10^{-12} Watt[39]

Required Speech Intelligibility	Soft Voice	Normal Voice	Raised Voice	Very Loud
Marginal	50	56	62	68
Fair	44	50	56	62
Very Good	38	44	50	56
Perfect	32	38	44	50

[a] Power Levels listed are arithmetical averages of power levels in the three octave bands in the speech interference range (600–4800 cps). A 2 db allowance has been made for direct sound radiation; listener is assumed to be at far end of room from the speaker.

In some cases, it is not possible to determine acceptable noise limits by strictly acoustic considerations. All current makes of room air conditioners, for instance, produce a sound level well above the range listed in Table 4 for residences, and opinion polls[21] have confirmed noise as the most important consumer objection. In spite of this, annual sales continue to be high. It appears that people are willing to tolerate noisy equipment if it is relatively inexpensive and operated only on an intermittent basis. Room air conditioners meet these criteria and usually have provisions for operation at reduced speed and noise level when the weather is not extreme. The owner thus has full control over the noise and therefore seems *more tolerant.*

How to Meet Sound Quality Requirements

When the design goal for sound from an air handling system is specified in terms of one of the NC curves of Fig. 2, especially in a case where speech privacy is a factor, it is implied that the room noise spectrum should follow the general shape of the NC curve. However, the amount of duct attenuation required to reduce the fan noise below the specified level in the low frequency bands will generally take out more sound in the speech frequency range than is desired. Sound in this frequency range can be filled in by suitably sized air outlets,[39] as shown in Fig. 3.

In Fig. 3, however, the sound from the fan system alone approaches the specified NC curve only in the second, third, and fourth octave bands. On the other hand, the sound from the diffuser alone approaches the specified NC curve only in the fifth and sixth bands. This difference in spectrum shape means that sound from air outlets can be neglected when designing the sound control measures for the fan system, and vice versa. Moreover, air outlets can usually be selected from performance data in the 600–1200 or 1200–2400 cps bands. In designing sound control measures for the fan system, data for the 75 to 600 cps bands are often sufficient.

STEP 2—SELECTION OF ROOM TERMINAL UNITS

Since sound generated by unitary equipment and air outlets is radiated directly into the air-conditioned room, it cannot be attenuated along the path. Therefore, such devices must be selected for a sufficiently low noise output.

Air outlets can be selected to meet any design goal, merely by keeping the air velocity sufficiently low. For a given outlet style and air quantity, the sound level will increase approximately 2 db for each 10 percent increase in maximum air