Room-to-Room Privacy and Acoustical Design Criteria

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With the recent and continuing interest in loft-type condominiums and apartments, privacy between units is a significant issue.[1] Unfortunately, architects and designers have little more than Sound Transmission Class (STC) to guide them in choosing wall constructions with an eye to acoustical insulation. Virtually no distinction is made between Sound Transmission Class, Field Sound Transmission Class (FSTC) and Noise Isolation Class (NIC).[2] It is well known throughout the architectural acoustics community that even with the use of good construction practice, FSTC and NIC can be significantly lower than STC[3] – 5 to 10 points. In poor quality constructions, the difference can be much greater. This article examines STC as it relates to speech privacy and offers some guidelines for specifying wall construction based on STC ratings.

Prior to World War II buildings were massive, interior walls and ceilings were lath and plaster. Room-to-room privacy was not much of a consideration. After WWII the structure of buildings changed rapidly. Walls became light weight, ceilings became suspended lay-in and acoustical privacy declined. Now, faced with this in new as well as older multifamily buildings, it is important that privacy be considered as a design parameter.

Sound Transmission

In describing room-to-room sound transmission, it is convenient but unfortunate that Sound Transmission Class[4] (STC) has become the primary descriptor for room-to-room sound isolation. STC is a laboratory[5] measurement procedure for transmission of sound through a sample of a wall construction. When the same wall construction is built in the field, it has not only the basic construction as used in the STC test but also various holes, cracks and other paths by which sound can get from one side of the wall to the other. These other paths are referred to as 'flanking' paths. Flanking paths and other differences between the STC lab sample and the "real life" wall in terms of sound transmission can be significant. Unfortunately, there is not a one-to-one link between STC and privacy.

Expectations

Expectations for an acoustical environment in a building, particularly an apartment or condominium, are subjective. That is, different people have different expectations. It is incumbent on the designer to provide an acoustical environment consistent with the expectations of the occupants of the building. A quantifiable set of privacy criteria is needed for design purposes. Most disturbing is the ability to hear and understand speech from the opposite side of a wall. Psychoacoustically, we believe that if we can understand conversation coming our way, then our conversation can be understood going the other way. We want to keep our conversations private from our neighbors. We turn to the method of Articulation Index[6] (AI) as a means of quantifying privacy in terms of the percent of unfamiliar sentences (first presentation to listeners) that can be understood correctly.

Privacy

There is no such thing as 'soundproof,' and privacy is a subjective matter. Acoustical privacy could mean either speech privacy or freedom from non-spoken sounds intruding into the acoustical environment, or both. Speech privacy can be quantified to a reasonably precise degree. This is done in terms of the ability to hear and understand a percentage of words, sentences, or other intelligible spoken sounds. Articulation Index is a convenient and proven method for this purpose.

Non-speech acoustical privacy does not lend itself to convenient quantification. To provide non-speech acoustical privacy it is necessary to define the potentially offending sound (loud TV, Hi Fi, music practice, etc.) and how much of this is acceptable in the receiving space. If the criterion is "no sound," the costs are significant. Recording studios, broadcast studios, voice-over booths, hearing testing booths and music practice

Table 1. Approximate relationship of Articulation Index (AI) to speech privacy, speaker speaking with raised voice; NIC values are recommended to assure degree of privacy; to be safe, STC ratings should be at least eight (8) points greater than NIC ratings.

Articulation Index	Degree of Privacy	Listener Conditions	Typical Subjective Response
0 to 0.05	A. Confidential STC > 55 (NIC > 47)	Cannot understand speech from adjacent room. May not be aware of the presence of others others next door. May not hear activity sounds of others. Music usually can be heard, particularly when loud.	Complete privacy Sense of isolation No privacy complaints expected.
0.05 to 0.15	B. Normal STC 52 – 55 (NIC 44 – 47)	Occasionally hear the activity sounds of others in adjacent room. Aware of presence of others. Speech and machines audible, but not distracting. Music (usually) and other louder sounds can he heard.	Sense of privacy Some feeling of isolation No privacy complaints expected
0.15 to 0.20	C. Marginal STC 50 – 52 (NIC 42 – 44)	Aware of presence of others next door. Sense of community. Often hear activity sounds and voices of others. Conversations of others occasionally understood. Machines and speech audible and occasionally distracting.	Minimal sense of privacy Some loss of territory Privacy complaints may be expected
0.20 to 0.30	D. Poor STC 47 – 50 (NIC 39 – 42)	Continually aware of the presence of others. Activity sounds, speech and machines will be continually heard. Frequent distractions. expected.	Sense of community Loss of privacy Some loss of territory Privacy complaints
0.30 to 1.00	E. None STC < 47 (NIC < 39)	Conversation easily understood. Machine and activity sounds clearly audible. Total distraction from other tasks.	Sense of community Sense of intrusion on territory. No sense of privacy Many privacy complaints expected

rooms are examples of spaces that might require such extreme isolation. But it all comes at a price. One might well concede that these “high sound” uses are not compatible with adjacent residential occupancy.

Speech Privacy

Articulation Index was developed to provide a measure of the ability to understand words and sentences under various conditions. The ability to understand sentences, for example, can be equated to speech privacy. For purposes here, privacy is based on the ability not necessarily to hear sound from an adjoining room, but to understand spoken words or unfamiliar sentences. Computation of Articulation Index is a number crunching exercise that considers many factors that influence the ability to understand spoken sentences that may not be familiar to the listener – (1) the level and frequency spectrum of the speaker’s voice (the sound source) as received by the listener (receiver), and (2) the level and frequency spectrum of the background sound surrounding the listener. The calculations include weighting the sound reaching the listener by relative importance in each of the sixteen 1/3 octave bands used in the analysis. The relative weightings have been determined by “jury tests” in which many people have listened to test sounds and rated them according to their subjective judgement.

Five generally accepted definitions for classes of privacy are shown in Table 1. Table 1 rates the nominal correlation of Articulation Index with the degree of privacy as described in the third and fourth column of the table. These are based on computation of Articulation Index as discussed later. The AI concept is based on face to face conversation, but is applied to room-to-room spoken sentences. The underlined sections are applicable to room-to-room privacy. These are average reactions and, being subjective, deviations can be expected. Raised voice levels were used in the calculations for Table 1.

The results in Table 1 are based on noise reduction (NR) and noise isolation class (NIC)[8] because NR and NIC incorporate three factors that affect articulation index – (1) the attenuation of the common wall (transmission loss), (2) the area of the common wall and (3) the acoustical absorption in the receiving room. It is a simple matter for a designer to specify a NIC. However, the designer must also address in his/her designs how the specified NIC is to be achieved. It begins with the STC of the basic wall construction and includes paths by which sound goes around a wall. Such paths may include: through air leaks in a wall, over a partial height wall (i.e., one that stops at the ceiling or penetrates the ceiling only slightly), flanking via HVAC ducts, structure borne noise, and other paths. All of these are issues in the design to achieve the desired NIC. A reasonable rule of thumb based on experience is that a specified STC should be at least eight points greater than the required NIC. The results in Table 1 use the eight point difference.

Relation Between Wall Properties and Privacy

There is no widely accepted consensus on what privacy rating (Table 1) is appropriate for specific room-to-room pairs. Building codes largely ignore the issue. Others say the STC should be a minimum of 50 or, in some instances, 45. In this writer’s opinion 45 or 50 STC is at the low end of quality construction.

Table 2 offers some guidelines for STC between adjacent spaces within the same unit and between adjacent units based on the analysis done for this article. The criteria are based on the assumption that an STC rating, based on field experience,

Table 2. Sound transmission requirements for apartments, condominiums and multiple dwelling buildings. Based on speech privacy. Letters refer to degree of privacy in Table 1. STC = NIC + 8, NC25 background.

Partition Between Room and Room		STC Requirement Expected Degree of Privacy Confidential	Normal	Marginal
Bedrooms	Adjacent bedrooms, adjacent units	55 A	52 B	50 C
	Adjacent bedrooms, same units	52 B	50 C	39 D
	Bathrooms, adjacent units	59 A	56 A	52 C
	Bathrooms, same units	55 A	53 B	49 C
	Living rooms, adjacent units	57 A	54 B	50 C
	Living rooms, same units	54 B	51 C	48 D
	Kitchen areas, adjacent units[1]	55 A	53 B	50 C
	Kitchen areas, same units[1,2]	52 B	52 B	49 C
	Corridors, lobby, public spaces[3]	55 A	52 B	48 C
Living Rooms	Adjacent living rooms, adjacent units	55 A	54 B	52 C
	Adjacent living rooms, same units	52 B	52 C	48 D
	Bathrooms, adjacent units	55 A	54 B	52 C
	Bathrooms, same units	54 B	51 C	50 C
	Kitchen areas, adjacent units[1]	55 A	52 B	50 C
	Kitchen areas, same units[1,2]	52 B	49 C	45 E
	Corridors, lobby, public spaces[3]	55 B	52 B	50 C
Bathrooms	Bathrooms, adjacent units	52 B	50 C	50 C
Bathrooms	Corridors, lobby, public spaces[3]	52 C	50 C	50 C
Bathrooms	Kitchen areas, adjacent units[1,2]	55 B	52 B	48 D
Kitchen	Kitchen areas, adjacent units[1,2]	52 B	50 C	48 D
Kitchen	Corridors, lobby, public spaces[3]	55 A	52 B	48 D

If loud TV, Hi Fi, music practice, etc. expected, add at least 5 to STC for adjacent living rooms and 10 for adjacent bedrooms.
Where there are open doors between spaces, the effective STC between the spaces is negligible.
Louvers in MER doors negate any significant composite STC rating of the door/wall assembly.

1. Including dining, or family or recreation rooms
2. No door direct to living unit
3. Assumes no entrance door from corridor to living unit.

is nominally eight points higher than the more pertinent NIC and will generally result in the same privacy feeling in hopes this provides some guidance in the design of walls.

Procedures

American National Standards Institute (ANSI) S3.5, Methods for the Calculation of the Articulation Index, was used as the criterion for privacy. Transmission loss of a typical wall was based on an average of 22 STC tests of a typical wall consisting of one layer of 1/2 in. or 5/8 in. dry wall on each side of 3-5/8 in. metal studs spaced 16 in. or 24 in. on center and containing acoustically absorbent material in the cavity. A speaking voice sound level from Table 8 of ANSI S3.5 was used as the sound source level. Articulation Index was calculated for a range of NIC and background levels in the receiving room.[8] NIC begs the issue of absorption in the receiving room. Background sound was the spectrum defined by the noted Noise Criteria (NC) curve.

Figure 1 shows the results of a series of calculations of AI for a range of NIC values and background sound levels using a normal speaking voice. Figure 2 shows the same results for a raised speaking voice 10 dB louder than the normal voice. The corresponding privacy designations as described above are shown on these two figures.

Tables 3a and 3b are lower limits for the privacy categories in Figures 1 and 2. Tables 4a and 4b present the same calculations for raised voice. Both NIC and STC are given. Again, STC is taken as NIC +10.

Other Sound Intrusions (Music, TV, etc.)

Privacy as discussed so far has been concerned with understanding the spoken word from an adjacent room. Psychologically, this is the more disturbing issue for the people next door. Issues of loud television, Hi Fi systems and music practice are also privacy related issues. To some extent the spoken word is of concern, but the larger issue is competing sounds; i.e., hearing the TV next door while one is trying to listen to their own TV, possibly a different program, or while one is trying to sleep. To cope with this kind of sound intrusion, one must think of STC ratings greater than 60.

These kinds of sound intrusion are more difficult to control. The ideal objective is to reduce the offending sound to at least 10 dB below the background sound in the listener's room. Background in the listener's room can include the sound of the listener's TV or other local sound. Greater NR is required to avoid this problem. To reduce the sound from, say, 90 dBA in the source room to 10 dBA below a typical 40 dBA background in the receiving room, requires a 60 dBA reduction. This is feasible, but requires difficult and costly measures. To reduce from 90 dBA to 10 dBA below a nighttime sleeping environment of 25 dBA is nearly impossible except with draconian measures.

As a general rule, if non-speech sounds are of concern, the common wall must have an STC rating of 60 or greater depending on the specific circumstances. Privacy ratings are not absolute, but rather are a continuum. The classifications are based on average perceptions. Some judgement is required to decide if an NIC of 42 is really adequate for normal privacy or if a higher NIC value is appropriate.

To reiterate, NIC is a better measure of the in situ acoustical performance than STC. However, NIC contains information not readily available in the design process without detailed analysis of each specific situation. Therefore, for purposes here, STC is presented together with NIC based on the premise that in a typical field situation the STC will have to be eight points higher than NIC to achieve comparable privacy. This also represents a judgement call in selecting a partition construction based on STC. If the situation is critical, opt for a higher STC to be on the safe side.

Low Frequency Sound

STC and all of its derivative protocols are concerned with sound in the 125 to 4000 Hz range. This is largely because of the relationship to the range of speech frequencies, nominally from 300 to 3000 Hz. It is much easier to block sound in these ranges than to block sound below 125 Hz. Hi Fis, Sound Blasters, Boom Boxes and other instruments of this ilk as well as music per se, particularly classical music, all generate significant sound below 125 Hz. If this is happening next door, the perception is of a constant rhythmic thump, thump, thump with the higher frequencies attenuated by the common wall. This intrusion can be extremely objectionable even for a short period. It takes very special measures to provide significant low frequency attenuation. When low frequency sound is in the mix, it is advisable to look at the low frequency transmission properties of the construction much more so than the STC rating.

Concluding Comments

To reiterate, privacy is a continuum – not sharp divisions as shown in Table 1. Informed judgement is an essential part of providing the degree of privacy expected by the occupants of multi-family housing. Persons moving to a condominium from a private residence for the first time will have higher expectations of privacy than someone who has lived previously in a multi-family environment.

Obviously the larger the area of a wall between two rooms, the more acoustical power will be transmitted from one room to the other. So, to better compare the properties of two walls, a correction must be made for the relative wall areas. Also, the more acoustical absorption in the receiving room, the more of the transmitted sound power is absorbed, thus lessening the sound level in the room. A correction for the absorption must also be made to compare two wall constructions. To complete the picture, other similar measures are also used and are much more meaningful – noise reduction (NR) and noise isolation class (NIC). All STC and FSTC tests start out with the same basic measurements – the numerical difference between the

Table 3a. Normal voice NIC

Degree of Privacy	Background NC Level 25	30	35	40	45
	NIC for degree of privacy				
A	39	34	29	24	20
B	34	29	24	19	–
C	32	27	23	–	–

Table 3b. Normal voice STC

Degree of Privacy	Background NC Level 25	30	35	40	45
	STC for degree of privacy				
A	47	42	37	32	28
B	42	37	32	27	–
C	40	35	31	–	–

Table 4a. Raised voice NIC

Degree of Privacy	Background NC Level 25	30	35	40	45
	NIC for degree of privacy				
A	47	44	39	34	25
B	44	39	34	29	19
C	42	37	32	27	–

Table 4b. Raised voice STC

Degree of Privacy	Background NC Level 25	30	35	40	45
	STC for degree of privacy				
A	55	52	47	42	33
B	52	47	42	37	27
C	50	45	40	35	–

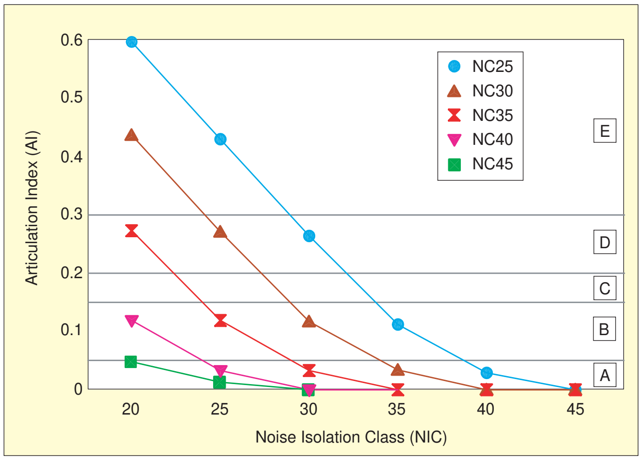

Figure 1. Normal speaking voice.

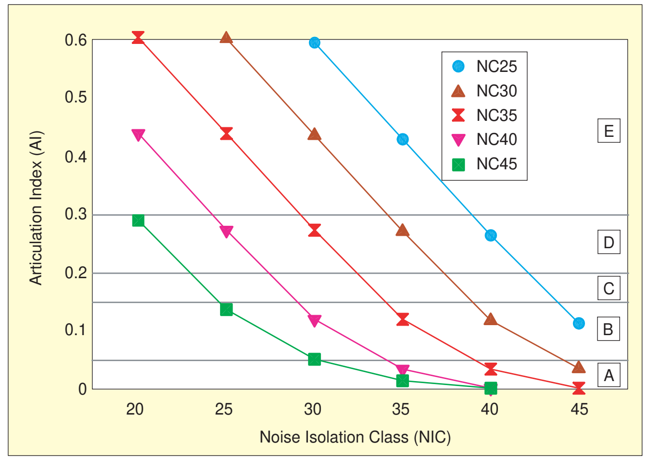

Figure 2. Raised speaking voice.

sound level (in decibels) on the noise source side of the wall and the noise receiver side of the wall. For NR and NIC no correction is made for common wall area or acoustical absorption in the receiving room. This difference is acoustical noise reduction.

Experience has shown that FSTC and NIC are generally 5 to 10 dB lower than the corresponding STC for the same wall construction, and can be as much as 15 dB lower with particularly shoddy workmanship. For example, if the STC is 5 dB greater than FSTC for a given wall construction, three times as much sound power is transmitted through the FSTC wall than through the STC wall. A 10 dB difference is a factor of 10 times as much sound power and a 15 dB difference is 31 times as much sound power transmitted. If sound transmission is a critical issue, it is suggested that close observation be maintained as walls are built to avoid flanking paths.

It is hoped that this brief essay will be helpful to designers and the community in general in selecting walls for their acoustical insulation values. It should be noted that floors and ceilings should likewise be selected for their acoustical properties according to the suggested NIC/STC criteria. These results are applicable to airborne sound transmission only. Impact sounds, footfalls for example, are a whole different story unrelated to the results presented here. Nonetheless, impact noise is a growing concern in multi-family buildings, but is beyond the scope of this treatise.

We see from Figures 1 and 2 that background sound is an important element in Articulation Index. However, background sound should be essentially broad band such as sound generated in the ducts of HVAC systems. Background can also be introduced by electronic means. TV, for example, should not be counted on as a background. Therefore, one should assume a low background to be conservative. Sleeping quarters are much more likely to have low background sound. Other rooms are more likely to have background closer to NC30 or NC35. Remember, there remains room for informed judgement.

The author would appreciate receiving comments and criticisms on this matter. Perhaps, if there is enough interest, consensus guidelines can be developed where none now exist.

Footnotes

1. As a side issue, the issuing of ANSI S12.60, Acoustical Performance Criteria, Design Requirements and Guidelines for Schools, a year ago has made privacy between classrooms an issue of concern.
2. STC is a laboratory test that tests the transmission of sound through a sample of a basic wall construction with no electrical boxes or other 'violations' of the structure. FSTC is an in situ test identical in most respects to STC except that it is testing a wall in the real world. Both STC and FSTC are reduced to per square foot and corrected for acoustical absorption in the receiving (listener's) room. NIC is similar to FSTC except that no correction is made for wall area or absorption in the receiving room. NIC is a "what you hears is what you gets," to paraphrase a famous comedian. All of these tests are detailed in the American Society of Testing Materials (ASTM) procedures.
3. It is worth noting that theoretically, if FSTC is more than 3 dB less than STC, more acoustical power is leaking around the wall (flanking) than is transmitted through the basic wall itself.
4. The entire procedure as set forth in the American Society of Testing Materials (ASTM) E90, Standard Method for Laboratory measurement of Airborne Sound Transmission Loss of Building Partitions, neglects sound below 125 Hz that is often of primary concern in preventing the transmission of low frequency sounds such as Hi Fi with heavy bass and like sounds.
5. ASTM E90, Standard Method for Laboratory Measurement of Airborne Sound Transmission Loss of Building Partitions.
6. See American National Standards Institute (ANSI) S3.5, Methods for the Calculation of the Articulation Index.
7. NIC is a single number rating computed in accordance with ASTM 413, Standard Classification for Determination of Sound Transmission Class, based on individual NR measurements.
8. This is not strictly a correct use of AI, but there had to be a starting place and it agrees reasonably with field experience. SV

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