An Introduction to Noise Control in Buildings

Course No: C02-016
Credit: 2 PDH

J. Paul Guyer, P.E., R.A., Fellow ASCE, Fellow AEI

Continuing Education and Development, Inc.
22 Stonewall Court
Woodcliff Lake, NJ 07677

P: (877) 322-5800
info@cedengineering.com

1. INTRODUCTION

This is an introduction to noise control in buildings. It is not an in-depth treatment, but it will introduce designers to some important principles and terminology. In simple applications on real projects the information provided here will give designers a good start in addressing acoustic control issues. For more acoustically complex projects designers will need to apply more detailed principles. There are excellent acoustical engineering treatises available commercially and from government agencies to provide practitioners with the necessary guidance in applying these more rigorous methods.

2. NOISE CRITERIA

2.1 General. This section includes data and discussions on generally acceptable indoor noise criteria for acceptable living and working environments. These criteria can be used to evaluate the suitability of existing indoor spaces and spaces under design.

2.2 Noise Criteria In Buildings. Room Criteria (RC) and Noise Criteria (NC) are two widely recognized criteria used in the evaluation of the suitability of intrusive mechanical equipment noise into indoor occupied spaces. The Speech Interference Level (SIL) is used to evaluate the adverse effects of noise on speech communication.

2.2.1 Noise Criterion (NC) Curves. Figure 1 presents the NC curves. NC curves have been used to set or evaluate suitable indoor sound levels resulting from the operation of building mechanical equipment. These curves give sound pressure levels (SPLs) as a function of the octave frequency bands. The lowest NC curves define noise levels that are quiet enough for resting and sleeping, while the upper NC curves define rather noisy work areas where even speech communication becomes difficult and restricted. The curves within this total range may be used to set desired noise level goals for almost all normal indoor functional areas. In a strict interpretation, the sound levels of the mechanical equipment or ventilation system under design should be equal to or be lower than the selected NC target curve in all octave bands in order to meet the design goal. In practice, however, an NC condition may be considered met if the sound levels in no more than one or two octave bands do not exceed the NC curve by more than one or two decibels.

2.2.2 Room Criterion (RC) Curves. Figure 2 presents the Room Criterion (RC) curves. RC curves, like NC curves, are currently being used to set or evaluate indoor sound levels resulting from the operation of mechanical equipment. The RC curves differ from the NC curves in three important respects. First, the low frequency range has been extended to include the 16 and 31.5 Hz octave bands. Secondly, the high frequency range at 2,000 and 4,000 Hz is significantly less permissive, and the 8,000 Hz octave band has been omitted since most mechanical equipment produces very little noise in this frequency region. And thirdly, the range over which the curves are defined is limited from RC 25 to RC 50 because; 1) applications below RC 25 are special purpose and expert consultation should be sought and; 2) spaces above RC 50 indicate little concern for the quality of the background sound and the NC curves become more applicable.

Table 1 lists representative applications of the NC curves. The evaluation of the RC curves is different than that for the NC curves. In general the sound levels in the octave bands from 250 to 2,000 Hz are lower than those of the NC curves. Should the octave band sound levels below 250 Hz be greater than the criteria a potential "rumble" problem is indicated. As a check on the relative rumble potential, the following procedure is recommended:

- Sum the sound pressure levels in the octave bands from 31.5 through 250 Hz on an energy basis.
- Sum the sound pressure levels in the octave bands from 500 through 4,000 Hz on an energy basis.
- Subtract the high frequency sum (step 2) from the low frequency sum (step 1).
- If the difference is +30 dB or greater, a positive subjective rating of rumble is expected, if the difference is between +25 and +30 dB a subjective rating of rumble is possible, if the difference is less than +20 dB a subjective rating of rumble is unlikely.

Also indicated on the RC curves (Figure 2) are two regions where low frequency sound, with the octave band levels indicated, can induce feelable vibration or audible rattling in light weight structures.

2.2.3 Speech interference levels. The speech interference level (SIL) of a noise is the arithmetic average of the SPLs of the noise in the 500-, 1000-, and 2000-Hz octave bands. The approximate conditions of speech communication between a speaker and listener can be estimated from Table 2 when the SIL of the interfering noise is known. Table 2 provides "barely acceptable" speech intelligibility, which implies that a few words or syllables will not be understood but that the general sense of the discussion will be conveyed or that the listener will ask for a repetition of portions missed.

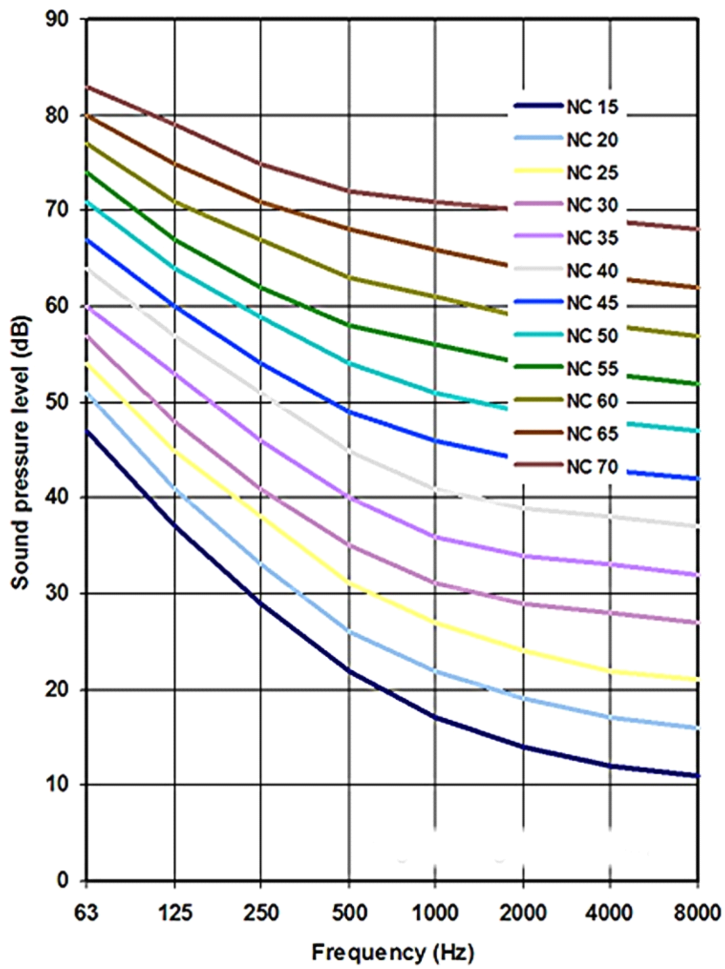

Figure 1
Noise Criterion (NC) Curves

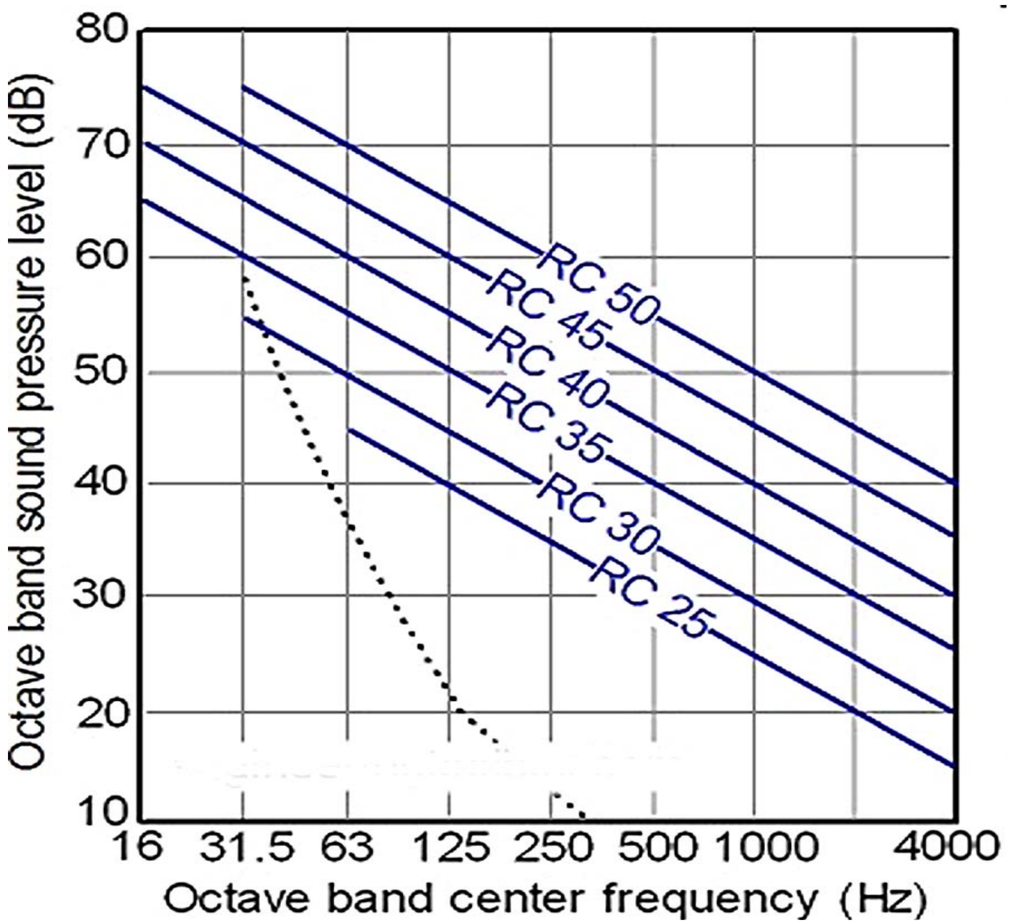

Figure 2
Room Criterion (RC) Curves

Category	Area (and Acoustic Requirements)	Noise Criterion[a]
1	Bedrooms, sleeping quarters, hospitals, residences, apartments, hotels, motels, etc. (for sleeping, resting, relaxing).	NC-20 to NC-30
2	Auditoriums, theaters, large meeting rooms, large conference rooms, radio studios, churches, chapels, etc. (for very good listening conditions).	NC-15 to NC-30
3	Private offices, small conference rooms, classrooms, libraries, etc. (for good listening conditions).	NC-30 to NC-35
4	Large offices, reception areas, retail shops and stores, cafeterias, restaurants, etc. (for fair listening conditions).	NC-35 to NC-40
5	Lobbies, drafting and engineering rooms, laboratory work spaces, maintenance shops such as for electrical equipment,etc. (for moderately fair listening conditions).	NC-40 to NC-50
6	Kitchens, laundries, shops, garages, machinery spaces, power plant control rooms, etc. (for minimum acceptable speech communication, no risk of hearing damage).	NC-45 to NC-65

Table 1
Representative Applications of the NC Curves

Distance (ft.)	Voice Level			
	Normal	Raised	Very Loud	Shouting
1/2	74	80	86	92
1	68	74	80	86
2	62	68	74	80
4	56	62	68	74
6	53	59	65	71
8	50	56	62	68
10	48	54	60	66
12	46	52	58	64
16	44	50	56	62

Table 2
Speech Interference Levels

3. SOUND DISTRIBUTION INDOORS

3.1 Sound Pressure level In a Room. The sound pressure levels at a given distance or the sound power levels for individual equipment items can often be obtained from equipment suppliers. Once the characteristics of the sound source have been determined, then the sound level at any location within an enclosed space can be estimated. In an outdoor “free field” (no reflecting surfaces except the ground), the sound pressure level (SPL) decreases at a rate of 6 dB for each doubling of distance from the source. In an indoor situation, however, all the enclosing surfaces of a room confine the sound energy so that they cannot spread out indefinitely and become dissipated with distance. As sound waves bounce around within the room, there is a build-up of sound level because the sound energy is “trapped” inside the room and escapes slowly.

3.1.1 Effect of distance and absorption. The reduction of sound pressure level indoors, as one moves across the room away from the sound source, is dependent on the surface areas of the room, the amount of sound absorption material on those areas, the distances to those areas, and the distance from the source. All of this is expressed quantitatively by the curves of Figure 3. Figure 3 offers a means of estimating the amount of SPL reduction for a piece of mechanical equipment (or any other type of sound source in a room, as one moves away from some relatively close-in distance to any other distance in the room, provided the sound absorptive properties of the room (Room Constant) is known. Conversely Figure 3 also provides a means of estimating the sound reduction in a room, from a given source, if the distance is constant and the amount of absorptive treatment is increased. Table 3 represents a simplification of Figure 3 for a special condition of distance and room constant.

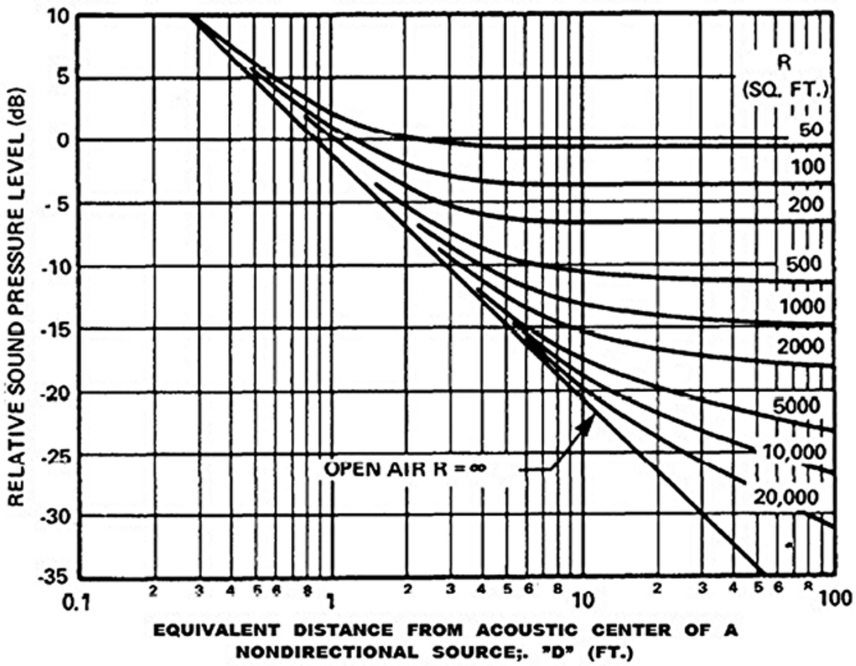

Figure 3

Room Constant "R" (ft.²)	Distance "D" (in ft.) from Equipment								
	3	5	10	15	20	30	40	60	80
100	-5	-4	-4	-4	-4	-4	-4	-4	-4
200	-3	-2	-1	-1	-1	-1	-1	-1	-1
320	-2	0	0	0	0	0	0	0	0
500	-1	1	2	3	3	3	4	4	4
700	0	2	4	4	5	5	6	6	6
1000	1	3	5	6	7	7	8	0	0
2000	1	4	7	0	9	9	10	10	10
3200	2	5	0	9	10	11	12	12	12
5000	2	6	9	11	12	13	14	14	15
7000	2	6	10	12	13	14	15	15	16
10000	2	7	11	13	14	15	16	17	10
20000	2	7	12	14	16	18	19	21	22
Infinite	2	7	13	16	19	22	25	20	31

1. Reduction of SPL in dB in going from normalized 3-feet distance and 800 sf Room Constant to any other distance and Room Constant.
2. Negative value of reduction means an increase in sound level.

Table 3

3.1.2. Sound absorption coefficients. For most surfaces and materials, the sound absorption coefficients vary with frequency; hence the Room Constant must be calculated for all frequencies of interest. Even room surfaces that are not normally considered absorptive have small amounts of absorption. Usually sound absorption coefficients are not measured in the 31, 63 and 8,000 Hz frequencies. Where the data at these frequencies are not available use 40% of the value of the 125 Hz for the 31 Hz band, 70% of the 125 Hz value for the 63 Hz band and 80% of the 4,000 value for the 8,000 Hz octave band. Values of sound absorption coefficients for specialized acoustical materials must be obtained from the manufacturer.

3.1.3 Estimation of Room Constant. In the early stages of a design, some of the details of a room may not be finally determined, yet it may be necessary to proceed with certain portions of the design. An approximation of the Room Constant can be made using Figure 4 and Table 4. The basic room dimensions are required but it is not necessary to have made all the decisions on side wall, floor, and ceiling materials. This simplification yields a less accurate estimate than does the more detailed procedure, but it permits rapid estimates of the Room Constant with gross, but non-specific, changes in room materials and sound absorption applications. Then, when a favored condition is found, detailed calculations can be made with an equation that is not presented here.

3.1.4 Use of Figure 4. Figure 4 gives a broad relationship between the volume of a typically shaped room and the Room Constant as a function of the percentage of room area that is covered by sound absorption material. Room area means the total interior surface area of floor, ceiling, and all side walls. The Room Constant values obtained from this chart strictly apply at 1000 Hz, but in this simplified procedure are considered applicable for the 2000- through 8000-Hz bands as well.

Octave Frequency Band (Hz)	Percent of Area of Thin Surfaces to Total Surface Area of Room							
	0	10	20	30	40	60	80	100
31	1	1.3	1.6	1.9	2.2	2.8	3.4	4.0
63	1	1.3	1.6	1.9	2.2	2.8	3.4	4.0
125	1	1.3	1.6	1.9	2.2	2.8	3.4	4.0
250	1	1.2	1.3	1.4	1.6	1.9	2.1	2.4
500	1	1.1	1.1	1.2	1.2	1.3	1.5	1.6

Table 4

Materials	Coefficients					
	125 Hz	250 Hz	500 Hz	1000 Hz	2000 Hz	4000 Hz
Brick, unglazed	.03	.03	.03	.04	.05	.07
Brick, unglazed, painted	.01	.01	.02	.02	.02	.03
Carpet, heavy, on concrete	.02	.06	.14	.37	.60	.65
Same, on 40 oz hairfelt or foam rubber	.08	.24	.57	.69	.71	.73
same, with impermeable latex backing on 40 oz hairfelt or foam rubber	.08	.27	.39	.34	.48	.63
Concrete Block, light, porous	.36	.44	.31	.29	.39	.25
Concrete Block, dense, painted	.10	.05	.06	.07	.09	.08
Fabrics						
Light velour, 10 oz per sq yd, hung straight, in contact with wall	.03	.04	.11	.17	.24	.35
Medium velour, 14 oz per sq yd, draped to half area	.07	.31	.49	.75	.70	.60
Heavy velour, 18 oz per sq yd, draped to half area	.14	.35	.55	.72	.70	.65
Floors						
Concrete or terrazzo	.01	.01	.015	.02	.02	.02
Linoleum, asphalt, rubber or cork tile on concrete	.02	.03	.03	.03	.03	.02
Wood	.15	.11	.10	.07	.06	.07
Wood parquet in asphalt on concrete	.04	.04	.07	.06	.06	.07
Glass						
Large panes of heavy plate glass	.18	.06	.04	.03	.02	.02
Ordinary window glass	.35	.25	.18	.12	.07	.04
Gypsum Board, 1/2-in. nailed to 2x4's 16-in. o.c.	.29	.10	.05	.04	.07	.09
Marble or Glazed Tile	.01	.01	.01	.01	.02	.02
Plaster, gypsum or lime, smooth finish on tile or brick	.013	.015	.02	.03	.04	.05
Plaster, gypsum or lime, rough finish on lath	.14	.10	.06	.05	.04	.03
Same, with smooth finish	.14	.10	.06	.04	.04	.03
Plywood Paneling, 3/8-in. thick	.28	.22	.17	.09	.10	.11
Water Surface, as in a swimming pool	.008	.008	.013	.015	.020	.025
Air, Sabins per 1000 cubic feet	.09	.20	.49	1.2	2.9	7.4

Absorption of Seats and Audience

Values given are in Sabins per square foot of seating area or per unit

	125 Hz	250 Hz	500 Hz	1000 Hz	2000 Hz	4000 Hz
Chairs, metal or wood seats, each, unoccupied	.15	.19	.22	.39	.38	.30
People in a room, per person (do not use for auditorium calculations)	2	3	4	5	5	4
Audience, seated in upholstered seats, per ft² of floor area, for auditorium calculations	.60	.74	.88	.96	.93	.85

Figure 4

4. SOUND ISOLATION BETWEEN ROOMS

Discussed here are data and procedures for estimating the changes in sound levels as one follows the “energy flow” path from a sound source to a receiver, through building components, such as walls, floors, doors etc. First, the sound pressure levels in the room containing the source drop off as one moves away from the source. Then, at the walls of the room, some sound is absorbed, some is reflected back into the room, and some is transmitted by the walls into the adjoining rooms (this also occurs at the floor and ceiling surfaces). The combined effects of this absorption, reflection, and transmission are the subject of this discussion.

4.1 Sound Transmission Loss (TL), Noise Reduction (NR) And Sound Transmission Class (STC). With the knowledge of the acoustical isolation provided by walls and floors, it is possible to select materials and designs to limit noise intrusion from adjacent mechanical equipment rooms to acceptable levels. The degree of sound that is transmitted is influenced by the noise isolation properties of the demising construction, the area of the demising wall, floor or ceiling and the acoustical properties in the quiet room.

4.1.1 Transmission loss (TL) of walls. The TL of a wall is the ratio, expressed in decibels, of the sound intensity transmitted through the wall to the airborne sound intensity incident upon the wall. Thus, the TL of a wall is a performance characteristic that is entirely a function of the wall weight, material and construction, and its numerical value is not influenced by the acoustic environment on either side of the wall or the area of the wall. Procedures for determining transmission loss in the laboratory are given in ASTM E 90. This is the data usually given in most manufacturers literature and in acoustic handbooks. Laboratory ratings are rarely achieved in field installations. Transmission loss values in the laboratory are usually greater, by 4 to 5 dB, than that which can be realized in the field even when good construction practices are observed. ASTM E 336 is a corresponding standard method for determination of sound isolation in buildings (in situ). There are many references that provide transmission loss performance for building materials. In addition many manufacturers also provide transmission loss for their products.

4.1.2 “Noise reduction” (NR) of a wall. When sound is transmitted from one room (the “source room”) to an adjoining room (the “receiving room”), it is the transmitted sound power that is of interest. The transmission loss of a wall is a performance characteristic of the wall structure, but the total sound power transmitted by the wall is also a function of its area (e.g. the larger the area, the more the transmitted sound power). The Room Constant of the receiving room also influences the Sound Power Loss (SPL) in the receiving room. A large Room Constant reduces the reverberant sound level in the room at an appropriate distance from the wall. Thus, three factors influence the SPL in a receiving room: the TL of the wall, the area of the common wall between the source and receiving rooms, and the Room Constant R2 of the receiving room. These three factors are combined in a manner that is beyond the scope of this presentation.

4.1.3 “Sound transmission class” (STC). Current architectural acoustics literature refers to the term “Sound Transmission Class” (STC). This is a one number weighting of transmission losses at many frequencies. The STC rating is used to rate partitions, doors, windows, and other acoustic dividers in terms of their relative ability to provide privacy against intrusion of speech or similar type sounds. This one-number rating system is heavily weighted in the 500- to 2000-Hz frequency region. Its use is not recommended for mechanical equipment noise, whose principal intruding frequencies are lower than the 500- to 2000 Hz region. However, manufacturers who quote STC ratings should have the 1/3 octave band TL data from which the STC values were derived, so it is possible to request the TL data when these types of partitions are being considered for isolation of mechanical equipment noise. The procedure for determining an STC rating is given in ASTM standard E 413.

4-3. Transmission Loss-Walls, Doors, Windows. Generally a partition will have better noise reduction with increasing frequency. It is therefore important to check the noise reduction at certain frequencies when dealing with low frequency, rumble type noise. Note that partitions can consist of a combination of walls, glass and doors. Walls can generally be classified as fixed walls of drywall or masonry, or as operable walls.

4.3.1 Drywall walls. These walls consist of drywall, studs and, sometimes, fibrous blankets within the stud cavity.

4.3.1.1 Drywall. Drywall is a lightweight, low-cost material, and can provide a very high STC when used correctly. The use of Type X, or fire-rated drywall of the same nonrated drywall thickness, will have a negligible effect on acoustical ratings. Drywall is generally poor at low frequency noise reduction and is also very susceptible to poor installation. Drywall partitions must be thoroughly caulked with a non-hardening acoustical caulk at the edges. Tape and spackle is an acceptable seal at the ceiling and side walls. Electrical boxes, phone boxes, and other penetrations should not be back-to-back, but be staggered at least 2 feet, covered with a fibrous blanket, and caulked. Multiple layers of drywall should be staggered. Wood stud construction has poor noise reduction characteristics because the wood stud conducts vibration from one side to the other. This can be easily remedied by using a metal resilient channel which is inserted between the wood stud and drywall on one side. Non-load-bearing metal studs are sufficiently resilient and do not improve with a resilient channel. Load-bearing metal studs are stiff and can be improved with resilient channels installed on one side.

4.3.1.2 Fibrous blankets. Fibrous blankets in the stud cavity can substantially improve a wall's performance by as much as 10 dB in the mid and high frequency range where non-load-bearing metal studs, or studs with resilient channels, are used. A minimum 2 inch thick, 3/4 lb/ft3 fibrous blanket should be used. Blankets up to 6 inches thick provide a modest additional improvement.

4.3.1.3 Double or staggered stud walls. When a high degree of noise reduction is needed, such as between a conference room and mechanical room, use double or staggered stud wall construction with two rows of metal or wood studs without bracing them together, two layers of drywall on both sides, and a 6 inch thick fibrous blanket.

4.3.2 Masonry walls. Masonry construction is heavy, durable, and can provide particularly good low frequency noise reduction. Concrete masonry units (CMU) made of shale or cinder have good noise reduction properties when they are approximately 50 percent hollow and not less than medium weight aggregate. Parging or furring with drywall on at least one side substantially improves the noise reduction at higher frequencies. The thicker the block, the better the noise reduction. An 8 inch thick, semi-hollow medium aggregate block wall with furring and drywall on one side is excellent around machine rooms, trash chutes, and elevator shafts.

4.3.3 Doors. The sound transmission loss of both hollow and solid core doors will substantially increase when properly gasketed. Regular thermal type tape-on gaskets may not seal well because of door warpage, and can also cause difficulty in closing the door. Tube type seals fitted into an aluminum extrusion can be installed on the door stop and fitted to the door shape. Screw type adjustable tube seals are available for critical installations. Sills with a half moon seal at the bottom of the door are recommended in place of drop seals, which generally do not seal well. Two gasketed doors with a vestibule are recommended for high noise isolation. Special acoustical doors with their own jambs and door seals are available when a vestibule is not practical or very high noise isolation is required.

4.3.4 Windows. Fixed windows will be close to their laboratory TL rating. Operable sash windows can be 10 dB less than the lab rating due to sound leaks at the window frame. Gaskets are necessary for a proper seal. Some window units will have unit TL ratings which would be a rating of both the gasketing and glass type. Double-glazed units are no better than single-glazed if the air space is 1/2 inch or thinner. A 2-inch airspace between glass panes will provide better noise reduction. Laminated glass has superior noise reduction capabilities. Installing glass in a neoprene “U” channel and installing sound absorbing material on the jamb between the panes will also improve noise reduction. Special acoustical window units are available for critical installations.

4.3.5 Transmission loss values for building partitions. Table 5 through Table 14 provide octave band transmission losses for various constructions, comments or details on each structure are given in the footnotes of the tables. STC ratings are useful for cursory analysis when speech transmission is of concern. The octave band transmission losses should be used when a more thorough analysis is required, such as when the concern is for mechanical equipment.

Octave Frequency Band (Hz)	Suggested Design Values						"Ideal Values"		
	Thickness of Concrete or Masonry (in.)						Thickness (in.)		
	4	6	8	10	12	16	4	8	16
	Approximate Surface Weight (lb/ft.²)						Surface Wt. (lb/ft.²)		
	48	72	96	120	144	192	48	96	192
31	29	32	34	36	36	36	30	36	38
63	35	36	36	36	36	37	36	38	38
125	36	36	37	37	38	41	38	38	44
250	36	38	41	43	44	46	38	44	52
500	41	44	45	47	48	49	43	52	58
1000	45	48	49	50	51	53	51	58	64
2000	50	52	53	54	55	57	57	64	70
4000	54	56	57	58	59	61	63	70	76
8000	58	60	61	62	63	65	69	76	82
STC	45	48	49	51	52	53	49	55	62

Notes:

1. "Dense" concrete and masonry assumes 140-150 lb/ft.³ density.
2. For lower values of density, estimate the actual surface weight (in lb/ft.² of wall area) and use the TL from the column in the table that is closest to that surface weight.
3. If desired, install hollow-core block and fill voids completely (a course at a time) with concrete or mortar of the required density.

Table 5

Transmission Loss (in dB) of Dense Poured Concrete or Solid Core Concrete Block or Masonry

Octave Frequency Band (Hz)	Suggested Design Values						"Ideal Values"		
	Thickness of Concrete or Masonry (in.)						Thickness (in.)		
	4	6	8	10	12	16	4	8	16
	Approximate Surface Weight (lb/ft.²)						Surface Wt. (lb/ft.²)		
	28	36	44	52	60	76	28	44	76
31	26	28	29	31	32	33	26	30	34
63	31	33	35	36	36	36	32	36	38
125	35	36	36	36	36	36	37	38	38
250	36	36	36	37	37	38	38	38	39
500	37	38	41	42	43	44	38	42	48
1000	42	44	45	46	47	48	45	50	54
2000	46	48	49	50	51	52	53	56	60
4000	50	52	53	54	55	56	59	62	66
8000	54	56	57	58	59	60	65	68	72
STC	42	43	45	46	47	48	45	48	52

Notes:

1. "Dense" concrete and masonry assumes 140-150 lb/ft.³ density, if solid.
2. For lower density concrete, estimate the actual surface weight and use the TL for that value.

Table 6
Transmission Loss (in dB) of Hollow-Core Dense Concrete Block or Masonry

Octave Frequency Band (Hz)	Suggested Design Values				"Ideal Values"	
	Thickness of Cinder Block (in.)				Thickness (in.)	
	4	6	8	10	4	10
	Approximate Surface Weight (lb/ft.^{2})				Surface Wt. (lb/ft.^{2})	
	24	36	48	60	24	60
31	22	26	27	28	24	30
63	27	28	28	28	29	30
125	28	28	28	28	30	30
250	28	29	30	33	30	35
500	30	34	36	37	32	42
1000	36	38	40	41	41	48
2000	40	42	43	44	47	54
4000	43	45	46	47	53	60
8000	46	48	49	50	59	66
STC	36	38	39	41	39	46

Notes:

1. Lightweight block material assumes 65-75 lb/ft.^{3} density.

2. If hollow-core block or block of other density is used, select TL value for equivalent surface weight; interpolate or extrapolate if necessary.

3. Both sides of wall surfaces should be sealed with a plaster skim coat or two coats of heavy paint to achieve these values.

Table 7

Transmission Loss (in dB) of Cinder Block or Other Lightweight Porous Block Material with Impervious Skin on both Sides to Seal Pores

Octave Frequency Band (Hz)	Suggested Design Values					"Ideal Values"	
	Thickness of Plaster (in.)					Thickness (in.)	
	1/2	3/4	1	1-1/2	2	1/2	2
	Approximate Surface Weight (lb/ft.^{2})					Surface Wt. (lb/ft.^{2})	
	4-1/2	7	9	13	18	4-1/2	18
31	8	12	14	17	20	10	22
63	14	18	20	24	26	16	28
125	20	24	26	27	28	22	30
250	26	28	28	28	28	28	30
500	28	28	28	28	29	30	30
1000	28	28	29	32	34	30	38
2000	29	32	34	36	38	30	44
4000	35	37	38	40	41	38	50
8000	38	41	42	43	44	44	56
STC	29	30	31	33	34	31	37

Table 8
Transmission Loss (in dB) of Dense Plaster

Octave Frequency Band (Hz)	Type 1	Type 2	Type 3	Improvements A	Improvements B
31	4	9	6	2	2
63	10	16	12	2	2
125	17	24	20	3	2
250	26	34	30	3	3
500	34	42	39	4	4
1000	40	48	46	4	4
2000	46	46	52	3	5
4000	44	48	50	3	6
8000	48	52	54	3	5
STC	37	44	41	3	3

Notes :

Type 1 One layer 1/2=in. thick gypsum wallboard on each side of 2x4-in. wood studs on 16-in. centers. Fill and tape joints and edges; finish as desired. For equal width metal studs, add 2 dB in all bands and to STC.

Type 2 Two layers 5/8-h. thick gypsum wallboard on each side of 2x4-in. wood studs on 16-in. centers. Fill and tape Joints and edges; finish as desired. For equal width metal studs, add 3 dB in all bands and to STC.

Type 3 One layer 5/8-in. thick gypsum wallboard on outer edges of staggered studs, alternate studs supporting separate walls. 2x4 in. wood studs on 16-in. centers for each wall. Fill and tape joints and edges ; finish as desired. For equal width metal studs, add 1 dB in all bands and to STC.

Table 9

Transmission Loss (in dB) of Stud-Type Partitions

Octave Frequency Band (Hz)	Thickness of Plywood or Lumber (in.) 1/4	1/2	1	2	4
	Approximate Surface Weight (lb/ft.^{2}) 1	2	4	8	16
31	0	2	7	12	17
63	2	7	12	17	18
125	7	12	17	18	19
250	12	17	18	19	22
500	17	18	19	22	30
1000	18	19	22	30	35
2000	19	22	30	35	39
4000	22	30	35	39	43
8000	30	35	39	43	47
STC	18	21	24	28	33

Notes:

1. Surface weight based on 48 lb/ft.^{3} density, or 4 lb/ft.^{2} per in. thickness.

2. Lumber construction requires tongue-and-groove Joints, overlapping joints, or sealing of joints against air leakage. For intermediate thicknesses, interpolate between thicknesses given in table.

3. For ungasketed hollow-core flush-mounted wood doors, use TL for 1/h-in. thick plywood.

4. For solid-core wood doors or approximately 2-in. thickness, well gasketed all around, use TL for 2-in. thick plywood.

5. For small-area doors or boxes, framing around Cage of panel adds effective mass and stiffness and will probably give higher TL values than shown.

Table 10
Transmission Loss (in dB) of Plywood, Lumber and Simple Wood Doors

Octave Frequency Band (Hz)	Thickness of Glass (in.) 1/8	1/4	1/2	3/4
	Approximate Surface Weight (lb/ft^2) 1-1/2	3	6-1/2	10
31	2	7	13	17
63	8	14	19	22
125	13	20	24	26
250	19	25	27	28
500	23	27	29	29
1000	27	28	29	30
2000	27	28	31	32
4000	27	31	36	38
8000	31	34	40	43
STC	26	28	30	31

Notes :

1. Variations in surface area and edge-clamping conditions can alter the TL values considerably. There is not much consistency among published data.

2. TL tests usually are not carried out at 31-63 Hz; values given are estimates only.

3. In typical operable windows, poor seals can reduce these values.

4. Special laminated safety glass containing one or more viscoelastic layers sandwiched between glass panels will yield 5-10 dB higher values than given here for single thicknesses of glass; available in approximately 1/4- to 3/4-in. thicknesses.

Table 11
Transmission Loss (in dB) of Glass Walls or Windows

Octave Frequency Band (Hz)	Width of Air Space (in.)		
	1/4	1-1/2	6
31	13	14	15
63	18	19	22
125	23	26	30
250	26	30	35
500	29	34	40
1000	34	38	43
2000	31	37	44
4000	34	41	50
8000	38	46	54
STC	31	37	43

Table 12

Transmission Loss (in dB) of Typical Double-Glass Windows,
Using 1/4-in.-Thick Glass Panels with Different Air Space Widths

Octave Frequency Band (Hz)	Filled Metal Panel Partition[a]	Acoustic Doors, Nominal Thicknesses				
		2-in. Thick[b]	4-in. Thick[c]	6-in. ThicK[d]	10-in. Thick[e]	Two Sets 4-in. Doors in Double Walls 32-in. Air Space[f]
31	19	--	27	34	--	42
63	22	--	29	37	--	48
125	26	31	34	41	47	54
250	31	34	36	47	53	60
500	36	37	40	52	61	67
1000	43	39	45	55	66	75
2000	48	43	49	59	65	84
4000	50	47	51	62	69	90
8000	52	--	--	60	--	95
STC	41	40	45	58	64	71

Notes:

[a]Constructed of two 18 ga. steel panels filled with 3 in. of 6-8 lb/ft.[3] glass fiber or mineral wool; Joints and edges sealed airtight.

[b]Average of 4 doors, 1-3/4- to 2-5/8-in. thick, gasketed.

[c]Average of 2 doors, all 4-in. thick, gasketed around all edges, range of weight 12-23 lb/ft.

[d]Average of 4 doors, 6- to 7-in. thick, gasketed, installed by manufacturer, range of weight 23-70 lb/ft.[2]

[e]Average of 2 doors, each 10-in. thick, gasketed, installed by manufacturer, range of weight 35-38 lb/ft.[2]

[f]Estimated performance, in isolated 12-in. thick concrete walls, no leakage, no flanking paths.

Table 13

Transmission Loss (in dB) of a Filled Metal Panel Partition and Several Commercially Available Acoustic Doors.

Octave Frequency Band (Hz)	Aluminum			Steel				Lead			
	Thickness (in.)			Thickness (in.)				Thickness (in.)			Lead/Vinyl Curtain
	1/16	1/8	1/4	1/16	1/8	1/4	1/2	1/32	1/16	1/8	
	Surface Weight (lb/ft.²)			Surface Weight (lb/ft.²)				Surface Weight (lb/ft.²)			Surface Weight (lb/ft.²)
	1	2	3½	2½	5	10	20	2	4	7½	1
31	0	3	9	5	11	17	23	2	8	14	--
63	3	9	15	11	17	23	29	8	14	20	--
125	9	15	21	17	23	29	35	14	20	26	13
250	15	21	27	23	29	35	40	20	26	32	17
500	21	27	29	29	35	40	40	26	32	38	20
1000	27	29	29	35	40	40	40	32	38	44	28
2000	29	29	29	40	40	40	41	38	44	50	34
4000	29	29	30	40	40	41	48	44	50	56	38
8000	29	30	40	40	41	48	54	50	56	56	--
STC	25	28	29	33	38	40	41	30	36	42	26

Notes:

1. Surface weight of aluminum based on 170 lb/ft.³ density or 14 lb/ft.² per in. thickness.
2. Surface weight of steel based on 480 lb/ft.³ density or 40 lb/ft.² per-in. thickness.
3. Surface weight of lead based on 700 lb/ft.³ density of 59 lb/ft.² per in. thickness.
4. Variations in surface area and edge clamping conditions can alter the TL values of aluminum and steel. Lead assumed "limp." Application of vibration damping material to one surface of steel or aluminum will reduce resonances and help increase TL values in resonance regions.
5. TL tests usually are not conducted at 31-63 Hz; values given are estimates only.

Table 14
Transmission Loss (in dB) of Aluminum, Steel and Lead