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Sound Insulation in Office Buildings

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Please note

Whenever two or more independent occupants share the same building, sound insulation between occupancies becomes an important design consideration. The requirement varies with every set of occupants, but there are generic types of buildings that can and must be dealt with in a general way. A multi-tenant office building, for example, must be designed to accommodate, over the years, a variety of occupants, each with his own activities and insulation requirements. Office buildings will therefore form the subject of this Digest. Some general cautionary remarks were made in a previous discussion of noise transmission in buildings (**CBD 10**); it is proposed here to develop office problems in more detail, with special attention to partitions.

Subjective Perception of Noise

Human reactions to noise were discussed in some detail in **CBD 41** here it will suffice to restate the conclusions that affect sound insulation in offices. One's ability to perceive a particular noise requires not only that it be above the threshold of audibility, but also that in at least some frequency ranges its level be above the level of background noise. For reasons relating to the sensitivity of the ear and the spectra of common noises the middle frequencies (about 350 to 2500 cycles/sec) are usually the most important.

Background or ambient noise can be defined as noise that is generally accepted as part of the environment; it must be sufficiently random and meaningless in character for no individual part of it to be identifiable. For present purposes, one's own noise, if it is always present, will be classed as background noise because it helps to mask intruding noise from the nearest neighbour. The most severe problem arises where there is little or no locally-produced noise. There are two main varieties of office noise. One is the clatter of typewriters and other fairly meaningless quantities that are tolerable in a business environment up to the point where they interfere with normal office occupations such as communication. This first category, in moderation, serves a useful purpose by adding to the background level, thus helping to mask less acceptable noises.

The other common noise is speech. When transmitted from a neighbouring office speech is particularly objectionable if it is intelligible or nearly so. Conversely, a speaker may feel under constraint if aware that he can be understood next door. Avoidance of intelligibility in transmitted speech is less stringent a requirement than complete inaudibility. Hence, there has arisen the criterion of *speech privacy*, which may be defined as a condition under which less than about 5 per cent of transmitted speech is understood. Speech levels, of course vary with the speaker or with speaker-listener spacing; the normal speaker must raise his voice higher when listeners are 10 feet away than when they are 5 feet away. Competition with others, as at a conference table, also leads to louder than normal speech.

It follows that the occupants of large general offices in which there is a business-like hum of activity are not likely to be bothered by noise intruding from neighbours. Nor is large-office noise very troublesome to occupants of adjacent private offices, although the latter may be concerned lest their speech be understood in the general office. A more difficult problem arises in an assembly of private offices in circumstances where speech privacy between them is important. Here the level of masking noise may be low, and there may be little spatial separation; all depends, perhaps, on prefabricated office partition and a suspended acoustical ceiling. The most difficult room of all is the conference room. Here voices may be louder than normal and the subject matter more confidential.

Noise Ratings

A noise may be measured and expressed in a variety of ways (see **CBD 41**). In this Digest the family of reference curves known as *Noise Criteria* (NC values) will be used. The NC value for a given noise corresponds to the highest NC curve that is tangent to the noise spectrum at any frequency band. Sometimes minor excesses in noise at the extreme frequency ranges are disregarded, but essentially the NC Curve puts a maximum level on the noise for each frequency band.

A simpler index is the *A-weight sound level*, which is measured with an ordinary sound-level meter. The A-weighting system involves approximately the same relative weighting of frequencies as do the NC curves, and for most office noises (including speech) A-weighted sound levels are consistently related to the corresponding NC values. Considering the other variables in the process of predicting noise levels, a serious error is not probable if the NC value is taken to be 5 db lower than the A-weighted sound level.

As background noise is usually a random assemblage of unrelated sounds, it is difficult to predict. In naturally-ventilated buildings with openable windows, or in any building on a busy thoroughfare, traffic noise may be a dominant factor. Where mechanical ventilation is employed the background level may be dominated by fan noise. Indeed, there is the possibility of securing a predetermined background level by specifying it as a maximum level for ventilation equipment; if the installer inadvertently gets too far below the specified limit he can usually rectify the matter.

It is of course important that the ambient level be low enough to provide satisfactory performance within the occupancy. Here speech communication is usually the criterion. The requirement may vary from intermittent communication at a range of 5 feet to continuous communication at 20 feet, as in a large conference room.

On the basis of these two requirements - speech *communication* within an occupancy and speech *privacy* relative to adjacent occupancies - two sets of noise assumptions for typical offices are presented in Table I. Optimum NC values for background noise in the listed occupancies are given in column I. These are actually the maximum levels that will permit the indicated communication functions within the occupancies, and can be used in specifications for ventilation and other mechanical equipment. In this Digest they will also be assumed to denote minimum levels for determining the required insulation against intrusive noise from adjacent occupancies. The latter assumption will not ordinarily be very far out; in a business environment the problem is usually to achieve an adequately low level.

Table I Design Noise Levels for Office Insulation

	I Optimum Background Noise	II Criterion of Locally-produced Noise

1	Executive offices; used for small conferences, communication up to 20-ft range	NC-30	Normal speech + 5 db
2	Small private or semi-private offices, speech communication up to 10-ft range	NC-35	Normal speech
3	Conference rooms seating 50 persons	NC-30	Normal speech + 10 db
4	Conference rooms seating 20 persons	NC-35	Normal speech + 10 db
5	Conference rooms seating 10-15 persons	NC-35	Normal speech + 5 db
6	General offices, drafting rooms, etc.; speech at 6 ft. telephone use; limited machine noise	NC-45	Normal speech
7	Typing pools, etc. employing light office equipment; intermittent communication 3 to 6 ft	NC-50	Normal speech + 5 db
8	Business machine rooms, some communication in raised voice at 3 to 6 ft	NC-55	NC-55 (formula [3])

Column II gives the maximum noise condition that should be assumed in considering transmission to adjacent occupancies. Note that except for the last item in Table I the quantity given in column II is related to the source (speech) rather than to the noise level in the room, this is the most convenient index for the calculations to be presented later. Relatively meaningless noises such as office machinery are most readily defined in terms of NC levels in the source room as is indicated in the last item of Table I.

Insulation Ratings for Structures

For many years the customary index of sound insulation performance was simply the average of sound transmission loss measurements made at a series of nine test frequencies. This index had the disadvantage that for modern construction especially it failed to give proper emphasis to the middle-frequency range. A recently developed rating system the ASTM Sound Transmission Class corrects this defect. It is strongly dependent on the mid-frequency region which largely determines the loudness of typical sounds and the intelligibility of speech.

The procedure for determining the sound transmission class for a given partition is illustrated in Figure 1. The upper curve is the actual transmission loss curve for a typical light-weight partition. The lower curve is the corresponding STC contour one of a family of parallel contours; the STC value is numerically the transmission loss in the flat upper segment of the STC contour. Fitting is done according to the following rules: no deficiencies below the STC contour are permitted in the middle segment, deficiencies averaging 1 db are permitted in either or both end segments.

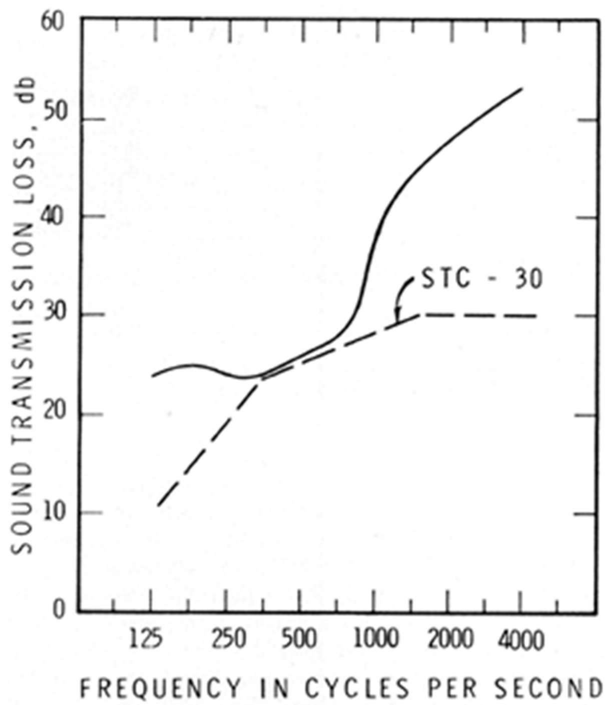

Figure 1. Transmission Loss and Sound Transmission Class of Typical Light-weight Partition.

The STC rating system is now in common use and will be the basis of the following derivation. Generally it agrees closely with the ASTM 9-frequency average, and the latter may be substituted in the absence of STC values. Beware, however of other "averages" based on restricted frequency ranges which usually result in higher numbers. Beware also of the results of tests that do not conform in every respect to the ASTM E90-61T, "Recommended Practice for Laboratory Measurement of Airborne Sound Transmission Loss of building Walls and Floors." The only safe place to check these points is in the original test report.

Partition Design Formulas

In this section formulas will be developed for determining the required sound transmission class of a partition separating any two of the occupancies described in Table I. As the rating systems employed all represent simple approximations of complex quantities it might be worth noting that the calculative error in a typical calculation would be small compared with the variables due to various occupants and their day-to day activities.

The following formulas are developed for determining the sound transmission class required for a partition separating two occupancies. If the occupancies are different it will generally be necessary to make the calculation for both directions of transmission and to use the higher STC thus deduced.

Speech privacy between occupancies (normal speech)

$STC + NC = 86 + 10 \log S - 10 \log A_1 - 10 \log A_2$ (1)

while STC is the requirement for the partition, NC is the background noise rating for the receiving room (from Table I, column I), S is the area of transmitting surface of the partition and A_1 and A_2 are total absorptions of source and receiving rooms respectively. The three logarithmic terms may be determined with the aid of Figure 2 it will be seen that only rough estimates of S, A_1 and A_2 are needed. The absorption of a room (in sabins) is obtained by adding the products of surface areas (in sq ft) and associated absorption coefficients. Usually it is close enough to use as A the total area of the major absorbing surfaces (acoustical materials, carpet, curtains) and forget the rest. If there are no absorbing materials use about 10 per cent of the total surface area of the room.

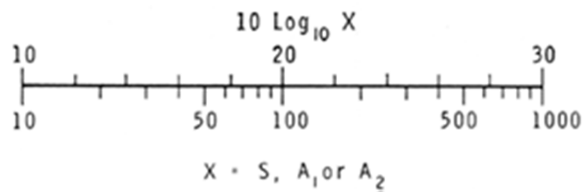

Figure 2. Chart for determining 10 log S, 10 log A, and 10 log A_2 (Formulas 1, 2 and 3).

Normal speech is assumed in (1); for higher speech levels where noted in Table I, column II increase the requirement accordingly. Speech inaudibility between occupancies:

STC + NC = 96 + 10 log S -10 log A_1 - 10 log A_2 (2)

Complete inaudibility is a more stringent requirement than speech privacy by about 10 db; hence the base figure in Formula (2) is 96 instead of 86 as in Formula (1). As before, an additional increase may be required for higher than normal speech levels.

Inaudibility between occupancies of given noise ratings:

STC = $(NC)_1$ - $(NC)_2$ + 10 log S - 10 log A_2 (3)

In this formula $(NC)_1$ is the maximum noise rating in the source room and $(NC)_2$ is the minimum ambient level in the receiving room.

Example - Design a partition to provide speech privacy between the following two rooms: (a) a conference room seating 50 persons, 20 x 30 x 10 ft high, with 300 sq ft covered by acoustical material(b) a private office, 12 x 20 x 10 ft high, with full acoustical ceiling; separating partition 20 x 10 ft.
Solution - Consider transmission from (a) to (b). From Table I, NC = 35 (office), and intruding speech level from conference room is 10 db above normal; S = 200 sq ft; A_1 = 300 sabins; A_2 = 240 sabins. Using Figure 2 for the S, A_1 and A_2 terms Formula (1) becomes (incorporating an extra 10 db for the high speech level):

STC + 35 = 96 + 23 - 25 - 24,

STC = 35.

Considering transmission in the reverse direction, NC = 30 (for conference room) and the speech level is normal (for private office). A_1 and A_2 are interchanged, but this does not affect the calculation. Substituting in Formula (1):

STC + 30 = 86 + 23 - 24 - 25

STC = 30

Therefore the first value, STC-35, governs the requirement.

Note that for complete inaudibility Formula (2) would be used, resulting in a requirement of STC-45.

Ceiling Plenum Insulation

A common sound insulation problem is the combination of a suspended acoustical ceiling with partitions that terminate at the suspended ceiling level. With such a system, sound may be transmitted up through the suspended ceiling into the plenum space, through the plenum above the partition and down on the other side. It should be noted that the ceiling areas do not affect the process in a simple way; transmission is greatest through regions nearest the partition and becomes progressively less with distance from the partition.

In the U.S.A. the Acoustical Materials Association has developed an index suitable for rank-ordering ceiling structures, but the "attenuation factors" so obtained are not directly applicable to design. It is found, however, that for most acoustical ceilings the attenuation factor at 350 cycles/sec is numerically equivalent (approximately) to the Sound Transmission Class of the system. Where AMA attenuation factors are available, appropriate STC values may be thus deduced for use with Formulas (1) to (3) (using the plenum area over the partition as the transmission area S). If ordinary transmission loss measurements are available a conservative STC value for the system will be double the STC of one ceiling. This neglects the effect of absorption in the plenum space itself, which results in additional attenuation.

The STC requirement thus deduced for the partition and ceiling systems independently does not quite suffice when the two systems are combined; the total transmitted power would then be twice the permissible maximum. Each system must be at least as good as the calculated value, and one or both must be somewhat better. Quantitatively, the sum of the two requirements should be about 6 db better than the sum of values obtained by the independent calculations.

If adequate design information is lacking another approach is to require that the contractor or supplier construct a sample pair of rooms, where the actual performance can be determined. Such a step is very useful in any case, because it ensures that the performances of the individual components are not invalidated by an assembly problem.

Doors

Doors constitute a serious weakness in a good wall. Insulation ratings for solid-core doors vary from about STC-15 for a swinging door with clearance all around to STC-27 for the same door completely sealed by gaskets or weather stripping all around. A more typical installation, with stops on three sides but no gaskets, is about STC-20. The requirement for a door alone (in a perfect wall) may be determined by applying the appropriate formula as before, making S equal to the door area. The result for the combined wall and door should be adjusted as for wall and ceiling. Other weaknesses in a partition, such as holes or cracks, may also be studied in the same way.