SoundSmart

City of Vancouver Noise Control Manual

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Section 1 INTRODUCTION

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1.1 Why do we need a noise control manual?

As Vancouver's population has grown in recent decades, so have the volumes of traffic on our streets and aircraft in our skies and the numbers of noisy machines we employ in both our work and recreation. More and more, Vancouverites are living in multiple family dwellings where the noise we make, while indoors as well as outdoors, can bother our neighbours and the noise they make can bother us. New residential buildings are often located within mixed use areas where activities associated with commercial land uses can interfere with the rest and enjoyment of those living nearby.

While the City combats urban noise through land use planning, bylaw enforcement, traffic management and policing, there are limits to what local government can do to protect citizens from excessive noise exposure in a vibrant and evolving city like Vancouver. By explaining in a straight-forward manner what noise is, how it affects us, how it is produced and behaves and how it may be avoided or controlled, it is believed that this manual will enable Vancouverites to take steps to limit exposure to urban noise - their own as well as their neighbour's.

1.2 What lead to the creation of this manual?

Growing concerns about the increase in noise and its apparent effects on every day life in Vancouver led to the creation in 1996 of the Urban Noise Task Force. This citizens group, with the assistance of City staff and councilors, documented the wide range of noise issues and concerns raised by City residents. The resulting *"City Noise, Report of the Urban Noise Task Force"* (Reference 1), made 165 recommendations for improving Vancouver's *"Soundscape".* Local citizens groups, like the one representing East 1st Avenue residents, have worked towards having traffic noise levels in their neighbourhoods reduced, while others have encouraged "traffic *calming"* measures. In recognition of the growing urban noise problem, and specifically to provide those living along arterial roads and in other noisy locations with a tool to assist them in reducing their personal exposure to noise, Vancouver City Council authorized the creation of this manual.

1.3 What are its key objectives?

The key objectives of this manual are:

- to familiarize Vancouverites with urban noise and its sources, how noise affects us and how it can be controlled,
- to assist prospective homebuyers and tenants in avoiding living situations that they may find too noisy,

- to assist residents, landlords, property managers, contractors and tradespersons alike in identifying the appropriate steps to take and the right materials to use to effectively reduce the levels of noise entering their properties or residences,

- to provide suggestions to assist citizens in reducing their contributions to urban noise,

- ideally this manual would form part of an overall urban noise abatement strategy or "package" including the design of residential buildings, schools, offices and other workplaces, major infrastructure projects, recreational facilities and other public spaces with noise control and good acoustical design in mind.

Section 2 SOUND AND NOISE; THE BASICS

- ***What is sound and how do we perceive it?***
- ***What is noise and why does it bother us?***
- ***What effects can noise have on us?***

2.1 What is sound and how do we perceive it?

When a solid object, such as a bell, is struck and set into vibration, the rapid back and forth motion of its surface jostles adjacent air molecules creating small fluctuations in the pressure of the surrounding air. Similar fluctuations can be created by moving liquids (running water) or pulsating gases (motorcycle exhaust). The structures located within our middle and inner ears are very sensitive to these rapid but tiny fluctuations in air pressure. We call these pressure fluctuations, and the sensation that they produce in our ear and brain, sound. *"Sound is then vibration of the air that we can hear".* Sound travels in waves, spreading out from the source in all directions like ripples on a pond where a stone has been tossed in. The stronger the motion of the source (the bigger the stone), the more intense the pressure waves and the louder the sound. The faster the source vibrates, i.e., the more times its surface moves back and forth in a second, the higher the frequency, or pitch, of the sound. Large objects, like a bass drum, tend to vibrate slowly and therefore produce low-pitched sounds, while small objects, like coins or keys, tend to vibrate quickly and produce high pitched sounds.

The human ear is sensitive to an enormous range of sound intensity (loudness) A sound that begins to cause a tickling or painful sensation in the ear (a racing car or a hard rock band up close) is at least a million times more intense than a sound at the threshold of hearing (gentle breathing). In order to compress this huge range of audible sound intensities into a more manageable form, it has been converted into a logarithmic scale similar to the Richter Scale of earthquake magnitude. The units of this sound level scale are decibels, or dB, and the entire range of normal hearing may then be represented within a range of approximately 0 to 130 dB. For a given type of sound, each 10 dB increase in sound level corresponds to roughly a doubling of the loudness of the sound perceived by the listener.

The ear is also sensitive to a wide range of sound frequencies, or pitches, ranging from very low (such as from a fog horn, or "sub-woofer") to very high (such a produced by jingling keys or hissing steam). Our ears are more sensitive to middle and higher-frequency sounds than to low frequency ones. In order to measure sound in the same way that people hear it, sound measurement instruments (sound level meters) contain an electronic filter known as the A-weighting. This weighting is almost always used when measuring sound in the community or the workplace and the resulting sound levels are expressed in units of A-weighted decibels, or dBA.

Figure 1 shows the typical sound levels (in dBA) created by familiar noise sources in the home and community.

Appendix A provides a more detailed discussion of sound, noise and their effects on people.

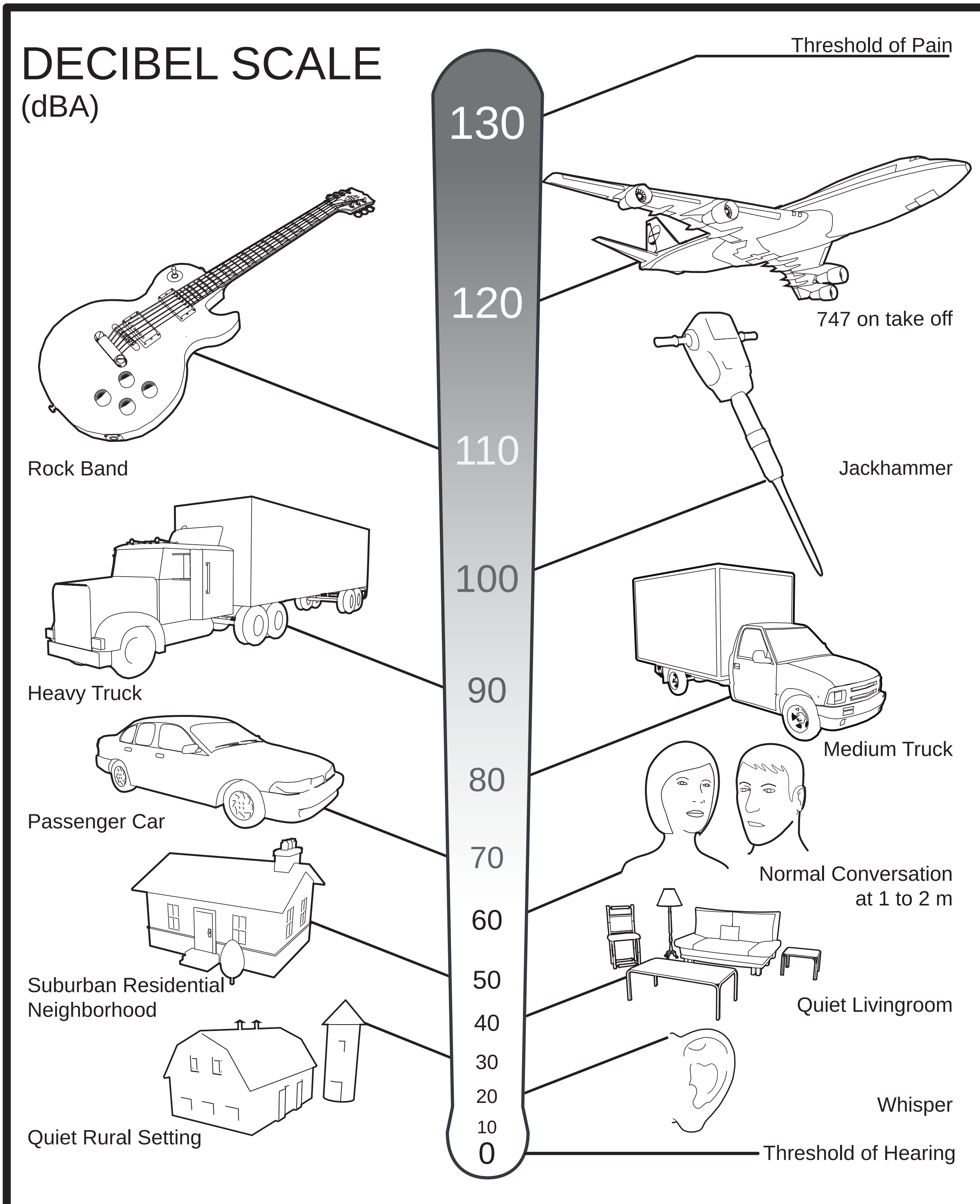


Figure 1: Decibel Scale- Showing sound levels typically created by familiar sources of noise in the home and community

2.2 What is noise and why does it bother us?

A familiar riddle asks *"When a tree falls in forest with no one about, does it make any sound?"*. From our experience we would expect that such a falling tree would indeed create pressure fluctuations in the air, and therefore, given the definition provided above, it would clearly create sound. However, interpreting a particular sound as "noise" involves a personal judgment that depends on the sensitivity, attitudes and past experience of the listener. What is music to one person's ears (e.g., a Wagner opera or a Harley Davidson at full throttle) may be noise to another's. However, noise is often defined as "***unwanted sound"*** and there are some aspects of sound which tend to make it more likely to be unwanted. This may be because the sound has undesirable characteristics like pure tones (whines, hums, squeals), or impulsive components (hammering, shooting, barking dogs) or is continually coming on and off so that it is very difficult to "tune it out". Perhaps it interferes with important activities like sleep, relaxation, conversation or listening to music, TV, radio or natural sounds. The sound may have unpleasant associations for the listener, create fear, convey unwanted information or result from an activity that is considered destructive or pointless but is outside the listener's control. *Therefore, while the tree that falls in a deserted forest clearly creates sound, it does not create noise, since there is no one to hear the crash and judge it to be noisy.*

Noise is widely recognized as a form of environmental pollution. However, there is a significant difference between noise and others familiar forms of pollution such as that of air and water. There may be some disagreement over what levels of air or water pollution are truly harmful but there is general agreement that air and water pollution are not "good things" and that the world would be better off without them. However, in the case of noise, there are often significant groups of people that think the noise they are creating or being exposed to is, in fact, a "good thing" (e.g. motorcycle clubs, boom-car owners or fans at an outdoor rock concert or car race). Such groups often can't understand why others are bothered by their noise and/or don't particularly care if they are. Such differences in perception of what constitutes noise and how the rights of individuals or groups to make noise should be weighed against the rights of others to enjoy peace and quiet often lead to conflicts within multi-family residential buildings, within neighbourhoods, at public and council meetings and in courtrooms. They also complicate the process of establishing community noise guidelines and/or limits that are considered fair and reasonable by all parties.

2.3 What effects can noise have on us?

At the levels and for the durations that most of us are exposed to unwanted sound in our homes or in the community, noise can have the following general types of negative effects: it can interfere with essential/important activities, it can cause annoyance/fear, or it can do both. The thresholds for interference with activities like speech and sleep are fairly well known and have been used to establish guidelines for acceptable levels of noise in residential areas such as the widely referenced 24-hour average noise level of 55 dBA established for road traffic noise by the Canada Mortgage and Housing Corporation, or CMHC (Reference 2). Intrusive noise at 55 to 60 dBA can begin to interfere with normal outdoor speech at a separation of 1 to 2 m. Speech interference can begin to occur at much lower levels (35 to 45 dBA) in classroom and group situations. The level at which noise will begin to disrupt sleep depends on how deeply one is sleeping (sleep stage) but can be as low as 30 to 35 dBA for sustained noise. Quite low levels of intrusive noise can also delay our falling asleep. Much louder noises are required to arouse people from the deepest sleep stages. While many sleepers appear to habituate or "get used to" familiar nighttime noises and are no longer regularly aroused or wakened by them, the body still reacts to such noises in sub-conscious ways which impair sleep quality and deprive the body of needed rest.

It is more difficult to define a noise level threshold below which people will not be annoyed by noise. Annoyance due to intrusive noise, and the stress and aggravation that often accompanies it, are largely personal, subjective responses. Whether a particular noise is found annoying depends on the listener, their state of mind and health and the activity they are engaged in. Sensitivity to annoyance by noise varies greatly from person to person. Some are driven to distraction by sounds that others can barely hear and pay no notice to. Others live and work in very noisy environments with no apparent concern. Some noises can cause annoyance even at levels not much above the threshold of hearing, particularly if they have undesirable characteristics such as tonality (e.g. hot tub or heat pump hum) or impulses (footsteps, or hammering), carry unwanted information (speech or music) or if past experience has caused the listener to become "sensitized" to the noise.

Because of the many other physical and social factors involved, it has proven difficult for investigators to prove that prolonged exposure to excessive noise in the community or workplace is directly related to negative health effects other than hearing loss. However, the World Health Organization (Reference 3) considers noise to be an "unspecific stressor" which stimulates body systems, and, along with other environmental and lifestyle factors, can have significant temporary and permanent effects on overall human health.

At sustained levels of 80 to 85 dBA or more, daily exposure to noise over many years (as in the workplace – typically for 7 to 8 hours per day), or over much briefer periods at higher levels, can cause significant hearing damage. High frequency sensitivity tends to be lost first and this can lead to difficulty in understanding speech. It is this kind of hearing loss that the exposure limits specified by the Workers' Compensation Board of B.C (Reference 4) are intended to prevent.

Section 3 NOISE IN CITY; THE URBAN SOUNDCAPE

- ***A historical look at urban noise***
- ***Dominant sources of urban noise***
- ***How much noise are we exposed to in the city?***
- ***Trends in urban noise***

3.1 A historical look at urban noise

Noise has been a concern of city dwellers at least since Roman times when rulers passed a bill that prohibited the driving of chariots through the cobblestone streets of Rome at night. Noise levels in more modern cities have increased steadily with the growth of mechanization. Initially this was due largely to industrialization and motorized transport so that by 1899, excessive noise was the number one “quality of life” complaint in New York City! Then came labour saving gas and electric powered tools and equipment for use at home and work such as lawn mowers, power saws, weed eaters and leaf blowers. More recently, electronic sources such as powerful car stereos (particularly “boom cars”), vehicle alarms, canned music in stores and restaurants and cellular phones have added to the urban din.

Widespread concern about noise in Greater Vancouver dates from the early 1960’s to early 1970’s. This timeframe corresponds with introduction and rapid growth of jet airliner traffic at Vancouver International Airport and with the coining of the term “Soundscape” by Simon Fraser University’s R. Murray Schafer in connection with SFU’s World Soundscape Project. At that time the widespread impact of early and very noisy jetliners and the general dawning of awareness about pollution in all its forms gave rise to such organizations as the Greater Vancouver Citizen’s Committee on Noise Abatement, the Community Forum on airport Noise Control and the Scientific Pollution and Environmental Control Society, or SPEC.

3.2 Dominant sources of urban noise

The noise source that impacts the largest numbers of city dwellers is road traffic – far exceeding the numbers impacted by noise from aircraft, heavy or light rail or industry. On the plus side, people tend to be more tolerant of road traffic noise at moderate levels and consider it to be inherently less annoying than aircraft or railway noise of the same average sound level. However, above certain quite frequently-exceeded levels, traffic noise begins to limit the use and enjoyment of our homes and communities and negatively affect our health and quality of life.

3.3 How much noise are we exposed to in the city?

Table 3.1 below shows the ranges of outdoor 24-hour average sound levels typically experienced in rural, suburban and urban environments, in particular, near busy roadways. Again, each 10 dBA increase corresponds to roughly a doubling of the average loudness, or noisiness, of the acoustic environment.

Table 3.1; Representative Outdoor 24-Hour Average Noise Levels within Residential Areas as a Function of their Proximity to Various Types of Roadways.

Residential Environment	Representative 24-Hour Average Noise Levels (dBA)	Subjective Loudness/Noisiness
Undeveloped Rural	35 – 40	Baseline – Extremely quiet, like typical quiet living room
Rural residential	40 – 45	40% louder/noisier (still very quiet)
Quiet suburban	45 – 50	Twice as loud/noisy (but still quite quiet)
Urban residential away from arterial/main streets	50 – 55	Three times as loud/noisy (still generally no significant noise impacts in residential areas)
Urban residential near arterial road	55 – 60	Four times as loud/noisy (threshold for onset of noise impacts due to speech and sleep interference)
Urban residential on arterial road or minor highway	60 – 65	Six times as loud/noisy (speech interference outdoors, increasing potential for sleep disturbance)
Urban residential on major arterial or highway	65 – 75	Eight to Eleven times as loud/noisy (outdoor spaces generally not usable, potential indoor speech interference, significant sleep disturbance)

A noise study commissioned in 2003 by the City showed that 24-hour daily average noise levels at residences along East 1st Avenue, at 67 to 68 dBA, fall into the anticipated range for such a major arterial street. Daily average noise exposures measured at residences along the east side of Cassiar Street, prior to the construction of the Cassiar Tunnel, exceeded 70 dBA.

Due to limited setback distances and high traffic volumes including many busses, heavy trucks and noisy personal vehicles (boom cars, sporty exhausts, motorcycles), still higher noise exposures may be found adjacent to major downtown streets. Noise may be even more problematic on such busy streets if they are lined with tall buildings. Here, to the detriment of those living on upper floors, street noise is often reinforced by the reflection (bouncing) of sound back and forth between the buildings. Section 6.4.5 discusses steps that can be taken to reduce traffic noise exposures on the balconies of high rise buildings and within adjoining rooms.

3.4 Trends in urban noise

There has been no ongoing noise monitoring program that can prove that noise levels in Vancouver have been steadily increasing. However, a survey of 1,000 citizens conducted in 1996 by the Urban Noise Task Force (Reference 1) found that 53% of Vancouverites felt their city has become noisier in recent years, while only 6% felt it has become less noisy. The Task Force expected that Vancouver has followed trends seen in other major cities in which the average sound intensity has doubled roughly every six years corresponding to a 3 dBA increase in average sound levels. Since an increase in sound level of about 10 dBA is required to give the impression that loudness or noisiness has doubled, at the above rate of noise increase, *it would take roughly twenty years for the City to become twice as noisy*. Even if urban traffic volumes have grown at a steady rate of 5% per year, this substantial growth would account for less than half of the Urban Task Force's expected noise level increase of 3 dBA every six years, or 10 dBA in twenty years. The rest of this growth in noise, if it has occurred, would then have to be attributed to other effects of increasing population densities and the introduction of new sources of noise.

Table 3.2 illustrates the relationship between increasing traffic volumes on a given roadway, the resulting average sound intensity and the impressions of listeners in terms of the perceived loudness of the traffic noise.

Table 3.2; How Average Noise Levels and Perceived Loudness Increase with the Number of Equal Noise Sources – Here Represented by Traffic Volumes on a Roadway.

Traffic Volume (vehicles per hour)	**Increase in Traffic Volumes**	**Increases in Average Traffic Noise Level (dBA)**	**Increase in Perceived Loudness of Traffic Noise**
1,000	Base	Base	Base
1,250	25%	1	7% louder
1,600	60%	2	15% louder
2,000	100% (twice as many)	3	23% louder
4,000	300% (four times as many)	6	50% louder
7,000	600% (seven times as many)	8.5	80% louder
10,000	900% (ten times as many)	10	100% louder (twice as loud)
50,000	4,900% (50 times as many)	17	225% louder
100,000	9,900% (100 times as many)	20	300% louder (four times as loud)

Section 4 THE "ABC'S" OF NOISE CONTROL

- ***Natural noise control***
- ***Noise control at source, along the path and at the receiver***
- ***Blocking the sound path – what makes a good noise barrier?***
- ***Soaking up noise – sound absorption materials***
- ***Controlling noise by controlling vibration – damping materials***
- ***Common misconceptions about noise and noise control materials***

4.1 Natural noise control

As sound waves move out from the source, their intensity (loudness) steadily decreases due to several natural phenomena. Two of these (geometric wave spreading and air absorption) are always present to some degree, while three others (ground effect and wind and temperature gradient effects) occur only under certain, fairly common conditions. These phenomena are described below.

4.1.1 Sound wave spreading with distance

In the same way that a balloon is stretched thinner and thinner as it is blown up, sound waves become weaker and weaker as they travel outward from their source and their energy is spread over larger and larger areas. This concept is illustrated in Figure 2. For ***"point" sources of sound*** (that is, sources that are physically small compared to the listener's distance from them) such as an aircraft in the sky or an ambulance siren, this spreading is spherical (think of an expanding round balloon) and causes sound levels to decrease at a rate of ***6 dB per doubling of distance.*** Due to this spherical spreading, noise from point sources becomes at least 35% quieter with each doubling of distance. When the sound source region is large compared to the distance to the listener's position, sound levels decrease more gradually. For example, traffic on a busy roadway represents a ***"line source" of sound*** from which sound waves spread out cylindrically (think of the expansion of a long, thin "party" balloon). Sound levels from a line source decrease at ***3 dB per doubling of distance*** – or half the rate of point sources. In typical urban settings where setback distances are limited, geometric spreading generally accounts for most of the natural sound attenuation between noise sources and receivers.

4.1.2 Absorption of sound by the atmosphere

As sound waves pass through the atmosphere, they lose energy as they "jostle" the air molecules. This is a gradual process that depends on air temperature and humidity. Over the limited source-to-receiver distances typically experienced in the city, atmospheric absorption has very little effect. Over larger distances (100 m or more), it can begin to reduce overall noise levels as well as alter the character of complex sounds (such as traffic noise). This is because air absorption attenuates high-frequency components much more rapidly than low-frequency ones and this is why the noises from distant traffic, trains, industries or jet aircraft tend to have a low, "rumbling" character.

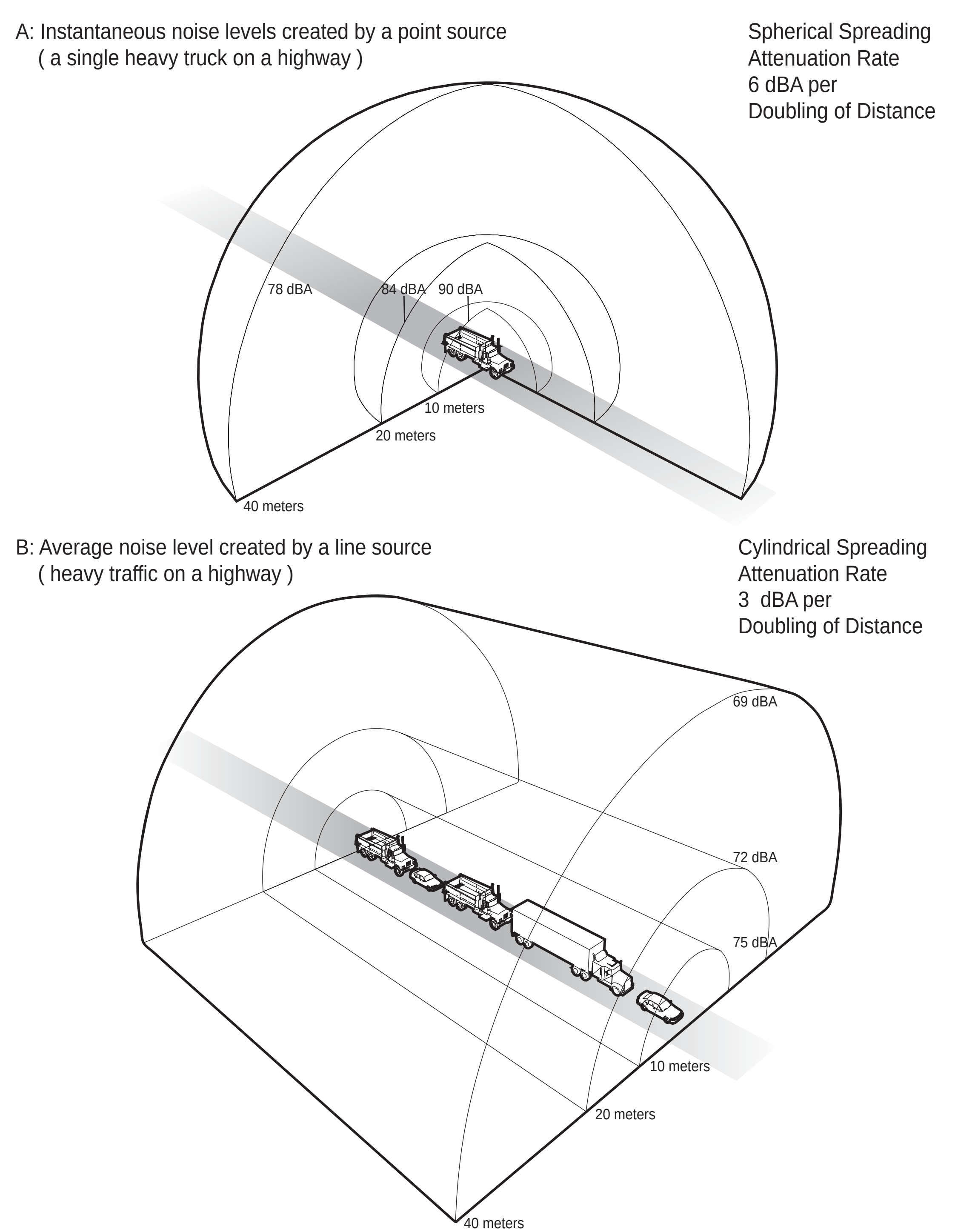


Figure 2: Spreading of sound waves from point and line sources

4.1.3 Ground effect

A third source of natural noise attenuation called ***"ground effect"*** occurs when sound waves pass close to soft, porous ground surfaces (lawns, fields, forest floors) on their way from the source to the receiver. This effect (which is caused by the local cancellation of direct and ground-reflected sound waves) can be large, particularly at distances of more than 100 m or so and when both the noise source and receiver (listener) are located close to the ground. In extreme cases where the listener is separated from a busy roadway by a wide, flat stretch of soft terrain, the ground effect can render noise from this roadway virtually inaudible over other contributors to urban hum. Even at typical smaller distances (10 to 15 m) across urban lawns or boulevards, the effect can be significant for receivers near ground level. There is then some benefit to be obtained from retaining or installing soft surfaces (e.g., lawns, gardens or flower beds) between a roadway, or other noise source, and one's residence. Figure 3 illustrates the typical effects which setback distance has on the average noise levels created by traffic on a long straight roadway.

4.1.4 Wind and temperature gradient effects

When wind blows against the direction of sound travel (i.e. from the noise receiver location towards the noise source location) it causes sound waves to bend upwards away from the earth's surface (see Figure 4A). This can create a ***"sound shadow"*** (i.e., a zone of quiet) at large distances. When the wind blows in the same direction as the sound (i.e., from the noise source towards the receiver), sound waves are bent down towards the earth (see Figure 4B). Where the intervening ground is "soft" so that ground effect is possible, or where some sort of noise barrier is present, this downward bending of sound waves can substantially increase the level of noise reaching distant receivers. However, at the short setback distances typical of most urban noise situations, the most significant effect of wind is to raise background noise levels, thereby potentially masking intrusive noises.

Strong air temperature gradients can cause similar sound-bending effects. In particular, during clear, calm nights, the air is often colder near the ground than higher up. Under such *"temperature inversion"* conditions, sound waves bend downwards towards the ground giving rise to the common perception that distance sound sources are louder at night, a perception that may also occur because "background noise" levels from common noise sources such as traffic tend to be reduced at night. During normal daytime "temperature lapse" conditions (i.e., when air is warmer near the ground), sound is bent upwards, away from the ground so that, under calm conditions, sound shadows may occur in all directions from the source.

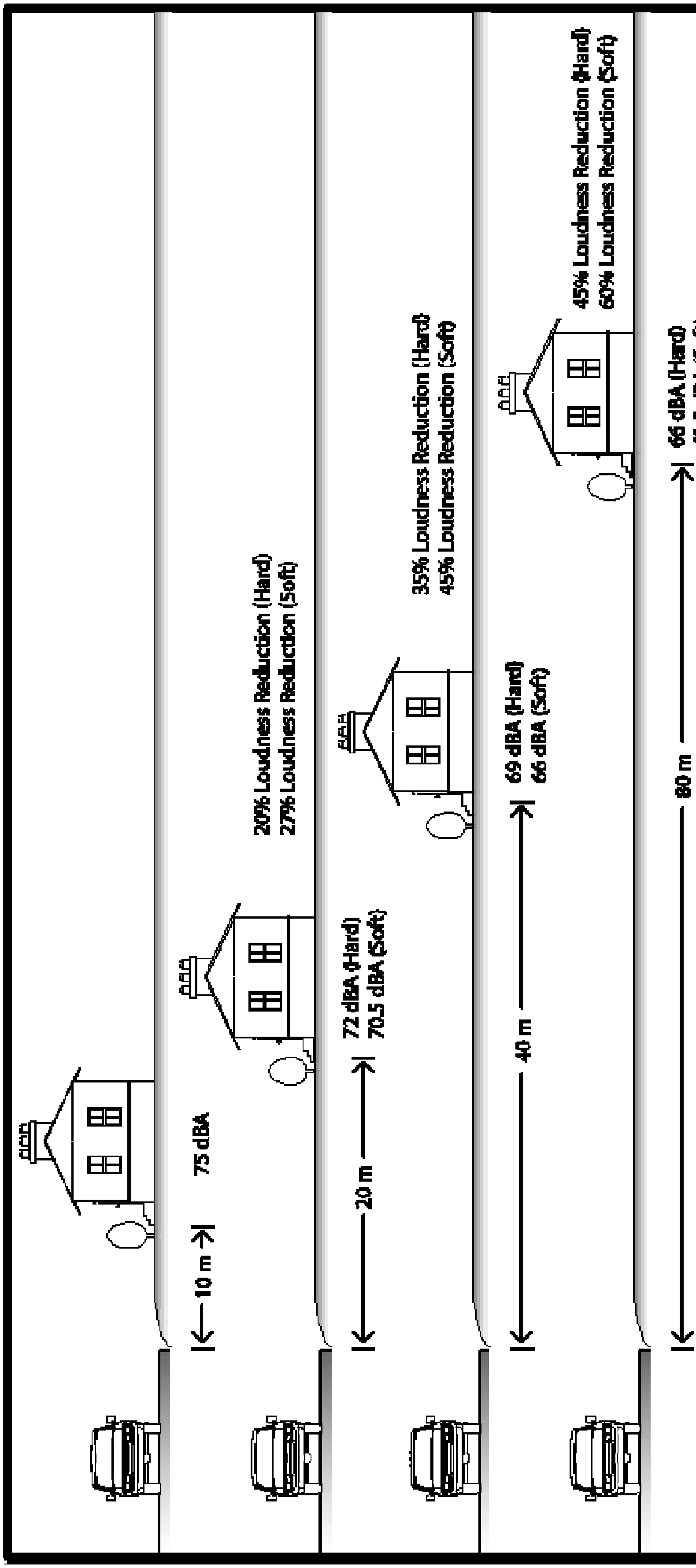


Figure 3: Decrease in the average level and perceived loudness of traffic noise with distance over hard and soft ground

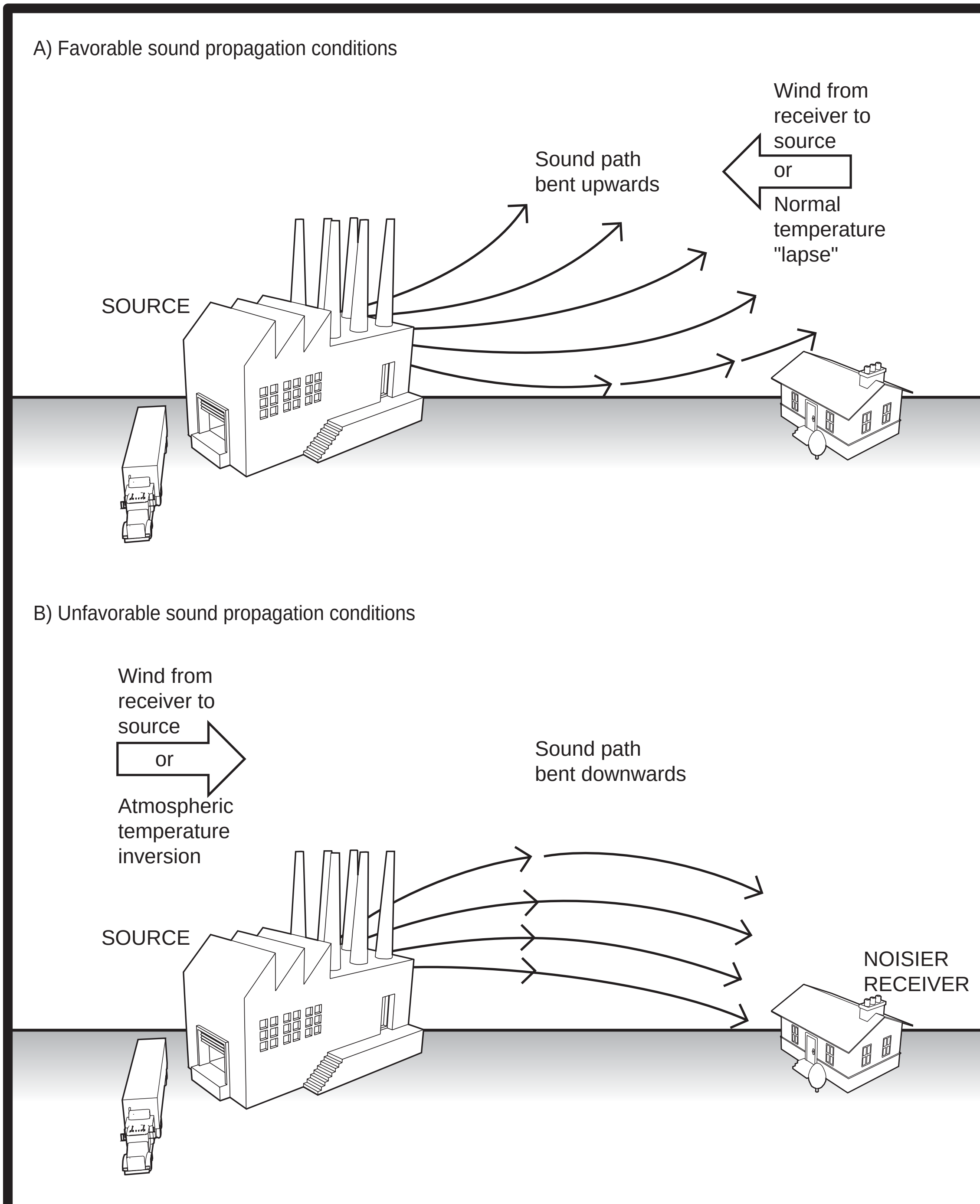


Figure 4: Effects of wind and air temperature gradients on sound propagation

4.2 Noise control at the source, along the path and at the receiver

All community noise situations involve one or more noise sources, one or more noise paths and one or more noise receivers. In planning for effective noise control, it is then useful to consider opportunities that may exist to control noise at each of these three stages of its transmission. Figure 5 illustrates the opportunities that generally exist to control noise at these three stages in the context of a residence located near a busy road.

4.2.1 Noise control at the source

Noise control at the source typically involves avoiding generation of excess noise through selection of inherently quieter equipment, regular maintenance and sensible operation. Examples of inherently quieter equipment are busses manufactured in some European countries under stricter noise emission regulations than apply to local buses and leaf blowers designed to meet a noise limit of 65 dBA at 15 m. Source control may also involve preventing noise from escaping from the source by adding appropriate control devices such as mufflers, covers or enclosures. For many prominent urban noise sources, such as arterial traffic, railways, aircraft and industry, source control measures are not in the hands of individual residents. However, at the time of this writing, the City is investigating the prominence of various urban noise sources in more detail to determine where noise control efforts should be concentrated. In addition, as may be seen in Section 5.3, there are many things Vancouverites can do to limit their personal contributions to urban noise.

4.2.2 Noise control along the sound path

Once noise has been created and has escaped from the source, there are various ways to prevent it from reaching noise sensitive areas. These may include noise barriers located close to the noise source (e.g., screens or partial enclosures around localized sources such as heat pumps, and walls, earth berms or non-sensitive buildings along a highway) or close to the noise receiver (e.g., a solid fence, earth berm or outbuilding on the noisy side of a residence to shield sensitive indoor spaces or a solid fence or screen to protect outdoor recreation areas).

4.2.3 Noise control at the receiver

Noise control at the receiver (here, the residence) may involve the upgrading of windows, doors, walls and, in some cases, roofs to better exclude noise from sensitive interior spaces (see Section 6.5 and Appendix B). It may also include the optimal location and configuration of the residence on the property to minimize noise exposure (see Figures 3 and 5) and/or the design of the floor plan (see Figure 7) which places less sensitive spaces closest to the noise source thereby creating a “buffer zone” to reduce noise exposures within the more sensitive spaces such as living rooms, bedrooms and dens.

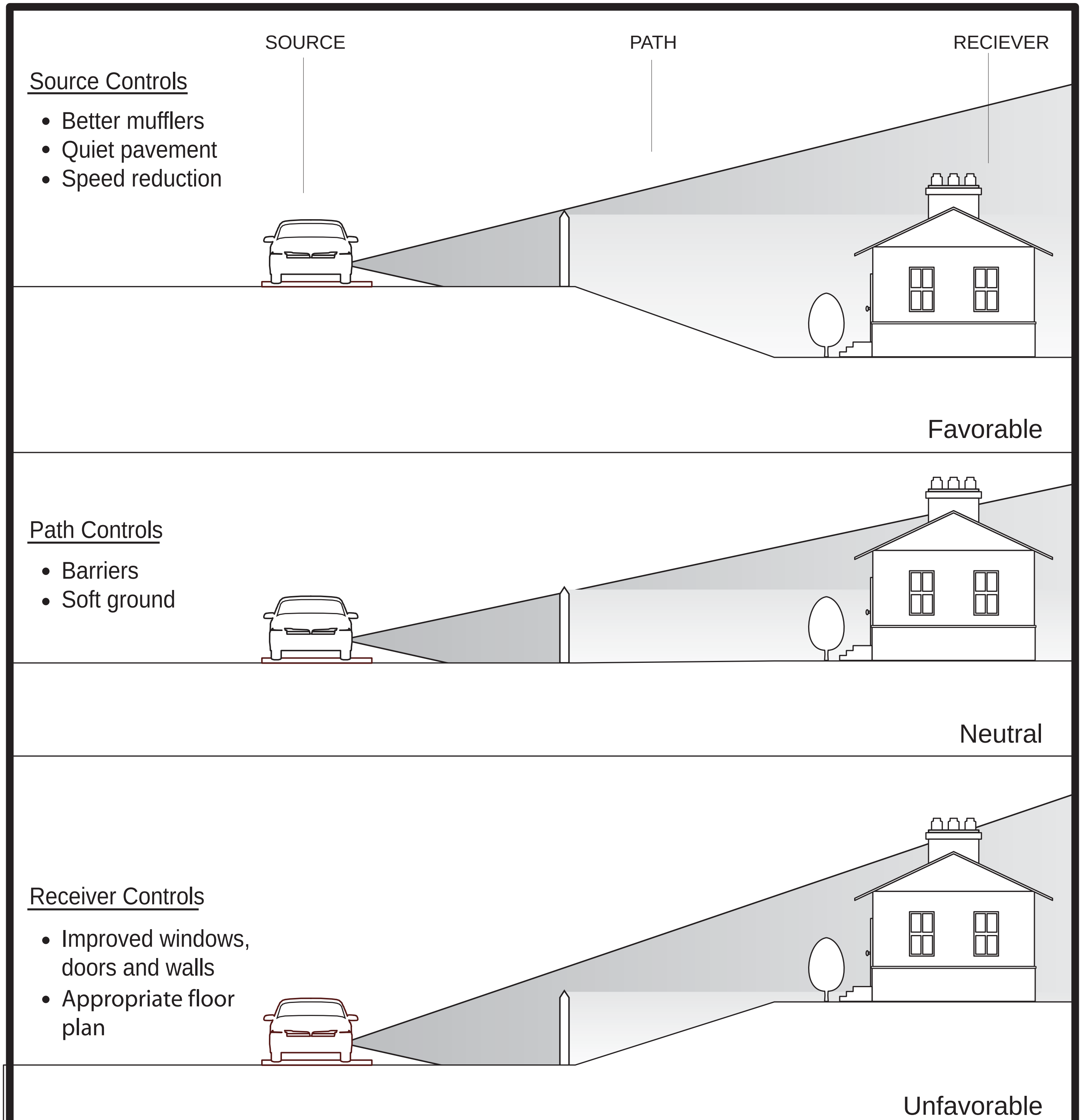


FIGURE 5 : Traffic noise control options at the noise source, along the path and at the receiver

4.3 Blocking the sound path - noise barriers

4.3.1 What makes a good noise barrier?

The most familiar means of reducing residential exposures to noise from road traffic or industrial sources is to erect a noise barrier of some sort between the sound source and the receiver. Noise barriers most often take the form of vertical walls, but other types (such as earth berms, berm/wall combinations and buildings) are also used. An effective noise barrier must meet the following three requirements:

1. It must be tall enough and long enough to clearly block the line of sight from the noise receiver to the noise source zone. For free-flowing arterial traffic, tires are the dominant noise source, so that the source zone is close to the pavement where it can often be shielded by barriers of moderate height. Where average speeds are lower, and particularly where the heavy truck mix is high, engine and exhaust noise are also important and, to be effective, noise barriers must be higher,

2. It must be dense (heavy) enough and be free from gaps and cracks so that there is no significant transmission of sound through it,

3. It must be continuous throughout the noise source zone. For example, a traffic noise barrier will not be effective if it must be frequently interrupted to accommodate walkways or driveways.

Figure 6 introduces basic noise barrier concepts. Shown are the three paths by which sound can reach a receiver located behind the barrier (here a vertical wall).

1. The first path, and often the most challenging to deal with, is associated with sound that diffracts (bends) over the top, and potentially around the ends, of a noise barrier. Low-frequency sounds (e.g. boom car noise or exhaust noise from heavy trucks) bend around barriers and other objects much more readily than do high-frequency ones (such as the “swishing” noise created by ordinary vehicle tires).

2. The second possible path is through gaps or cracks in the barrier. High-frequency sounds “leak” though these small openings much more easily than low-frequency ones.

3. The third path is directly through the barrier material itself. Low-frequency sounds are transmitted through solid noise barriers materials much more efficiently than are high-frequency sounds. It is to limit such low-frequency sound transmission that noise barriers must be made of a relatively heavy material, so that they weigh at least 10 kg/m^2 (2 lb/ft^2) and so that sound passing through the barrier will generally be attenuated in level by 20 dBA or more.

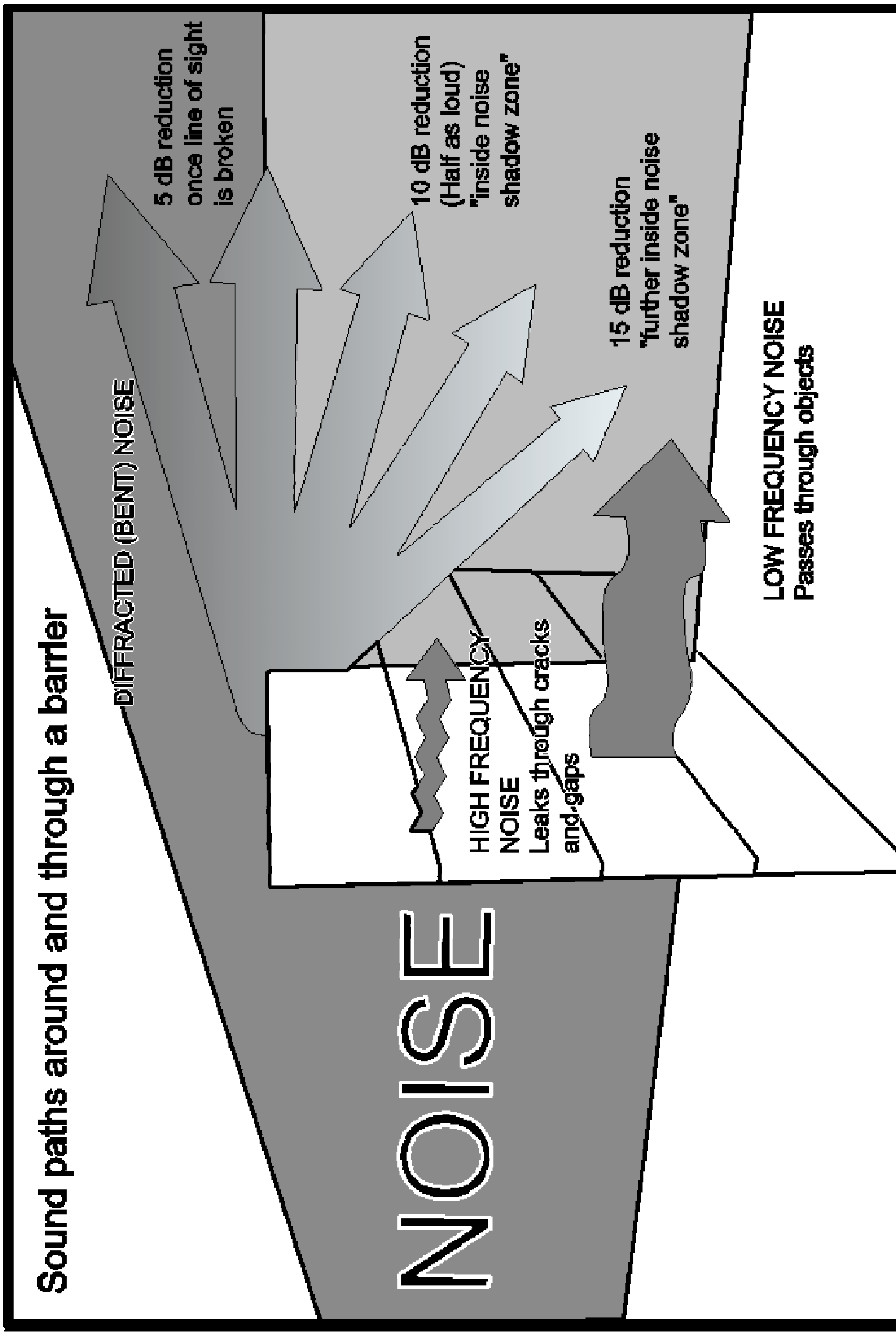


Figure 6: Basic noise barrier concepts - the three paths by which sound can reach a receiver behind a barrier

4.3.2 How much noise reduction can a barrier practically provide?

If a noise barrier is heavy enough and free from leakage, then the amount of noise reduction it will provide depends on where it is located relative to the noise source and receiver positions. The greater the extra distance (compared to the direct line form source to receiver) that sound must travel to get over or around the barrier and reach the receiver, the greater the noise reduction provided. For this reason, a noise barrier works best when it is located close to the noise source, the receiver or both. The following range of noise reductions can generally be achieved (see Figure 6):

- 5 dBA (about 30% reduction in perceived loudness) – usually achievable once the barrier just blocks the line of sight from the receiver to the source,

- 10 dBA (about 50% perceived loudness reduction) - achievable at locations well within the acoustic "shadow zone" but the line of sight must be substantially blocked, i.e., the barrier must typically rise 2 to 3 m above the "*line of sight*" from the receiver position to the dominant source position,

- 15 dBA (about 65% perceived loudness reduction) – achievable only in very favourable situations where the receiver is deep within the acoustic "shadow zone", such a where the barrier can be made very high relative to the source and receiver or where the receiver is located at a much lower elevation than the source. e.g., a residence located below the level of an adjacent highway.

4.3.3 What can noise barriers be made of?

Noise barriers can be made of almost any solid, reasonably heavy and durable material. The materials most commonly used for noise barriers in the Greater Vancouver area are listed below along with some examples:

- Pre-cast concrete posts and panels (e.g., Lonsdale and Westview Interchanges on the Upper Levels Highway, Deer Lake Parkway in Burnaby, Highway 17 east of Highway 10 in Delta),

- Concrete block (e.g. Highway 1 at south end of Cassiar Tunnel),

- Corrugated steel panels and steel posts (e.g., Hamilton/Westminster Interchanges at north end of Alex Fraser Bridge in Richmond),

- Timber posts and planks, minimum 50 mm (2") thick (Boundary Road, Burnaby),

- Earth berms or berm/wall combinations (Deer Lake Parkway, Burnaby and Highway 17 west of Highway 10 in Delta). Note, while earth berms require much more space than vertical walls, they tend to have advantages in terms of cost, visual impact and the ability of their soft, inclined surfaces to both absorb sound and deflect it upwards.

With the exception of earth berms, the above noise barriers have acoustically "hard" surfaces which reflect (bounce) most of the sound energy back in the general direction that it can from. That is, they do not absorb or "destroy" much of the noise but simply redirect it away from the most noise-sensitive areas. Sound-absorbing noise barriers are available however. A local example is located on the Upper Levels Highway just east of Lonsdale Avenue. It is of a double-layer steel “sandwich panel” construction with perforated sheet steel on the highway-facing side and 75 to 100 mm (3” to 4”) of sound-absorbing insulation in the wall cavity.

4.4 Soaking up noise with sound absorbing materials

4.4.1 Most building materials reflect sound waves

Similar to most of the noise barriers described above, common building materials (e.g., concrete, brick, steel, timber, glass and gypsum board) are largely sound reflective, that is, they reflect back most of the sound energy that strikes them.. In many cases such sound reflections are not a problem because they do not significantly increase noise levels at any sensitive receiver locations. However, in some situations they can substantially increase noise exposures. For example:

- Where hard, vertical noise barrier walls are constructed on both sides of a relatively narrow roadway, repeated sound reflections back and forth between these hard surfaces reduce the effectiveness of both noise barriers,
- Where a large reflective surface, such as a building or wall, directs noise towards a receiver location that is otherwise shielded from direct exposure to the noise by another building, wall or land form,
- Where a building, group of buildings or other structures “focus” sound reflections toward a particular sensitive receiver location,
- The common situation where rows of tall buildings line both sides of downtown streets and confine traffic noise within *“urban canyons”* as illustrated in Figure 7,
- Where the hard surfaces of a room (or other enclosed space) repeatedly reflect sound back and forth and result in the “build-up” of noise levels within the space. This *“excessive reverberation”* effect is commonly experienced in gyms, ice arenas, lobbies or other large public spaces and even in some open-design, *“west coast style”* houses with high ceilings and little carpeting or draperies.

4.4.2 Sound absorbing materials

The reflected noise problems described above can be largely avoided by making the surfaces involved sound absorbing. Most common sound absorbing materials are highly porous and can absorb 60 to 90% of the sound energy that strikes them while some materials can absorb 95 to 99% of high-frequency sound energy. The tiny pores and passages within such materials (e.g., heavy fabrics, draperies, carpeting and upholstery, glass or mineral fibre insulation and open-celled foam rubbers), permit sound waves to enter. In squeezing through these tiny passages, the energy of the sound waves is dissipated – i.e., turned into heat in the same way that heat is generated when you rub your hands together briskly (i.e., through friction). Mid to high frequency sound can be effectively absorbed by quite thin (25 to 50 mm) porous materials while thicker materials (75 to 100 mm) are required to efficiently absorb lower-frequency sounds. Lower-frequency sounds may also be absorbed, to varying degrees, by thin, flexible panels of wood, plastic, steel, glass or gypsum board. Sound waves set these panels into vibration and the resulting rapid back and forth flexing of the panels turns some of the sound/vibration energy into heat – in the same way that a piece of wire gets hot when you bend it back and forth rapidly.

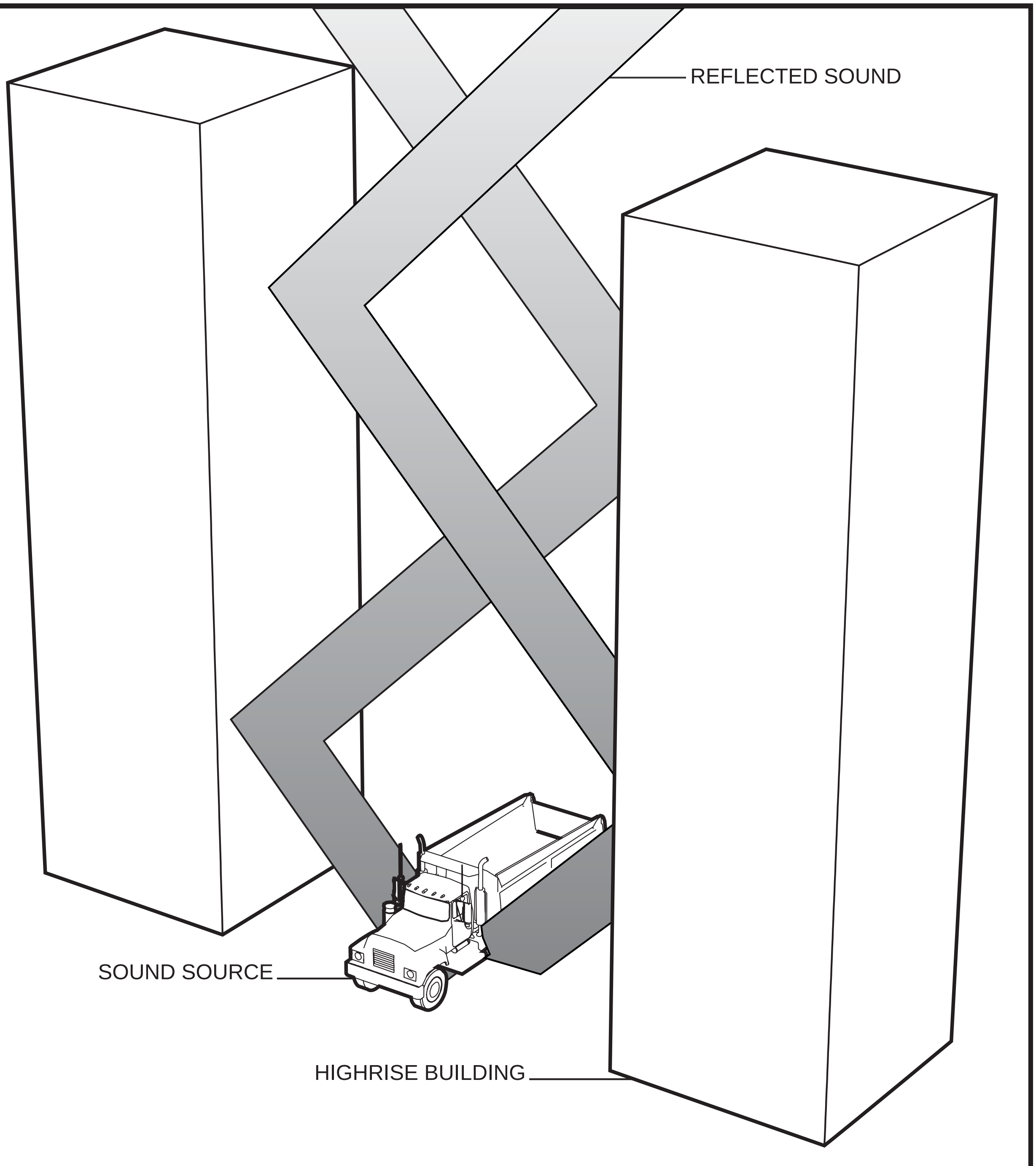


Figure 7: The Urban Canyon Effect- Sound reflection between highrise buildings

4.5 Controlling noise by controlling vibration

4.5.1 Damping materials

Since sound is often produced and transmitted by vibrating objects, it makes sense that we can control noise by controlling vibration. Consider what happens when we place a hand on a ringing bell or a wine glass that been make to “sing” by rubbing its rim – the sound quickly dies away. Here we are “damping” the ringing object by allowing its vibrational energy to flow into an object (our hand) which has much greater damping capacity than either brass or glass. More practical examples of damping materials include the soft “mastic” material used to coat car body panels to control engine and road noise and the thin plastic layer which separates the two sheets of glass used in making laminated or safety glass.

4.5.2 Vibration isolation

As most people will have observed, when an operating power tool or appliance comes in contact with a large, flexible surface such as a sheet of plywood, a table top or a wall, its noise is amplified. This phenomenon is demonstrated in a pleasing way by the bodies of violins and guitars which greatly amplify the sound of their vibrating strings. The amplification of noise from engines, electric motors, appliances or power tools can then be avoided by eliminating any rigid contact between these devices and flexible surfaces such as machinery enclosures, counter tops or the wooden floors and gypsum board walls of residences. In practice this can be done by placing resilient rubber pads or matting beneath appliances and the countertops or floors supporting them. Similarly, fans, pumps and motors can be mounted on neoprene pads or steel springs to prevent their vibration and noise from entering supporting floors and walls and spreading throughout the building.

4.6 Common misconceptions about noise and noise control materials

Sound goes up!

Unlike hot air, sound/noise does not prefer to rise or “go up”. While some sound sources, such as high-frequency loudspeakers, or “tweeters”, are quite directional, most common noise sources tend to radiate sound fairly evenly in all directions. Once created, sound (think of it as a “ray” in this case) tends to continue traveling in a straight line until it encounters a solid object or until wind or air temperature gradients cause it to bend. The impression that “sound goes up” may come from the common observation that sounds appear louder when the listener is in an elevated position such as on a hill top or the upper floors of a high-rise building. While this is often true, it is because sound waves traveling well above the ground tend to suffer little or no extra attenuation due to shielding and/or ground effect, not because sound prefers to “go up”.

Styrofoam is a good sound control material.

Because Styrofoam is a very good insulator against heat and cold and is commonly placed against building foundations and inside exterior walls, it is often assumed to be a good sound control material as well. However, unlike like glass, mineral or cellulose fibre insulations which absorb sound effectively due to their open surface structure and small-scale porosity, Styrofoam has a closed-cell structure which does not allow sound waves to enter it easily. As such, it is not a good sound absorber and should not be placed inside wall or floor cavities where effective sound control is required. Further, Styrofoam is too light to act as an effective noise barrier. For the same reason, glass and mineral fibre blankets (batts) or semi-rigid boards are not good noise barriers on their own.

Lead is the ultimate noise barrier.

Because of its extreme heaviness and high damping capacity (i.e., it does not vibrate), inch for inch, lead sheet provides the greatest airborne noise reduction of any widely available material. However, lead sheet is expensive, weak, limp and toxic. In some situations (e.g. improving the noise insulation of an engine or pump enclosure on small boat or under a hot tub) where the areas involved are small and out of the way and available space is very limited, lead sheet can be applied (either on its own or in combination with a sound absorbing material) to wood, aluminum or other lightweight panels to boost their noise insulation value. Lead, Barium or other mass-loaded vinyl sheets can also be used as noise curtains, for example to enclose or isolate a particularly noisy machine in a factory. However, in most cases of sound transmission between residential properties or between rooms within a building, sufficient noise control can be achieved using more common, and much less expensive, building materials such as timber, plywood, gypsum board, and glass or mineral fibre insulation.

A row of vegetation can be an effective noise barrier.

It is quite commonly believed that planting a row of vegetation (hedges, rows of trees or bushes) across the front of one's property will reduce exposure to noise from traffic or other sources. This is an understandable misconception since, by obscuring one's view of the traffic, vegetation may have perceptual benefits (i.e., noise levels may appear reduced due to the *"out of sight, out of mind"* effect). This may in fact be a beneficial perception when it helps to reduce our awareness of, and resulting annoyance with, intrusive noise at low to moderate levels. However, landscaping vegetation, in amounts that may generally be planted as treed borders or hedges, is too open and porous to significantly attenuate noise. Belts of mature forest (25 m or more) can, however, provide worthwhile extra noise attenuation (compared to open ground) and should be maintained whenever possible. Dense vegetation can also be useful when placed in front of a fence, wall or building as it will absorb some sound energy and thereby reduce the noise that is reflected back from these hard surfaces.

Doubled-glazed windows are much better at blocking sound than single-glazed.

Provided window perimeters are well sealed, double glazed windows are not significantly better at blocking traffic noise than a single-glazed window with the same total thickness of glass. This is because, as far as sound waves are concerned, particularly at lower frequencies, the standard (13 mm or 0.5") airspace between the two sheets of glass is not wide enough to effectively disconnect or "decouple" them. Note however, that since standard double-glazed windows have roughly twice the total thickness of glass as single glazed windows, they tend to provide (see Section 6.5.7) about 3 dBA more sound reduction.

If double-glazed windows are good, triple-glazed windows must be better

Tests have shown that triple-glazed windows are no better than double-glazed if they include the same total weight of glass and the same maximum airspace width between the outer panes of glass. Using heavier double glazing (with wider airspace) is then a less expensive means of getting similar performance. However, applying a widely-spaced storm window (see Section 6.5.7) over an existing double-glazed window is effective, as it is when applied over a singe-glazed window.

The walls of my house are of 2" x 6" (38 x 140 mm) construction - I won't have any problems with traffic noise.

While walls of insulated 2" x 6" wood stud construction provide greater thermal insulation than similarly insulated 2" x 4" walls, they do not provide significantly more traffic noise insulation (see Section 6.5.10). This somewhat counterintuitive result occurs because, regardless of the depth of the wood studs, they still create direct, rigid connections between the outside and inside surfaces of the wall. These connections provide pathways by which structure-borne sound can travel efficiently from the exterior to the interior of the residence.

I plan to replace the carpeting in my condo with hardwood flooring. As long I use one of those "sound control" underlays, I won't create any noise problems for the neighbours below me.

None of the thin (less than 12 mm or 0.5" thick) resilient underlay materials available commercially provide nearly the degree of footstep noise control provided by good carpet and underlay. Before replacing carpet with hardwood, ceramic tile, vinyl sheet, cork or other relatively hard floor finishes, permission should be sought from the strata council. The strata council should then consult with a noise control professional (see Appendix C), not a hardwood flooring or resilient underlay salesperson (see Sections 7.13 to 7.18 for further discussion of noise transmission through floors).

Egg crates make good sound absorbers and scatterers

It is common to see the wall and ceilings of home studios or music practice rooms lined with cardboard egg crates (cartons) in an attempt to make the room acoustically "dead" (non-reverberant) and to encourage uniformity of sound within the space. While egg crates are cheap and readily available and no doubt absorb and scatter some mid to high frequency sound, they are not particularly effective. Much better sound absorption can be attained from heavy draperies, deep pile carpeting or upholstered furniture or by applying fiberglass batt insulation or semi-rigid fiberglass boards to the walls and covering them with stretched fabric, perforated paneling (such as pegboard) or with narrow wooden slats spaced 12 to 25 mm apart. Better sound diffusion (uniformity) can be attained by making the interior walls of the room non-parallel and by placing larger, randomly-shaped and sized solid objects (e.g. furniture) on the floor or applying them to the walls.

Section 5 CONTROLLING NOISE IN THE CITY

- ***What is the City doing?***
- ***What are other levels of Government doing?***
- ***What can Vancouverites do?***
- ***Parallels between controlling noise and conserving energy***

5.1 What is the City doing?

The City of Vancouver acts to avoid and control noise impact and conflict situations in the following ways:

- Applies zoning regulations that avoid/minimize noise conflicts by controlling the activities that can occur on a given piece of land,
- Designates bus and truck routes throughout the city,
- Sets speed limits on city streets and employs other "traffic calming" measures (e.g., local street closures, intersection roundabouts) to control traffic, increase safety and reduce noise,
- Requires developers seeking approval to construct residential buildings along arterial streets to have a traffic noise assessment done and to incorporate measures in the layout and design of their buildings to adequately control traffic noise intrusion,
- Requires developers of multi-family buildings to follow the building code (see Section 7.7) in providing minimum levels of sound insulation between adjacent dwelling units,
- Requires the organizers of public events which are anticipated to create noise disturbances to obtain a special permit which imposes conditions and restrictions on the types of activities and their timing,
- Requires licenses and places other restrictions on buskers and street musicians,
- Enforces its Noise Control By-law No. 6555. This by-law sets daytime and nighttime decibel limits for noises originating within one property and being received within another property. It contains limits for construction noise, noise/music from commercial premises (stores, restaurants and nightclubs) and noise from power equipment such as lawn mowers and leaf blowers. It also limits the hours for construction work and refuse pick-up.
- Enforces Vehicle Noise Abatement By-law No. 4338. This bylaw permits the issuance of "violation notices" for vehicles which demonstrate "excessive alarm sounding" and which can result in the vehicle being towed and impounded.

5.2 What are other levels of government doing?

The B.C. Provincial government's role in controlling noise includes of the following:

- The Workers' Compensation Board and the Ministry of Energy and Mines set limits on the allowable noise exposure of workers while on the job,

- The Ministry of Transportation requires that the impacts of new and upgraded provincial highways (largely freeways and expressways) on adjacent communities be assessed and that mitigation measures such as walls, earth berms and quiet pavement be applied (if practical and effective) where projected increases in community noise levels exceed certain thresholds,

- The B.C. Environmental Assessment Office requires that complete environment impact assessments (including noise) be conducted and appropriate mitigation measures taken for major infrastructure projects such as the Sea-to-Sky Highway, and TransLink's planned "RAV" Line and New Fraser River Crossing (Golden Ears Bridge Project) between Surrey/Langley and Pitt Meadows/Maple Ridge,

- Provides information and standards through the B.C. Building Code that require residential developers to achieve adequate degrees of sound insulation between new and converted residential units.

The Federal government's role in controlling noise includes the following:

- Transport Canada sets limits on the noise emissions of new motor vehicles while the Canadian Standards Association (CSA) and other federal agencies address the noise from equipment, toys and other devices,

- Transport Canada develops noise exposure contours around major airports and provides guidelines to assist municipalities in determining appropriate land uses near airports,

- The National Research Council's "Institute for Research in Construction" conducts research and publishes guidebooks aimed at assisting the designers and buildings of residences to control sound transmission between dwellings. The results of this research often find there way into National and Provincial Building Codes,

- Health Canada has developed the "National Guidelines for Environmental Noise Control" (Reference 5) for the purposes of promoting a uniform approach to dealing with community noise issues in Canada and to assist municipalities in developing noise regulations and by-laws,

- The Federal Environmental Assessment Office participates in the review of environment impact statements for projects of a certain magnitude and/or where Federal funding is involved (e.g. Sea to Sky Highway Improvement Project and the Golden Ears Bridge Project). Experts in various relevant federal departments act as reviewers.

5.3 What can Vancouverites Do?

There are many things the citizens of Vancouver can do to reduce noise levels in their own communities and minimize the impacts of their noise on their neighbours:

- Carry out noisy activities during the daytime and try to avoid Sundays - the City's Noise By-Law No. 6555 prohibits construction activity on Sundays,

- Let your neighbours know when you, your kids or your tenants are planning to make more noise than usual such as from a house party or a renovation project. If the party is outdoors, keep music levels down. If you have to raise your voice to talk over it, chances are your neighbours are being disturbed – consider inviting them over?

- Consider your neighbours when locating potentially noisy outdoor devices such as air conditioners, fans, heat pumps, pool pumps or hot tubs,

- Maintain lawn and garden equipment in good working order, paying particular attention to gasoline engine exhaust mufflers. Use a hand mower and trimmer if your yard is not too big – its great exercise!

- Use devices such as weed eaters and leaf blowers moderately and responsibly as spelled out in the City's Noise By-Law. Use electric-powered garden devises instead of gas-powered. Better yet, use a rake to get more exercise!

- Reduce your contributions to traffic noise while saving gas (and money) by:

    - walking or cycling whenever possible,
    - using the public transit system,
    - buying a quiet, fuel efficient vehicle and maintaining it well,
    - if you operate a motorcycle, keeping the muffler in place and in good shape,
    - combining errands to reduce number of trips,
    - driving the speed limit and avoid "jackrabbit starts" and sudden stops,
    - shopping locally and buying locally-made products,
    - Reporting excessively noisy vehicles including boom cars and motorcycles.

Section 8 provides a list of things that residents of multi-family dwellings can do to avoid disturbing neighbours within their own building.

5.4 Parallels between controlling noise and conserving energy

5.4.1 Noise is wasted energy!

When a machine makes excessive noise, it is often a sign that it is not operating efficiently and/or needs maintenance. While the noise generated by a gas engine, vacuum cleaner or a leaf blower represents a very small portion of the total energy consumed by these machines, if they can be designed to operate more smoothly, with less vibration and noise, chances are they will do a better job and last longer while consuming less energy. Therefore, if you buy a tool or appliance that creates less noise while delivering the same performance, it is likely to serve you longer with lower operating costs. Conversely, if you buy a more efficient appliance, such as a refrigerator or furnace, in order to conserve energy, chances are that it will be quieter than your old inefficient or worn out appliance. There would then be many parallels between B.C. Hydro's "Power Smart" program and a "Noise Smart" program.

5.4.2 Thermal insulation versus sound insulation

It is generally true that a house which is poorly insulated against heat or cold will also be poorly insulated against noise. Loose-fitting and draughty doors, single-glazed windows and hollow (uninsulated) exterior walls allow heat to quickly drain out of a house while permitting noise to quite freely enter. Weather-stripping doors, installing tight-fitting double-glazed and/or storm windows and blowing loose-fill insulation into exterior walls and ceilings will then have the double benefit of lowering heating and cooling costs while reducing intrusive noise.

The parallels between thermal (heat) and acoustic (sound) insulation arise because most good thermal insulators consist of materials which are themselves poor conductors of heat (such as glass, cellulose or mineral wastes) and are formed into porous, fibrous blankets or granular fills that trap air in countless tiny, interconnected pores or cavities. This fine-scale porosity greatly slows the transfer of heat and also dissipates sound energy as the sound waves must squeeze through the tiny pores, thereby losing energy through friction and conversion to heat.

5.4.3 Not all good thermal insulators are good sound insulators

Some building materials, such as Styrofoam and other closed-cell, urethane foams, are good thermal insulators but poor sound absorbers. This is because the tiny air pockets inside these materials are not interconnected so that sound waves cannot easily penetrate into them. Styrofoam sheets are also not good sound barriers since, while fairly stiff, they are very light and easily set into vibration by sound waves.

5.4.5 Double-glazed windows – effects of airspace width

Standard double-glazed windows are designed for optimal thermal insulation. Their narrow (13 to 19 mm) airspaces provide effective thermal insulation because they limit "convection" (i.e., air circulation caused by temperature differences) within the window cavity and thereby minimize the transfer of heat from one side of the window to the other. Heat transfer due to convection increases with the width of the air cavity. Conversely, sound transmission through double-glazed windows (particularly at lower frequencies) decreases with the width of the airspace. Therefore, while double–glazed windows with 50 to 100 mm wide airspaces provide significantly better sound insulation that single-paned windows, standard double-glazed windows, with a 13 mm airspace, are only slightly better that a single layer of glass of the same total weight. The optimal configuration for both thermal and sound insulation may then be achieved by installing a widely spaced storm window over a standard double-glazed window.

Section 6 REDUCING EXPOSURE TO EXTERNAL NOISE FROM TRAFFIC & OTHER SOURCES

- ***Reducing your day-to-day exposure to noise***
- ***Buying or renting a home – avoiding noisy situations***
- ***Planning a new home or renovating – excluding noise by design***
- ***Reducing the exposure of your residence to noise***
- ***Reducing the noise entering your residence***

6.1 Reducing your day-to-day exposure to noise

6.1.1 Protecting your hearing

In the past it was quite common for people (mostly men) to suffer permanent hearing loss due to noise exposure while working in industry, mining or forestry or though more traumatic noise events associated with shooting or blasting. Such occupational hearing loss has become less common since the number of workers exposed to such noise has steadily decreased and Workers' Compensation Board (WCB) safety regulations have required the wearing of hearing protection devices (HPD's) such as ear plugs and muffs (Reference 5) in noisy working situations. However, there is now evidence that the population, particularly the younger component, is suffering hearing loss due primarily to noise exposure received during the course of daily, non-industrialized, life. For young people, much of this excessive noise exposure comes from entertainment options such as Walkmans/Discmans/MP3's, home stereos, video and computer games, rock concerts, dance clubs and more recently, powerful car stereos (boom cars) and movie theatres - both commercial and at-home. Thrown into this mix are other noisy pursuits such as motorcycling, jet skiing, snowmobiling and ATV vehicle use. Hearing damage due to exposure to such an array of noisy activities can only be avoided through a combination of education, moderation and in some cases, the use of hearing protection.

When on the job, at play or doing chores around the house, we should all be aware that many machines, power tools recreational devices and appliances produce noise levels at the user's ears which can approach or exceed the WCB's scale of daily noise exposures limits (Reference 4). Selected values from this scale include: 85 dBA over an 8-hour day, 95 dBA over 50 minutes, 100 dBA over 15 minutes and 105 dBA over 5 minutes.

Generally speaking, we should wear a HPD when using gas-powered lawn and garden equipment and other power tools such a chain saws, skill saws and power-washers and when engaged in activities that create intense, impulsive noises such as hammering. It is not enough that such equipment meets the City's noise bylaw limits since these were established for the benefit of the neighbours, not the operator. These limits, which are generally enforced at a distance of 15.2 m (50 ft.) from the source, include 87 dBA for chain saws, 77 dBA for general power equipment and 65 dBA for leaf blowers. However, such power equipment is typically operated at a distance of 1 to 2 m from the user's ear. Therefore, the noise levels to which operators would be exposed from equipment just meeting the various bylaw limits would range from 104 to 110 dBA for chain saws, from 94 to 100 dBA for general power equipment and from

82 to 88 dBA for leaf blowers. The use of HPD's is then clearly advisable when using the first two categories of equipment and marginally warranted for bylaw-complying leaf blowers given the limited duration of typical non-occupational exposures.

6.1.2 Take the road less traveled!

Average traffic noise levels along the edges of busy arterial roads and highways can often reach 75 to 80 dBA while maximum levels from passing heavy trucks and busses and motorcycles can reach 90 to 100 dBA – levels that can cause temporary hearing sensitivity degradation over short exposures and permanent hearing loss over more prolonged exposures. For safety reasons, it is not advisable to wear hearing protectors in such situations - particularly when biking. However, there may be opportunities to use quieter side streets or alternative routes that will get you where you are going only slightly less quickly, with greater safety and less wear and tear on your hearing.

6.1.3 Buyer beware!

Many small appliances (vacuum cleaners, hair dryers, blenders etc.) produce uncomfortably high noise levels. To avoid unnecessary noise exposure, potential purchasers of such devices should ask about the noise ratings of different makes and models and try them out before taking them home. Try to find out what setback distance the noise rating is based on. Of particular concern is the noise created by toys intended for infants and small children. While some toys may not seem unduly loud when we try them out at arms length, consider what the noise would be like if the toy was held right next to the ear, as a young child might do. Note (as discussed in Section 4.1.1), that noise levels from a small, localized source increase at roughly 6 dBA per halving of distance so that a toy that produces only 75 dBA at the ear when held 0.6 m (2 ft.) away will produce about 103 dBA when held only 25 mm (1 inch) from the ear.

6.2 Buying or Renting a Home – Avoiding Noisy Situations

The most obvious way to avoid being exposed to excessive noise from traffic or other permanent sources is not to choose a home on or near a busy street, a railway line an airport, a factory or a nightclub. Of course many other factors come into play when finding a residence such as location relative to work, transit services, schools, recreation and shopping as well as affordability. However, while the noise situation may be readily apparent if your future residence is on a busy arterial street, other locations that may appear quiet on first viewing may not be found to be nearly so peaceful at other times of day or week, or after longer exposures. Take the time to fully experience the noise environment (day and night, weekday and weekend), particularly before buying a residence. Don't be shy about asking future neighbours.

Talk to the City planning and traffic departments. Find out if there are any plans to upgrade local roadways, change local traffic patterns or allow a major traffic generator (such as mall, big box store, office building or school) to enter the neighbourhood.

6.3 Planning a new home or renovating – excluding noise by design

Are you planning to build a new home or have major renovations done to an existing one? You then have an opportunity to incorporate noise control features into the design. Things that should be taken into consideration at such a time include:

- Location of the home on the property,
- Choosing a floor plan that locates noise-sensitive rooms (bedrooms, living rooms, dens) away from the noise source and uses less-sensitive spaces such as garages, entryways, hallways, storage and kitchens as noise buffers (see Figure 7) .
- Orientation and configuration of home relative to the street or other noise sources,
- Location of outdoor amenity spaces (decks, patios) relative to noise sources,
- Location and construction of doors and windows.

6.4 Reducing the exposure of your residence to noise

6.4.1 Location of residence on property

As was seen in Figure 3, each doubling of distance from the street will reduce average traffic noise levels at a residential façade by from 3 to 5 decibels (roughly 20 to 30% quieter). Instantaneous noise levels from sources such as boom cars, sirens or busses decreases by 6 dB or more with each doubling of distance. Clearly there is a benefit to locating your residence near the rear of your lot. However, this must be weighed against the resulting reduction of noise-shielded outdoor amenity space in the back yard. If this type of outdoor space is valued, it may be wiser to locate your new house nearer the street, incorporate the necessary noise control features into its facade and maximize the useable quiet space at the rear.

6.4.2 Choosing a floor plan that minimizes noise intrusion

Figure 7A indicates how the residential floor plan can be used to minimize exposure of the most noise-sensitive spaces (bedrooms, living room and den) by locating them at the rear of the house and using less-sensitive spaces as noise buffers. Where the location of noise-sensitive rooms on a unshielded (front) or partially shielded (side) facade can not be avoided and windows must be openable, solid baffles or screens may be attached to the outside of the house to shield the openable portion of the window from road noise. Examples of such baffles are shown in Section 6.5.8.

B: Good and poor house configurations

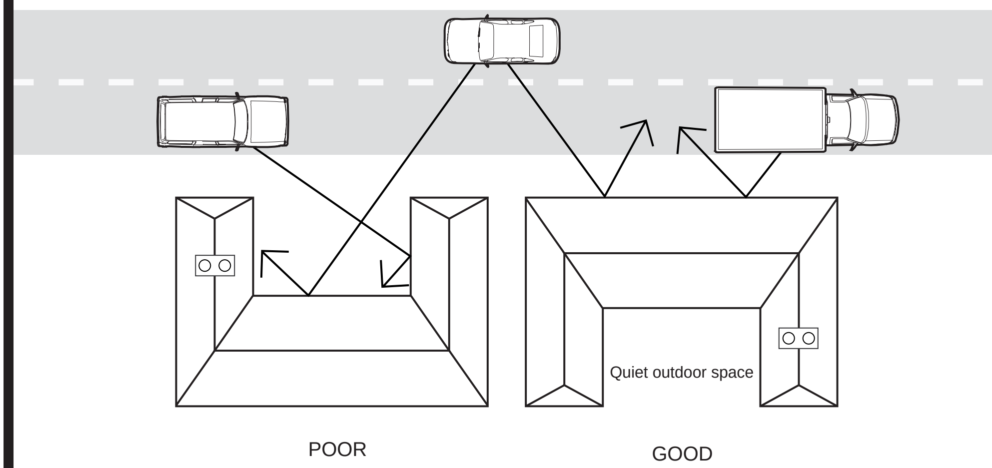


Figure 8A: Using floorplans and building configuration to exclude traffic noise

A: Good and poor floor plans

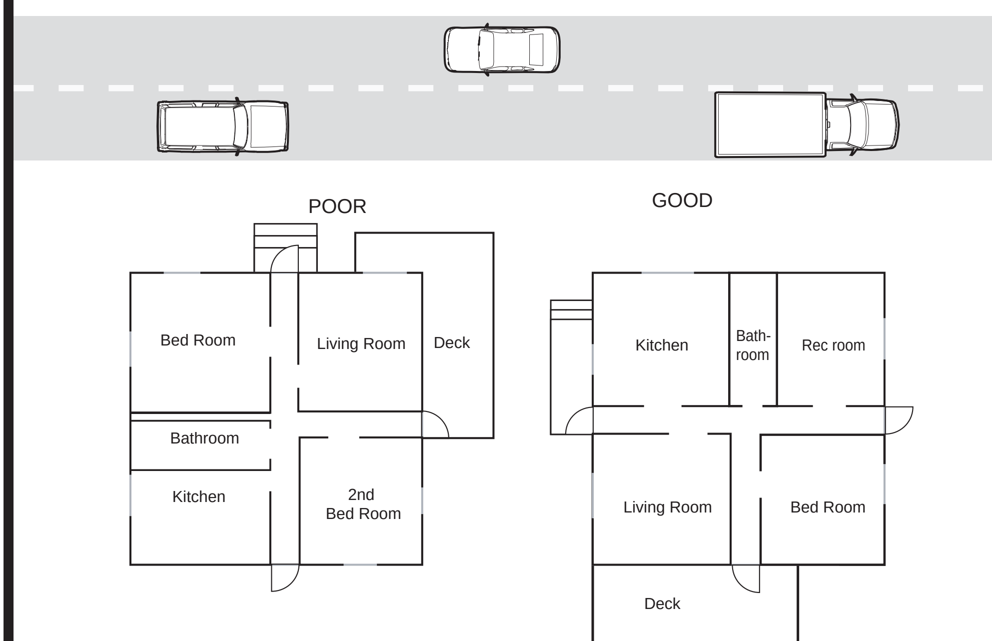


Figure 8B: Using floorplans configuration to exclude traffic noise

6.4.3 Orientation and configuration of buildings

Figure 7B.shows a somewhat extreme example of how the configuration or shape of a residence can lend itself to the creation of a noise-sheltered outdoor amenity space This principal also applies to more familiar cases, such as with L-shaped or curved residences or attached (row) housing. Even the more traditional rectangular-shaped residences can create sheltered spaces, particularly if residences are quite closely spaced along the road or if fences extending along the lot line enhance the shielding effect in the rear yard. Due to their greater height, optimally configured residences (or outbuildings) can provide more noise shielding of an outdoor space than can typical noise barriers.

6.4.4 Noise Barriers

As discussed in Section 4**,** noise from traffic and other sources located quite near the ground can be reduced by blocking the line of sight from the receiver location to the source with a noise barrier. Noise barriers typically take the form of walls, earth berms, or berm/wall combinations but may also be created by outbuildings (garages, car ports) or other structures. Figures 5 and 6 have shown the key features of noise barriers as well as their limitations. A barrier that just blocks the line of sight from the receiver to the dominant noise source region (e.g. the tires of vehicles on a free-flowing arterial road) can provide about 5 decibels of noise reduction (about a 30% reduction in loudness). As the barrier is made higher, its effectiveness increases by roughly 1.5 dBA per extra metre of height. A significant challenge in building an effective noise barrier (particularly in the form of a heavy fence or wall) then involves making it high enough given the fence height limitations specified in Vancouver's bylaws, namely 1.22 m (4 ft.) in front of the house and 1.83 m (6 ft.) in the rear and on the sides. A further limitation of noise barriers is that they are generally not able to be built high enough to effectively shield the upper floors of a multi-storey building from traffic noise.

To be effective, a noise barrier must also screen essentially all the noise source zone from view. As such, building a solid fence or wall across the front of a residential lot will generally not be very effective in reducing traffic noise exposures in the front yard or at the front windows unless you have a very wide property or the neighbours on each side construct similar walls. A rule of thumb (illustrated in Figure 9a) is that "to optimize the effectiveness of a noise barrier, it should extend beyond either end of the receiver zone by a distance three or four times that from the receiver to the barrier. Where this is not possible, Figure 9b illustrates an option which involves "returning" the noise wall along the property lines on each side of your lot.

In some situations, traffic noise barriers may raise security issues. Noise barriers tend to screen the view of residences from the street and may also screen the view of pedestrians from the residences. Other factors to be considered when planning a noise barrier are the potential restriction of access to residences from the street and sidewalk and the aesthetic impacts of the barrier wall or structure (visual dominance and potential for graffiti) on residents, pedestrians and motorists alike. The shade created by high noise barriers may also impact lawns and gardens.

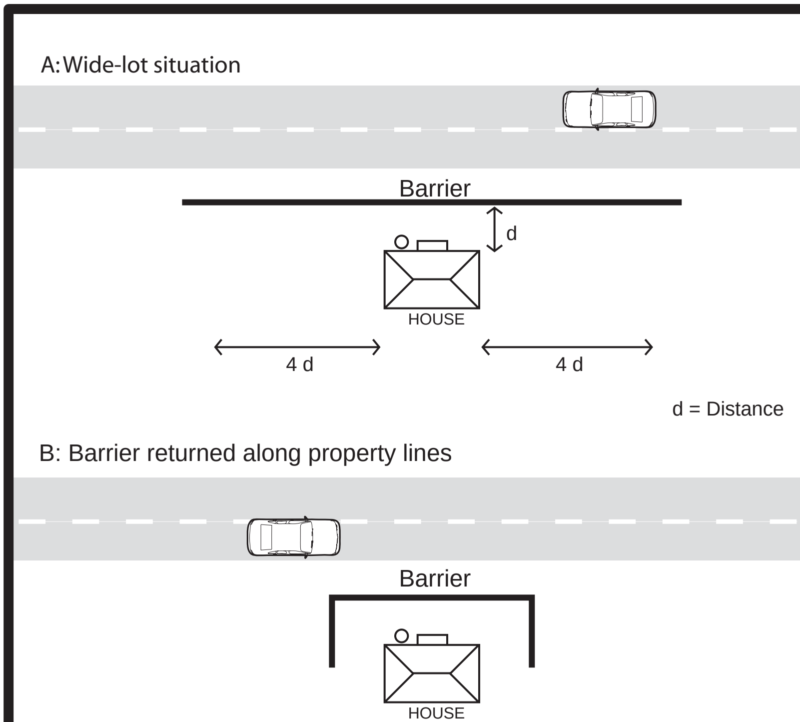


Figure 9: Effective residential noise barrier configurations

6.4.5 Reducing noise exposures on high-rise balconies

For the many Vancouverites who live in high-rise apartment or condominiums buildings, outdoor amenity spaces are often small balconies overlooking busy and noisy streets. Noise levels on these balconies due to traffic and other activities on the streets below are often uncomfortably high. The noise generally passes through the balcony and into the adjoining indoor living spaces via poorly sealed and/or openable windows and sliding glass doors. Three approaches to reducing noise exposures on high-rise balconies are described below and illustrated in Figure 10:

1. Noise levels on balconies are often amplified by the reflection of sound from the hard surfaces provided by the underside of the balcony above, the back of the railing (if of solid construction – i.e., not open bars) and the walls, windows and glass doors of the unit in question. The application of weather-resistant sound absorbing material (see Appendix C) to these surfaces will reduce noise levels both on the balcony and in adjoining rooms.

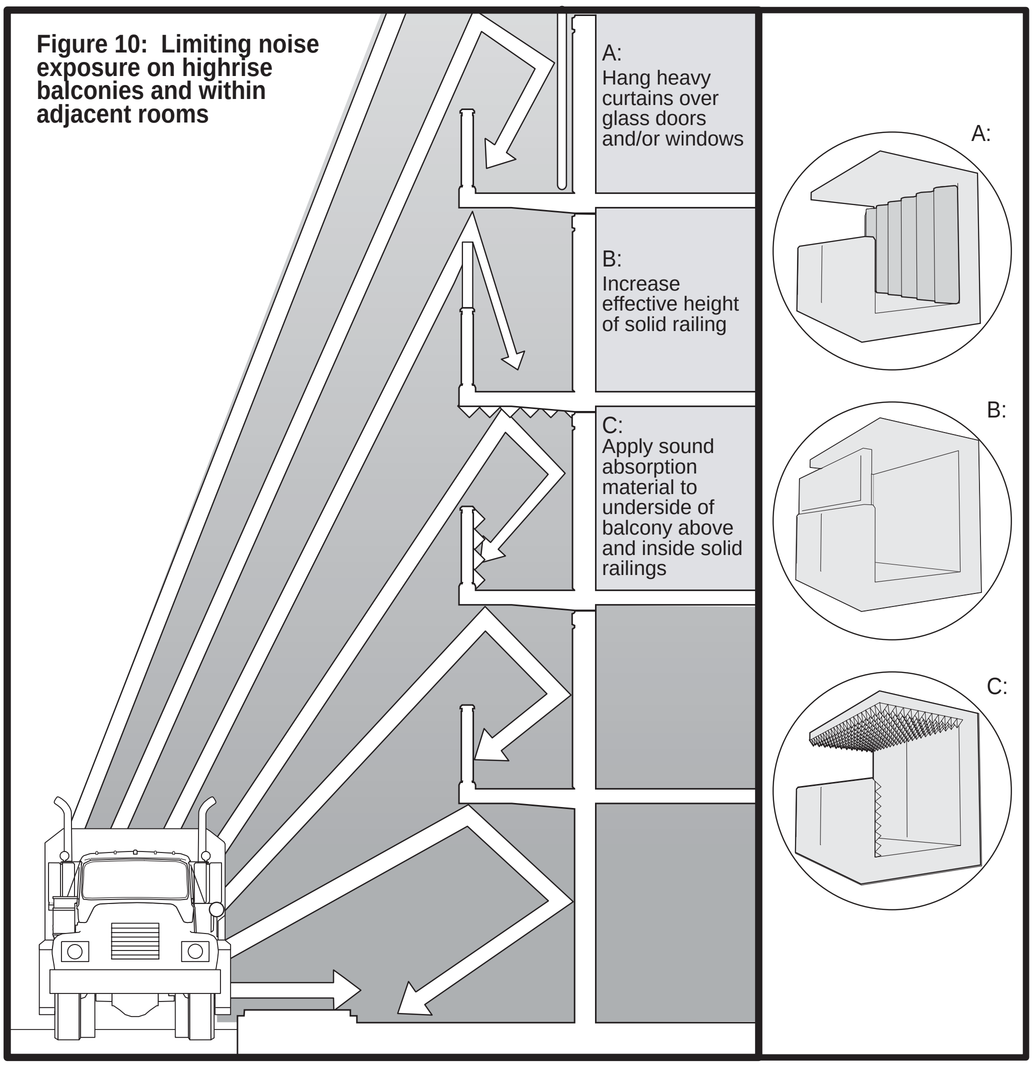
2. While the total enclosure of balcony space is not permitted under City zoning regulations, it may be possible to increase the effective height of the railing. This would best be done by attaching a strip of solid, weather resistant material along the top of the existing solid railing. In order not to block light, restrict views or have significant visual impact on the building, transparent materials such as Plexiglas, Lexan or tempered glass would be good choices. If the balcony railing is of an open design and you do not wish, or are not

permitted, to close it in with a solid, opaque material, it may be possible to install a transparent sheet material that extends upwards from the balcony floor to the height of the railing or beyond. The higher such a transparent noise shield can be extended, while still maintaining adequate ventilation, the greater the noise reduction.

3. To reduce the amount of noise entering the high-rise residential unit, heavy curtains can be hung across the glass doors and/or windows that open onto the balcony. Ideally these would be of a impervious, (airtight) material such as the mass-loaded vinyl curtains often used for industrial noise control or to temporarily separate rooms (as in a hotel or conference centre) to provide speech privacy. These vinyl curtains (see Appendix C) can be either opaque or transparent. Heavy fabric curtains (such as well-sealed canvas) would be more economical and readily available but are less effective, particularly against lower-frequency noise.

Like all residents exposed to excessive external noise, high rise dwellers can reduce their indoor noise exposures by improving the sound insulation performance of their windows and doors. Means of doing this are described in the Section 6.5.

Figure 10: Limiting noise exposure on highrise balconies and within adjacent rooms



6.5 Reducing the noise entering your residence

6.5.1 How does noise get into our residences?

Outdoor sounds enter residences via two types of paths: 1., by cracks, holes and other openings, and 2., through the exterior building structure (façade) itself. Since sound is simply the vibration of air, it passes easily through any cracks, holes or other openings into which air can penetrate. Higher frequency sounds pass through small gaps and holes much more easily than lower ones. To prevent such sound "leakage", cracks and holes must be effectively blocked with airtight sealant. In the case of large openings for vents etc., their exterior openings should be covered with a hood to prevent sound from passing directly into them while the interior of the vents and any connected ductwork should be lined with a sound absorptive material such as fiberglass duct liner (see Appendix C).

Sound is also able to enter buildings by making their exterior surfaces vibrate. Sound waves created outdoors strike the façade of the house and cause windows, walls and roof structures to vibrate to varying degrees. This vibration is transmitted through the exterior walls, windows and doors, setting their interior surfaces into vibration. These vibrating interior surfaces then radiate sound inwards, which is the noise we hear indoors. Generally, heavier, stiffer materials vibrate less when exposed to sound and therefore tend to make better noise barriers. However, the degree of structural separation (disconnection) between the outer and inner surfaces of building facades is also important in controlling the transmission of sound.

Figure 11 illustrates the various ways in which outdoor sound can enter a dwelling (in this case via an exterior wall). All these potential sound paths (including air gaps/leaks, structure-borne sound and direct transmission through the wall cavity) must be dealt with if a high degree of sound insulation is to be achieved.

6.5.2 Finding the weak links

As with any of life's challenges, to effectively deal with a noise problem you need to apply your efforts in the right place(s). When the challenge is keeping traffic, or other exterior noise, out of your dwelling, finding the weakest links is generally not too difficult. While the relative importance of each façade component may vary form one building to another, windows and doors are usually the prime suspects. However, when the noise in question has substantial low-frequency content (such as from heavy trucks, busses, or jet aircraft), then even the walls and roofs may contribute significantly to the overall levels of noise entering your house. To decide which elements of a residential façade need to be upgraded, both the nature (construction) and size (area) of each element need to be considered.

Appendix B provides a fairly detailed methodology for estimating the average traffic noise level at the façade of your residence, determining how much overall sound insulation your façade must provide to achieve the desired indoor noise levels and selecting appropriate constructions for each façade element (windows, walls, doors and roof) in order to achieve this objective. This approach is considered appropriate for those planning new residential buildings near busy streets or substantially upgrading an existing building and wishing to optimize the noise insulation provided by their building façades. Sections 6.5.3 though 6.5.14 provide the information needed to decide how to best improve the sound insulation performance of individual windows, doors, vents, walls and roofs.

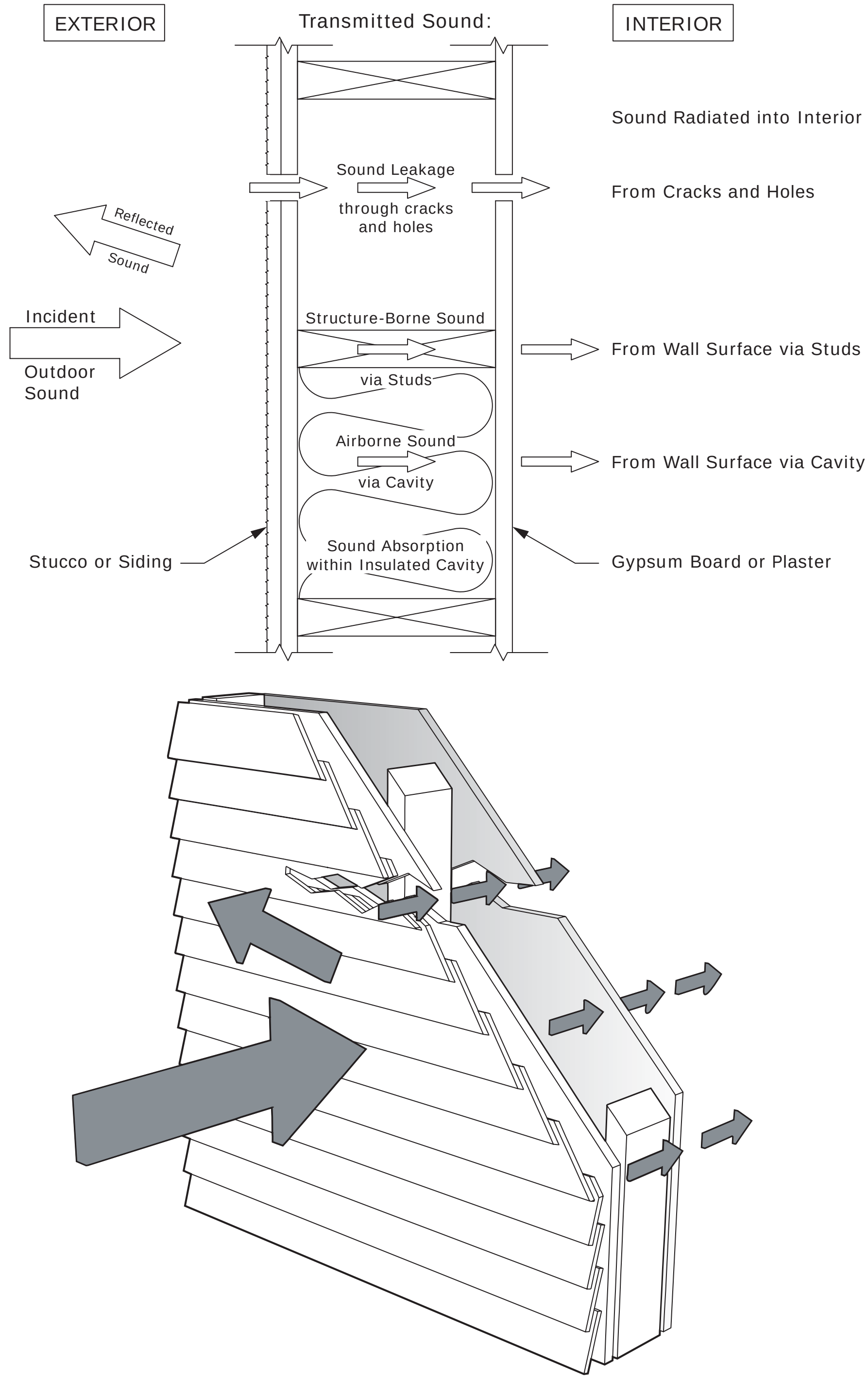


Figure 11: The Various Ways that Outdoor Noise can Enter a Residence (here via a typical exterior wall)

6.5.3 Sound insulation priorities

When attempting to improve the insulation properties of a residence against external noise, the following prioritized list of treatments will generally apply:

Windows:

- provide airtight perimeter seals,
- reduce window size,
- locate larger windows on quiet side of house,
- use heavier glass and larger airspace between sheets of glass,
- add layer of heavy glass with large airspace to existing window (i.e., create a storm window),
- if window must remain openable, consider using a solid screen or baffle to shield the opening from the noise source.

Doors:

- use solid wood, solid core or insulated steel doors,
- provide airtight seals along top, bottom and sides,
- add a second “storm door” separated by an airspace 100 to 150 mm (4” to 6”) deep - seal perimeters of both doors,
- create an entrance vestibule (entryway or “mud room”).

Vents and Holes:

- locate ventilation openings on quiet side of house,
- cover with hood and acoustically line ventilation ducts,
- caulk or otherwise seal all holes and cracks (airtight).

Walls:

- increase mass of lightweight constructions with additional interior layers of gypsum board or heavy external materials such as cement stucco or brick,
- fully insulate cavities (with glass, mineral or cellulose fibre batts or loose-fill, blow-in insulation),
- attach interior gypsum board (one or two layers) to the framing using resilient channels,
- consider using staggered-stud or double-stud exterior walls.

Roofs (particularly when dealing with aircraft noise):

- install 200 to 300 mm (8” to 12”) thermal/acoustical insulation in cavity between roof and ceiling,
- treat (attached duct section and acoustically line) attic ventilation openings,
- keep fireplace dampers closed when not in use, consider an enclosed fireplace (insert) or a wood stove,
- construct suspended ceiling using one or two layers of gypsum board mounted on resilient channels, or “Rez-Bar” (see Section 7.10 for info on using Rez-Bar).

6.5.4 Rating the sound insulation performance of building elements – STC

To compare various window, door and wall constructions and select the appropriate construction for use in one's home, we need to know by how much noise levels will be reduced in passing through each façade element. However, as noted previously, the noise reduction provided by building elements varies with the frequency, generally improving with increasing frequency for elements that are free from gaps, cracks and openings. ***Sound Transmission Class (STC)*** is a single-number rating of the general sound insulation capacity of various building elements. It is obtained by comparing the noise reduction performance of building elements at various frequencies against a standard noise reduction curve. For our purposes, the STC may be considered to represent (roughly) the amount by which sound levels are reduced in passing through a building element. For example, where the outside noise level is 75 dBA and the building façade provides STC 35, then the indoor level (at least near the façade in question) will be roughly 40 dBA. While originally developed to address the transmission of familiar indoor sounds such as from speech, radio and TV, STC has been used to rate and compare both exterior and interior building elements and select appropriate window, door and wall constructions. Appendix B introduces a more recent single-number sound insulation rating (OITC) which has been developed for use with exterior facades.

6.5.6 Guidelines for acceptable indoor noise levels

Before discussing how to improve the sound insulation of façade elements, it is helpful to know just what levels of interior noise are considered appropriate for residences. While the level of noise found acceptable within residences will vary form person to person depending on personality, lifestyle and state of health, the Canada Mortgage and Housing Corporation (CMHC) has established threshold levels that are considered to prevent any significant interference by external noise with essential activities such as speech and sleep and are widely used as guidelines in Canada (Reference 2). The CMHC's target noise levels for various indoor spaces – expressed in terms of the 24-hour equivalent sound level, or $L_{eq}(24)$ – are as follows:

Bedrooms	35 dBA
Living, dining and recreation rooms	40 dBA
Kitchens, bathrooms, hallways, utility rooms	45 dBA
Outdoor Recreation areas	55 dBA

6.5.7 Starting with windows

<u>*The weakest links*</u>

In most residences (newer or older) windows and/or glass doors form the weakest links in the noise insulation chain. To achieve substantial reductions in traffic noise it is then necessary to improve the sound insulation performance of windows to the point where they approach the performance of exterior walls. Since, within a given room, windows are generally, but not always, smaller than the walls, their STC rating does not usually need to be quite as high as the wall's to achieve a balanced design. Table 6.1 below indicates the incremental benefits of upgrading windows in various ways starting with typical unsealed, single-glazed windows. The benefits are expressed in terms of both the improvement in sound insulation rating (STC) and the approximate effect on the perceived loudness of the intrusive noise when heard indoors. Section drawings of several of the window types listed in Table 6.1 are provided in Figure 12 along with their representative STC ratings.

Row No.	Window Construction	Sound Insulation Rating (STC)	Improvement in Sound Insulation Compared to Previous Line (STC points)	Reduction in Loudness Compared to Previous Line (%)	Total Improvement in Sound Insulation Compared to Ref. Window	Total Reduction in Loudness Compared to Reference Window
1	Any window type, open slightly for ventilation	10-15	-	-	-	-
2	Single-glazed (3mm glass), closed, no weather- stripping/seals (REFERENCE WINDOW)	20	Reference	Reference	Reference	Reference
3	Single-glazed (3mm glass), closed, no weather- stripping/seals, with heavy curtains (estimate)	25	5	30%	5	30%
4	Single-glazed, closed with weather-stripping/seals	27	2	13%	7	38%
5	Single-glazed, closed and sealed with heavy curtains – (estimate)	29	2	13%	9	46%
6	Single-glazed (3mm glass), fixed	29	0	0	9	46%
7	Standard double-glazed (3mm glass, 13 mm airspace), openable	30	1	7%	10	50% (1/2 as loud)
8	Standard double-glazed (3mm glass, 13 mm airspace), fixed	32	2	13%	12	56%
9	Double-glazed (3mm glass, 25 mm air space), fixed	35	3	19%	15	65% (1/3 as loud)
10	Laminated glass,(6mm thick)	35	0	0	15	65%
11	Laminated glass,(13mm thick)	38	3	19%	18	71%
12	Double-glazed (3mm glass, 50 mm air space), or (6mm glass and 13 mm airspace). fixed	38	0	0	18	71%
13	Single-glazed with storm window added, separated by 50 mm air space, fixed	38	0	0	18	71%
14	Single-glazed with storm window added, separated by 100 mm air space, fixed	42	4	25%	22	78%
15	Double-glazed with storm window added, separated by 50 to 75 mm air space, fixed	43	1	7%	23	80% (1/5 as loud)
16	Single-glazed with "Magnacoustic" sound proofing window insert (commercial STC test)	44	1	7%	24	81%

Table 6.1; Representative Sound Insulation (STC) Performance of Various Window Constructions and Conditions

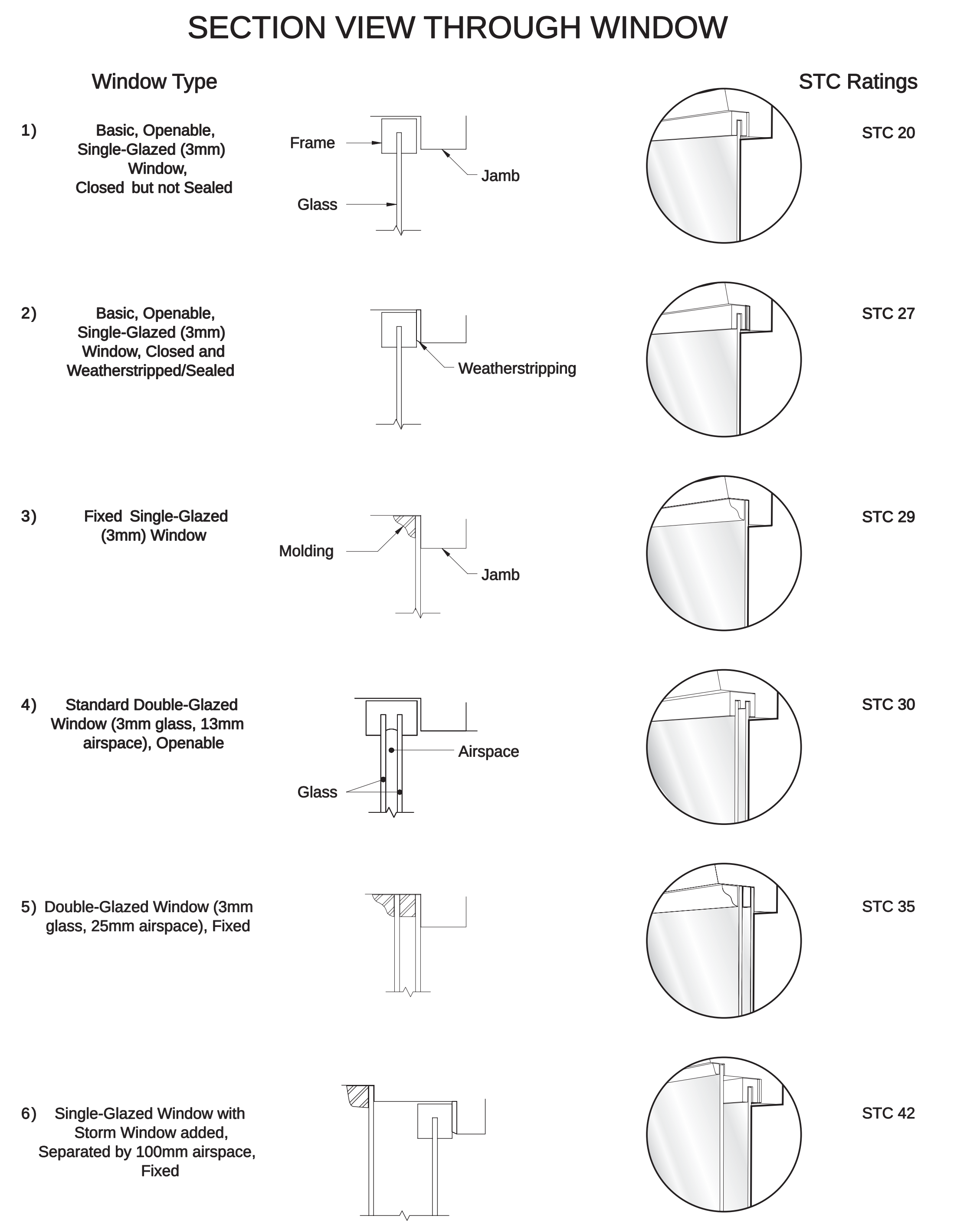


Figure 12: STC Ratings of Various Windows

What can a partially open window do?

Row 1 in Table 6.1 shows that, when left partially open, the sound insulation provided by any type of window will be limited to STC 10 to 15, thereby reducing outdoor sounds by roughly only 10 to 15 dBA. This means, for example, that inside near the window, traffic noise will be only about 50% to 65% quieter (about ½ to 1/3 as loud) than it is outside the window. To achieve the CMHC's target noise level for bedrooms of 35 dBA with the windows open slightly, the outdoor noise environment cannot then exceed 45 to 50 dBA. Such levels may exist (see Table 3.1) in rural and quiet suburban locations far from major streets, but are not likely to be found in urban residential areas. Improvement of window performance must therefore be considered.

Improving window performance

As Table 6.1 shows, the performance of windows may be improved in a variety of ways. The first step would logically be to keep them closed when quieter indoor conditions are required, thereby achieving roughly STC 20 with typical older, unsealed, single-glazed windows. Where bedroom windows are involved, this would generally be satisfactory for outdoor noise environments up to about 55 dBA. The second step would be to seal the perimeters effectively. Well sealed or fixed single glazed windows can reach STC 27 to 29, thereby reducing the loudness of indoor noise by close to 40 to 50% compared to closed, but unsealed, single-glazed windows. Adding full, heavy curtains to such windows can help somewhat – being particularly effective in reducing the higher-frequency noise that tends to leak around unsealed windows and thereby increasing the STC in such situations by up to about 5 points. Curtains, carpets, upholstered furniture and other soft, porous materials will also help to reduce the general "noisiness" of a room, whether the noise is created within the room itself or within an adjoining space or is entering through windows, doors, walls or floors.

Double-glazed windows

Comparing Rows 6, 7 and 8 of Table 6.1, it is seen that standard double-glazed windows -whether openable or fixed - are only slightly (1 to 3 STC points) more effective than fixed single-glazed windows. This is because the standard 13mm (1/2") airspace is too narrow to acoustically decouple (disconnect) the two sheets of glass, particularly at lower frequencies. Comparison of Rows 8, 9 and 12 shows that enlarging the airspace to 25 mm or 50 mm improves the STC by 3 or 6 points respectively. Similarly, doubling the thickness of the glass sheets from 3 to 6 mm (see Rows 8 and 12) produces about a 6 point STC improvement. It is also beneficial to use different thicknesses of glass on the two sides of a double-glazed window, thereby mismatching their vibration characteristics. A thickness ratio of about 2 to 1 generally works best.

Laminated glass

Laminated glass generally consists of two sheets of glass bonded together with a thin plastic interlayer. The plastic interlayer increases the vibration damping capacity, and therefore sound insulation properties, of the window. Laminated glass is somewhat more effective than standard double-glazing containing the same total thickness of glass, however, it is more expensive and does not provide as much thermal insulation.

Window films

Special plastic films may be applied to windows surfaces to alter their heat transmitting and radiating characteristics in the interest of conserving energy. However, these “Low E” and other energy conserving films are very thin - at most 0.35 mm (0.014”) thick compared to the 0.76 to 1.14 mm (0.030 to 0.045”) thick plastic interlayers used in laminated glass - and are not sandwiched, or “constrained”, between two layers of glass. For these reasons such films have only very minor effects on the sound insulation properties of the windows to which they are applied.

Storm windows

Rows 14, 15 and 16 of Table 6.1 show that generally the most effective approach to improving the sound insulation performance of existing windows is to add a separate “storm window” of plate glass or laminated glass over the existing single or double-glazed windows. Provided the airspace created between the new storm and the old window is 50 to 100 mm wide, STC ratings of 42 to 44 may be achieved, thereby reducing interior noise levels by up to 80% (1/5th as loud) compared to unsealed single-glazed windows. Assuming there are no other “weak links” in the façade of the residence, windows providing STC 40 or more would be able to achieve an indoor environment of roughly 35 dBA in locations with outdoor environments of 75 dBA or more. As Table 3.1 has shown, such traffic noise environments are found only along the busiest of arterial streets or major highways.

Alternate Ventilation Requirements

To achieve STC’s of more than about 15, windows must be closed. Therefore, alternative means of ventilation must generally be provided such as from a forced-air (mechanical) system or by opening windows on quieter sides of the residence,

STC versus Outdoor-Indoor Transmission Class (OITC)

The STC rating system was initially developed for use with familiar indoor noises such as speech, telephone and television sounds which, at least at the time, had limited low-frequency content. However, when the noise in question is from arterial traffic with many trucks or from aircraft, there tends to be much more sound energy at low-frequencies so that the STC is no longer the ideal sound insulation rating. A newer, and therefore less familiar, rating called Outdoor-Indoor Transmission Class (OITC) has been developed to better deal with such noises and has been used in the more detailed façade design methodology found in Appendix B. Because most building elements provide less sound attenuation at low frequencies, the OITC rating tends to be from 5 to 10 points lower than the corresponding STC for the same facade element.

6.5.8 Minimizing noise penetration through open windows

If windows must be left partially open for ventilation, it is possible to reduce the noise entering the open portion by attaching a noise screen or “baffle” just outside the window. Such baffles are intended to block the direct line of sight from the open window to the noise source. Figure 13 shows two possible noise baffle configurations suitable for use with double-hung (vertically opening) windows located on the front (road facing) façade of a residence. Similar baffles could be developed for installation along the sides of horizontally-opening (slider or hinged) windows, however, they would tend to be less effective since traffic noise would approach the window opening equally from both sides. Full, heavy curtains can reduce the levels of noise entering an open window somewhat (particularly the higher frequency components) but also restrict air movement.

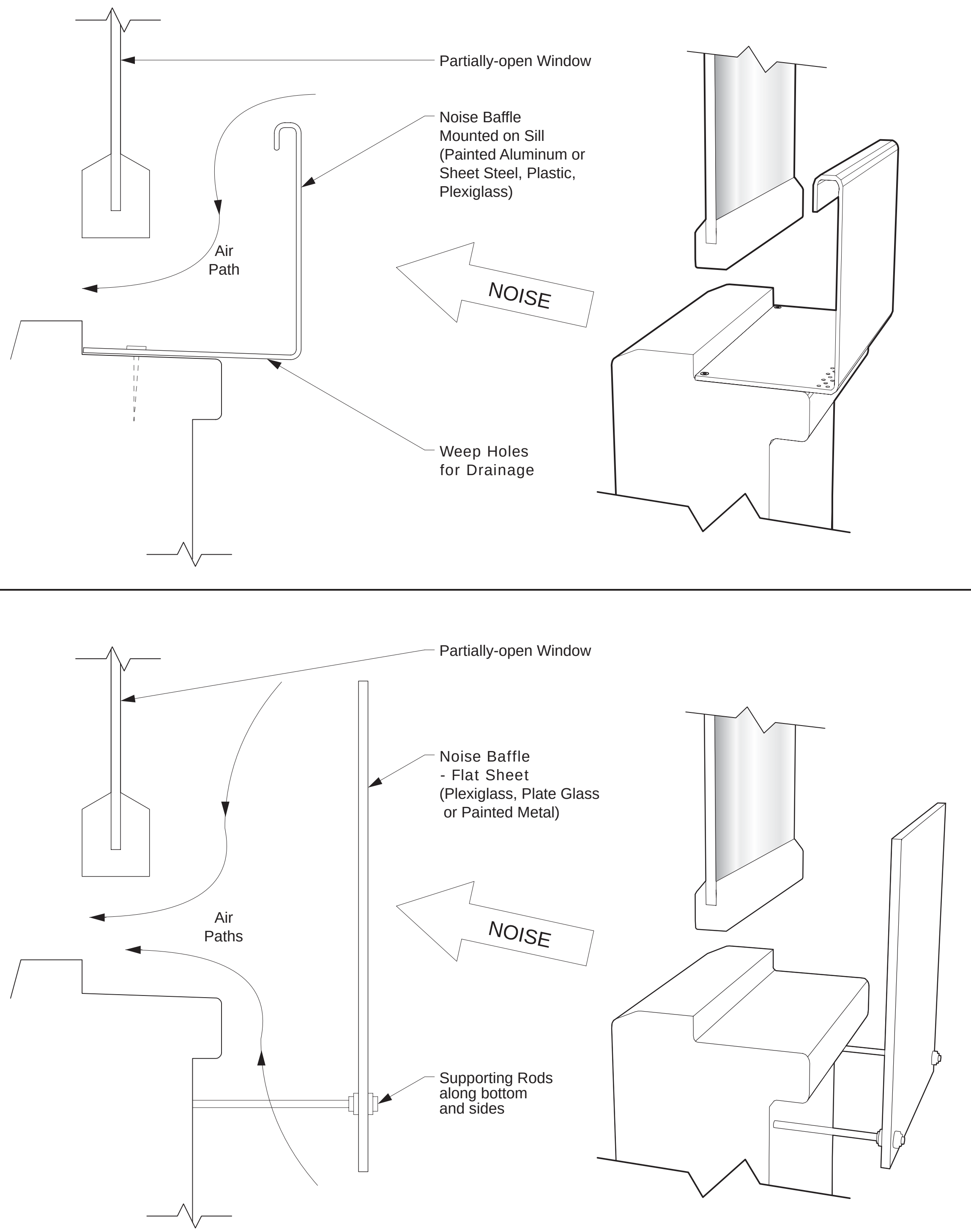


Figure 13: Two Configurations for Open-Window Noise Baffles

6.5.9 Dealing with doors

For both sound and thermal insulation reasons, all exterior doors should be of either solid wood (typically 45 to 50 mm thick) or insulated steel construction. Such doors will generally provide STC 30 to 33 if their perimeters are fitted with airtight seals (see Appendix C), but only about STC 20 to 22 if they are not sealed. Specially made acoustical doors are available with ratings of up to STC 45 to 50 however they are quite heavy and expensive and are generally used only in sensitive interior noise control situation such as studios, music rooms and theatres and in high noise areas such as engine test facilities. Some more practical and economical options by which the homeowner may improve the sound insulation of exterior doors are given below:

1. Use two solid core doors separated by an 100 to 150 mm (4" to 6") airspace; seal perimeters of both doors, e.g., add a "storm door" of insulated steel or solid wood construction, with or without a double-glazed window,

2. Create an entrance vestibule (entryway or "mud room"), seal outer or both doors.

6.5.10 Improving Exterior Walls

Table 6.2 provides laboratory-measured STC's for a variety of exterior wall constructions while section drawings of several of these constructions are shown in Figure 14. The sound insulation capacity of typical exterior walls is generally comparable to or better than that of typical sealed single-glazed or double-glazed windows. For example, as shown in Table 6.2 (Wall No. 1), an insulated 89 mm (3.5") wood stud wall with wooden sheathing and lightweight (cedar, vinyl or aluminum) siding on the outside and gypsum board or plaster on the inside will provide approximately STC 36. The addition of 19 to 22 mm (3/4" to 7/8") of cement stucco on the outside (see Wall No. 5) improves this wall's performance to STC 44 to 46. Therefore, it would generally only be necessary to consider improving the sound insulation of exterior walls beyond that provided by basic 89 or 140 mm (3.5" or 5.5") thick single wood stud wall if:

1. Your home is an older one and the existing exterior walls do not have adequate thermal insulation – here improving insulation (potentially by blowing loose-fill insulation into the walls) would reduce heating costs as well noise penetration,

2. Exterior noise levels are very high (65 dBA or more) and the sound insulation capacity of the windows has been, or will be, improved beyond the STC 27 to 30 typically provided by sealed, single-glazed or standard double-glazed constructions,

3. Exterior noise levels are high (60 dBA or more), you plan to build a new home or renovate the interior of your existing home and have the opportunity to improve exterior wall performance with minimal additional cost and disruption.

Table 6.2 shows that the sound insulation capacity of single wood stud exterior wall constructions can vary widely based on the nature (and weight) of their exterior finishes. Comparing Walls Nos. 1 and 2 with Nos. 5 and 10, it is seen that increasing the surface density of such walls (i.e., making them much heavier) by applying cement stucco or brick to their exterior surfaces can increase their STC ratings by from 8 to 16 points. Comparison of Walls Nos. 1 and 2 with Nos. 6, 7, 8 and 9 shows that if the rigid connections through these walls (as provided by the studs) are eliminated either by mounting the interior gypsum board layer(s) on resilient channels (Rez-Bar) or by constructing "staggered" stud walls, their STC ratings can be improved by from 11 to 16 points. Even larger sound insulation improvements may be obtained by combining these two approaches – increased weight and structural disconnection.

Ext. Wall No.	Exterior Wall Type	STC[2]
1	Basic 89 mm (3.5") insulated wood stud wall[1] with plywood, OSB or shiplap exterior sheathing, cedar, vinyl or aluminum exterior siding and gypsum board or plaster-on-lath on interior surface	36
2	Basic 140 mm (5.5") insulated wood stud wall with plywood, OSB or shiplap exterior sheathing, cedar, vinyl or aluminum exterior siding and gypsum board or plaster-on-lath on interior surface	37
3	Basic 89 mm (3.5") insulated wood stud wall (similar to No. 1) except that a second layer of gypsum board is applied to the interior surface	38
4	Basic 140 mm (5.5") insulated wood stud wall (similar to No. 2) except that a second layer of gypsum board is applied to the interior surface	39
5	Basic 89 to 140 mm insulated wood stud wall plus 19 to 22 mm (3/4" to 7/8") cement stucco on exterior surface	44-46
6	Basic 89 to 140 mm insulated wood stud wall with interior gypsum board (single layer) mounted on resilient channels, or "Rez-bar"	47
7	Basic 89 to 140 mm insulated wood stud wall with interior gypsum board (two layers) mounted on resilient channels, or "Rez-bar"	50
8	Basic 140 mm insulated staggered wood stud wall with single layer of gypsum board on interior surface	49
9	Basic 140 mm insulated staggered wood stud wall with two layers of gypsum board on interior surface	52
10	Basic 89 to 140 mm insulated wood stud wall plus 16 mm airspace and 89 mm Brick on exterior surface.	53
10	Basic 89 to 140 mm insulated wood stud wall plus 19 to 22 mm (3/4" to 7/8") cement stucco[2] on exterior surface plus interior gypsum board (single layer) mounted on resilient channels or "Rez-Bar".	54-56

1. All wood studs are spaced at 406 mm (16") on centre.
2. Note that these STC results were obtained in laboratory tests conducted by the NRC. In the field (real world) somewhat lower performance is to be expected.

Table 6.2; Representative STC's Provided by Various Exterior Wall Constructions

6.5.11 Structural implications of modifying walls or other building components

In addition to keeping noise and weather out, the exterior walls of your residence (and at least some of the interior walls) have critical structural (load-bearing) roles to play in supporting and stiffening the building. Therefore, no modification of structural walls should be undertaken without first consulting a professional building contractor, house designer, architect or structural engineer.

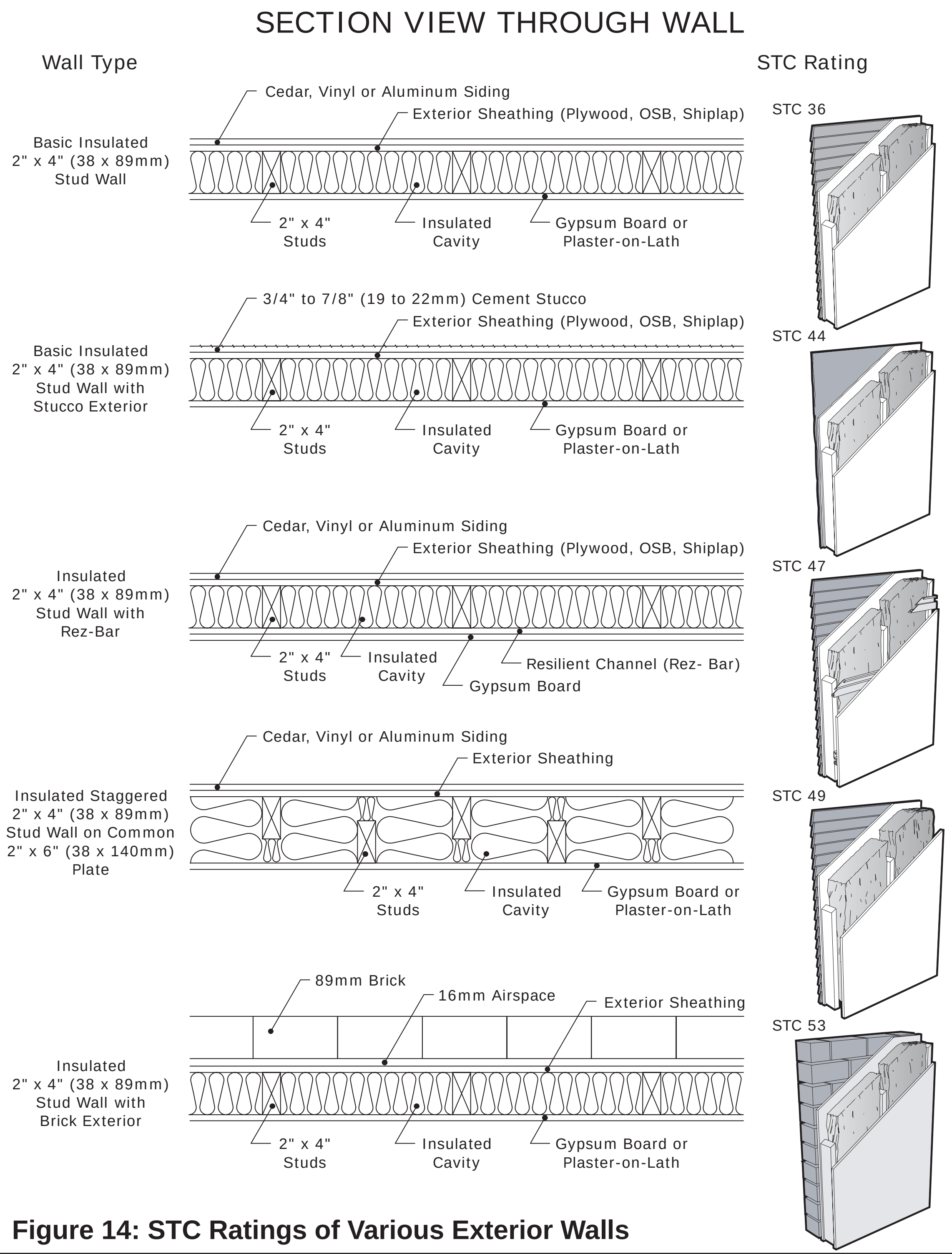


Figure 14: STC Ratings of Various Exterior Walls

6.5.12 Treating vents and other gaps and penetrations in walls

The sound insulation performance of an otherwise effective building façade can be severely compromised, particularly at higher frequencies, by even small ventilation openings, stove or bathroom exhaust fans ducts or other penetrations. For example, consider an exterior wall like Nos. 5, 6 or 7 in Table 6.2, having an STC rating between 44 and 50 when free from any gaps or vent openings. If a typical kitchen range hood exhaust fan should be installed directly into such a wall (i.e. with two back-draft flaps but no added ducting), the sound insulation provided by the wall assembly would be reduced by 20 decibels or more at mid and higher frequencies while the STC rating would be reduced by roughly 13 to 20 points, thereby more than doubling the loudness of the noise coming through the wall. To prevent such "leakage" of noise into the house, the following approaches should be taken:

1. locate ventilation openings on a quiet (noise shielded) side of house,

2. cover vent opening with a hood, preferably lined with sound-absorbing material such as semi-rigid fiberglass board,

3. acoustically line (for a length equal to 6 to 8 duct widths) ducts leading away from such vents – include sharp bends in the lined duct so as to avoid sound propagation directly down the centre of the duct,

4. caulk or otherwise seal (airtight) all holes, cracks and gaps around penetrations for vents, piping or wiring.

6.5.13 Improving the sound insulation of roofs

When dealing with noise from road traffic or other sources near the ground, roofs do not generally provide a dominant path for noise to enter residences. However, for homes located near airports or under their approach or departure flight paths or perhaps near an elevated section of roadway, sound transmission through the roof may need to be addressed if significant overall reductions in interior noise levels are to be achieved. As with walls, the sound insulation performance or roofs can be improved by including more (thicker) sound absorptive material in the cavity (attic space) between the ceiling and roof, by increasing the overall weight of the roof structure (e.g. by adding extra layers of gypsum board to the ceiling) and/or by eliminating/reducing rigid connections between the roof and ceiling structures (e.g. by attaching the gypsum board ceiling to the rafters using resilient channels). Table 6.3 lists the sound insulation capacity (as indicated by STC) of a variety of wood frame roof structures. Comparing Tables 6.3 with Table 6.2, it is seen that typical roof constructions (Roof Nos. 1, 4 and 6) provide greater sound insulation (by about 6 to 13 STC points) than do typical exterior wall constructions (Wall Nos. 1, 2, 3 and 4) unless the wall features an exterior cement stucco or brick finish.\

Roof No.	Roof Type	STC
1	Flat roof or cathedral ceiling with 3 mm (1/8") asphalt shingles on 11 mm (0.43") OSB, 203 mm (8") glass fibre insulation between 235 mm (9.3") deep wood joists[1], single layer of 13 mm (1/2") gypsum board on ceiling	42
2	Same as Roof No. 1 except that the single gypsum board layer ceiling is mounted to joists using Resilient Channels (Rez-Bar)	55
3	Same as Roof No. 1 except that two layers of ceiling gypsum board is mounted to joists using Resilient Channels (Rez-Bar)	59
4	Flat roof or cathedral ceiling with 3 mm (1/8") asphalt shingles on 11 mm (0.43") OSB, 264 mm (10.5") glass fibre insulation, 356 mm (14") deep wood trusses, single layer of gypsum board on the ceiling	46
5	Same as Roof No. 4 except that ceiling consists of two layers of gypsum attached to trusses with Resilient Channels	59
6	Sloped roof with 3 mm (1/8") asphalt shingles on 11 mm (0.43") OSB, 152 mm (6") glass fibre insulation between 1626 mm (64") deep raised heel wood trusses, single layer of gypsum board on ceiling	52
7	Same as Roof No. 6 except that 264 mm (10.5") glass fibre installed between trusses.	54
8	Same as Roof No. 6 except that 264 mm (10.5") glass fibre installed between trusses and second layer of 13 mm (1/2") gypsum board applied to ceiling.	56
9	Same as Roof No. 6 except that 264 mm (10.5") glass fibre installed between trusses and single layer of 13 mm (1/2") gypsum board applied to ceiling with Resilient Channels.	60

1. All wood joists and trusses are spaced at 406 mm (16") on centre.
2. Note that these STC results were obtained in laboratory tests. In the field (real world) one can typically expect somewhat lower performance

Table 6.3; Representative STC's provided by Various Roof/Ceiling Constructions

6.5.14 Effects of roof vents and chimneys

Most roofs contain several vents to permit air circulation through the attic space. These can compromise the sound insulation performance of the roof, particularly against aircraft noise. However, provided the attic space is insulated and there is a continuous ceiling layer below the roof joists, the effect of these vents is generally fairly minor (reducing STC by 1 or 2 points). If desired, this small negative effect of roof vents can be overcome by creating acoustically-lined baffle boxes beneath each vent or by adding a second layer of gypsum board to the ceiling.

Chimneys however, because they often provide a continuous air path from the outside world into the living room, den or family room, can be more problematic – particularly for aircraft noise. It is possible to fit the top of the chimney with a sound absorptive insert, i.e., a silencer, made from perforated metal (stainless steel would be best) backed up with semi-rigid fibreglass insulation. However, more practical approaches to this problem would include keeping the damper closed when the chimney is not in use, or installing a fireplace insert (enclosed fireplace) or woodstove so as to eliminate the direct opening to the outdoors.

6.6 Masking sound can cover up intrusive noises

When unwanted sound (noise) enters your residence either from the outdoors or from another occupancy within your building and you cannot, or do not wish to, reduce it sufficiently through the measures described above, then the intrusive noise(s) may be able to be obscured with masking sound - also referred to as “acoustic perfume”. To be effective, the frequency content (i.e. spectrum) and loudness (intensity) of the masking sound must be similar to those of the intrusive noise(s). It is therefore generally best to employ masking sound which contains a broad range of frequencies and has a pleasant, or at least innocuous, character. As sometimes used in open plan office situations to maintain speech privacy, this could be steady broad-band or “pink” noise played through a distributed speaker system. It could simply be continuous background music played on a home stereo. It is possible to purchase tapes or CD’s of natural sounds such as surf, rain, running water or wind in the trees that might be found more appropriate for use at home. Masking sound may also be created naturally, for example, by an outdoor or indoor fountain. Keep in mind however, that masking is most effective where the intrusive noise is of low to moderate intensity. This is because, as the intrusive noise becomes louder, so must the masking, until eventually the masking sound itself is likely to become intrusive, annoying and tiring.

Section 7 REDUCING NOISE WITHIN YOUR SINGLE OR MULTIFAMILY RESIDENTIAL BUILDING

7.1 Types of noises created inside residences

While many urban dwellers are bothered by noise from traffic and other external sources, large numbers of residents (mostly in multi-family dwellings) are also disturbed by noise that is created either inside their residence or within an adjacent unit in their building. This noise may be created by the activities of family members or of neighbours and it may result from a variety of sources and activities including:

- radio,
- television,
- stereo,
- live music
- speech, shouting,
- walking, running, playing
- vacuuming,
- maintenance and renovations,
- closing cupboards, drawers and doors,
- preparing food,
- pets,
- plumbing,
- HVAC systems,
- elevators,
- Jacuzzi tubs,
- appliances.

The following sections will provide some general approaches to reducing the levels of noise within your residence, for reducing the transmission of noise between adjacent dwelling units via party walls and floors and for reducing the impacts which noise created by the activities of residents of multi-family dwellings may have on their neighbours.

7.2 Noise control guidelines for designers/builders/renovators of multifamily dwellings

There are many things that the designers and builders of multi-family dwellings can do to reduce the transmission of bothersome sound between residential units. These measures apply to the building mechanical, plumbing and electrical systems and cabinetry as well as to the basic party wall and floor constructions. Many of the same approaches can also be employed to reduce noise transmission within single family dwellings. Section 8 contains guidelines that may be followed by residential designers and contractors and by individual home owners alike to control unwanted sounds within residences.

7.3 Noise control guidelines for residents of multifamily dwellings

There are many simple things that residents of multifamily dwellings can do to reduce the transmission of noise from their unit to adjacent units, thereby minimizing the disturbance of their neighbours. These include small physical modifications within their units (cupboard doors and drawers, chair leg bottoms, counter tops etc.) as well as changes in the manner and timing with which they carry out certain activities. Section 9 provides a list of Noise Control "Do's and Don'ts" which will assist condo and apartment dwellers in minimizing the potential for mutual disturbance by intrusive noises generated within their buildings.

7.4 What makes a good party wall – How can I build a good wall or improve an existing one?

Owners of single-family residences or condominiums may sometimes want to build a new party wall (i.e., a wall separating two different dwelling units) or improve an existing wall to achieve more acoustic privacy between their residence and adjacent one or between different parts of their own residence (e.g. they may want to create a music room or separate the teenagers space from the parents). A good party wall should have the following four key attributes:

1. It should have substantial mass (i.e., contain heavy elements such as gypsum board, plaster, particle board or concrete). Note, party walls within multi-family buildings must also meet minimum fire separation ratings, so that they generally contain either gypsum board or concrete,

2. There should be a structural break (disconnection) between the two sides of the party wall. In frame construction, this can be achieved through double stud or staggered stud wall configurations or by using resilient channels,

3. The cavity between the two sides of the walls should be as wide a possible (140 m or 5.5" or more) and largely (90% or more) filled with sound absorbing material such as glass or mineral fibre batts or blow-in, loose fill insulation made from cellulose, mineral or glass fibres. Again, flammability must be considered – particularly in multi-family dwellings,

4. The wall should be free from any holes, cracks or gaps – e.g., the joints at bottom of the wall where the base plate meets the floor and where the gypsum board meets the base plate. These joints should be sealed on at least one side of the wall with non-setting acoustical sealant, see Appendix C. Sound leaks may also occur around electrical outlets and other penetrations.

7.5 Sound Transmission Class (STC) of Party Walls

As with the windows and exterior walls discussed in Section 6, the general ability of interior party walls to insulate against noise is indicated by their Sound Transmission Class, or STC. For our purposes, the STC may be considered to represent roughly the amount (in A-weighted decibels, or dBA) by which sounds, as from speech, television and music, are reduced in level upon passing through the wall. The higher the STC rating, the greater the sound insulation provided.

7.6 Field Sound Transmission Class (FSTC) and Acoustic Privacy

When the sound insulation capacity of a party wall is tested in the field (I.e., in an actual residential building rather than in a laboratory), the result is expressed as a Field Sound Transmission Class, or FSTC. Table 7.1 (Source; Reference 6) gives us a feeling for the levels of speech privacy that are generally provided by party walls with various FSTC ratings under normal quiet residential background noise conditions.

Party Wall FSTC	Impressions of Speech/Noise Heard Through Party Wall under Typical Quiet Residential Background Noise Conditions (Approx. 30 to 35 dBA)
Less than 30	Usually results from sound "leakage" through gaps or cracks – complete lack of speech privacy
30 to 35	Typical of uninsulated single stud walls or insulated office partitions that extend only up to a suspended acoustic ceiling - speech is easily understood, speech privacy is poor
35 to 40	Typical of standard interior home construction (lightweight walls and hollow core doors) – normal speech clearly audible, some words understood
40 to 45	Quite good speech privacy unless listening conditions are very good (i.e., very low background noise),
45 to 50	Adequate for most private offices, but marginal between multi-family residential units due to potential for raised voices, television, stereo, etc.,
50 to 55	Confidential speech privacy assured for most situations, generally adequate for typical multi-family units. Note; flanking paths must be controlled.
More than 55	Assurance that most speech and noise will be inaudible. Adequate for luxury multi-family units. Flanking paths must be very well controlled.

Table 7.1; Degrees of Acoustic Privacy Typically Provided by Party Walls having Various FSTC Ratings.

7.7 FSTC versus STC – Building Code Requirements and Recommendations

The 1998 B.C. Building Code as well as the Vancouver City Building Code require that party walls (and floors) in all new multi-family dwellings provide a minimum STC rating of 50. Under the Code, architects and builders must demonstrate that their proposed party walls will meet this minimum rating based on the results of tests conducted either in a laboratory (STC 50) or in the field (FSTC 50). However, the Code encourages builders, when selecting a wall design, to keep in mind that party walls generally perform better (achieve higher STC's) when tested in the lab than in the field. This is because in the field (i.e. in an actual buildings) sound reaches the other side of the test wall not only by the "direct path" (i.e., straight through the wall), but also via other paths which permit sound to either "flank" around the test wall (i.e., travel along continuous floors and side walls in the form of vibration, or "structure-borne" sound) or "leak" through gaps, cracks or penetrations in the test wall. For the types of party walls typically used in new wood frame condominiums, the FSTC is typically 3 to 5 points higher than the STC. Therefore, the Code recommends that builders select a party wall design which has a lab rating of STC 55 dBA or somewhat higher, so that the minimum STC 50 requirement is likely to be achieved in the field. However, unless great care is taken to minimize flanking transmission, via floor and side walls, there is little to be gained form designing a wall to provide more than about STC 60. This is because flanking transmission is largely independent of the party wall design and therefore will generally prevent the additional airborne sound insulation potential of an STC 60 or better party wall from being realized in the field.

7.8 STC Ratings of Common Party Wall Constructions

Table 7.1 provides representative STC ratings for various interior wall constructions, ranging from the uninsulated, single-stud walls typically found in single family homes and in some older apartments, to the fully insulated, double-stud wall constructions commonly employed in newer condominiums. Each 10 point increase in the STC means that noises coming through the wall will be roughly half as loud. Figure 15 illustrates some of the more common party wall constructions and their STC ratings with and without cavity insulation.

Table 7.1 indicates that a single wood stud wall cannot provide more than about STC 32 when uninsulated and about 36 when insulated. The addition of insulation achieves only a 4 point) increase in STC because the wood studs still create rigid connections across the wall cavity and therefore efficient paths for structure-borne sound. These paths are not significantly affected by the cavity insulation and therefore prevent the benefit of insulation from being fully realized. Party Walls Nos. 4 and 6 show that once these rigid connections are weakened (here through use of resilient channels) or removed (here through use of staggered studs), much larger improvements (here to STC 45 and 47) are possible

Comparing Party Wall No. 2 with No. 10, it is seen that single stud walls constructed with light-gauge (non-load-bearing) steel studs provide much better sound insulation (here 11 STC points better) than do comparable walls with wood studs. This is because light steel studs are much more flexible than wood studs and therefore provide less rigid connections across the wall. In contrast, heavy gauge structural, or load-bearing, steel studs are much stiffer and provide roughly the same sound insulation performance as wood studs.

Comparing Party Wall No.1 with No. 3, it is seen that increasing the overall weight of the wall by doubling up the gypsum board on both sides can have a worthwhile benefit (here 4 STC points), even if there is no insulation in the cavity. Comparison of Walls Nos. 2 and 5 reveals that the introduction of a structural disconnection (here provided by resilient channels) in combination with the extra weight of double gypsum board can produce very large improvements in the STC (here 19 points).of even an uninsulated wall.

Total elimination of rigid connections through the wall (except at the perimeter) using staggered or double-stud wall constructions (see Party Wall Nos. 7, 8 and 9), permits still higher STC's to be achieved. The wider the cavity and thicker the insulation, the better the wall's performance, particularly against lower frequency sounds.

Party Wall No.	Party Wall Type	STC[2]
1	Basic 89 mm (3.5") uninsulated (hollow) single wood stud wall[1] with 16mm (5/8") gypsum board or plaster-on-lath on each side	32
2	Basic 89 mm (3.5") insulated (R12 batts) single wood stud wall with 16mm (5/8") gypsum board or plaster-on-lath on each side	36
3	Basic 89 mm (3.5") uninsulated (hollow) single wood stud wall[1] with two layers of 16mm (5/8") gypsum board and/or plaster-on-lath on each side	36
4	Basic 89 mm (3.5") insulated (R12 batts) single wood stud wall with 16mm (5/8") gypsum board or plaster-on-lath on one side and 16 m (5/8") gypsum board attached using resilient channels on the other side	45
5	Basic 89 mm (3.5") insulated (R12 batts) single wood stud wall with two layers of 16mm (5/8") gypsum board and/or plaster-on-lath on one side and two layers of 16 m (5/8") gypsum board attached using resilient channels on the other side	55
6	89 mm (3.5") staggered, wood stud wall on 140 mm (5.5.") plates (insulated) with 16mm (5/8") gypsum board or plaster-on-lath on each side	47
7	89 mm (3.5") staggered, wood stud wall on 140 mm (5.5.") plates (insulated) with two layers of 16mm (5/8") gypsum board on each side	56
8	Double 89 mm (3.5") wood stud wall on separate plates with insulated cavity and one layer of 16 mm (5/8") gypsum board on each side	57
9	Double 89 mm (3.5") wood stud wall on separate plates with insulated cavity and two layers of 16 mm (5/8") gypsum board on each side	66
10	Basic 89 mm (3.5") insulated (R12 batts) single, light-gage steel stud wall with one layer of 16mm (5/8") gypsum board on each side	47
11	Basic 89 mm (3.5") insulated (R12 batts) single, light-gage steel stud wall with two layers of 16mm (5/8") gypsum board on each side	56
12	Solid Concrete wall – 102 mm (4") thick	53
13	Solid Concrete wall – 203 mm (8") thick	58
14	Brick Wall 229 mm (9") thick with 12 mm (1/2") plaster finish both sides	52
15	Concrete block wall (dense aggregate) – 152 mm (6") thick (painted)	50
16	Concrete block wall (dense aggregate) – 203 mm (8") thick (painted)	54

1. All wood studs are spaced at 406 mm (16") on centre.
2. Note that these STC results (Source; 1998 B.C. Building Code). were obtained from laboratory tests. In the field (actual residences) one can typically expect 3 to 5 points lower performance.

Table 7.1; STC's Provided by Various Party Wall Constructions

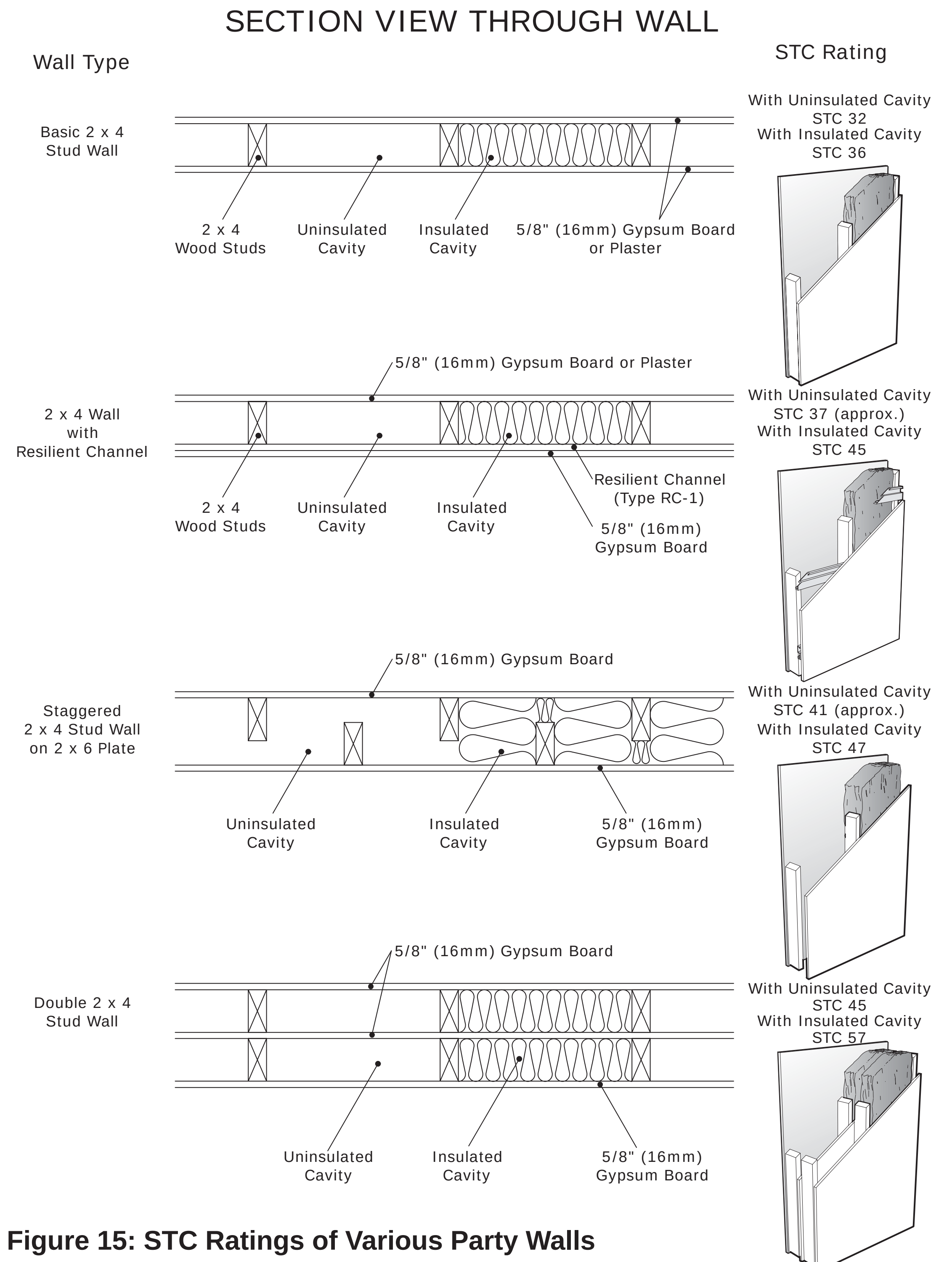


Figure 15: STC Ratings of Various Party Walls

7.9 Improving Performance of Existing Interior Walls

If you have single-stud party, or non-party, wall and wish to improve its sound insulation, the following steps, (shown in approximate order of increasing effectiveness) should be considered: Note; it is essential to eliminate any holes, cracks along the base of the wall or gaps around penetrations. The best approach is to fill these with a non-setting acoustical sealant (see Appendix C).

1. If wall isn't yet insulated and you don't want to remove the gypsum board or plaster before insulating it, blow wall cavity full of loose-fill insulation (see Appendix C) through holes drilled in gypsum board/plaster near top of each stud space and later patched,

2. Carry out Step 1 and then double up the gypsum board on one or both sides of wall,

3. Remove existing gypsum board or plaster-on-lath from <u>one</u> side of wall, insulate cavity with loose-fill or batt insulation, remount gypsum board on resilient channels,

4. Remove existing gypsum board or plaster-on-lath from <u>both</u> sides of wall, insulate cavity, remount gypsum board on both sides using resilient channels,

5. Carry out either Step 3 or 4 and then apply second layer of gypsum board to one or both of the sides to which resilient channels have been applied. Note, only the outer layers of gypsum board need to be finished (i.e., taped and mudded),

6. Create a "staggered-stud" wall - remove gypsum board from one side, add 64 to 89 mm (2.5" to 3.5") wide base and top plates and install a second row of offset, or "staggered", studs. Fully insulate the wall cavity and apply one or two layers of gypsum board,

7. Create a "double-stud" wall - remove gypsum board from one side, add second row of studs separated from existing stud row by a 25 mm (1") airspace. Fully insulate the cavity and apply one or two layers of gypsum board to new row of studs.

7.10 Tips on using Resilient Channel

Resilient channels (or "Rez-Bar") are light-weight strips of sheet metal, typically in the form of a flattened "Z". These channels are used to eliminate rigid contact between wood studs and ceiling joists and gypsum board walls and ceilings respectively. Due to its resilience (flexibility), Rez-Bar acts like a spring to isolate the gypsum board from vibration within the studs/joists much in the way your car's spring suspension isolates you from road-induced vibration and bumps. To maximize the benefit of installing Rez-Bar, consider the following:

- Make sure you get true "resilient channel", or "RC-1" (see Appendix C), as drywall contractors use many other metal channels and furring systems such a hat-channel and Z-channel which are intended for other purposes and are too stiff to have worthwhile noise reduction effects,

- When improving and existing wall or ceiling, always apply Rez-Bar directly to framing (studs or joists), never over top of an existing sheet of gypsum board, plaster, plywood or other sheet product as this can actually increase sound transmission at low frequencies. This practice is cautioned against on Page 554 of the 1998 B.C. Building Code. Remove the existing gypsum board/plaster, insulate cavity, apply Rez-Bar and then new gypsum board. If not practical to remove existing gypsum board/plaster, then create a much wider cavity (minimum 3.5 "/ 89 mm) by attaching light gauge steel studs to the existing wall or preferably as part of a free standing wall. Then completely fill (or even overfill a little) this cavity with batt insulation, apply Rez-Bar and new gypsum board),

- Rez-Bar works best on large areas of wall or ceiling where the effects of edges and other elements (doors, windows, lights) are minimized,

- Rez-Bar is capable of supporting more than one layer of gypsum board - adding a second layer can significantly improve sound insulation performance,

- Install the Rez-Bar horizontally across the studs or joists at intervals of at least 457 mm (18") and preferably 610 mm (24") since the fewer connections between studs and the gypsum board the better,

- To avoid "short-circuiting" the Rez-Bar due to contact between screws and wall headers and base plates, do not attach Rez-Bar less than 100 to 150 mm (4" to 6") from top and bottom of wall,

- Attach (screw) the narrow flange (leg) of the Rez-Bar to the wood studs or joists and later screw the gypsum board to the wide flange. This increases the likelihood of hitting the flange when screwing through the gypsum board into the Rez-Bar,

- Don't attach (screw) the gypsum board to the Rez-Bar at locations close to any of the screws holding the Rez-Bar to the studs - this would increase chances of hitting the studs and "short-circuiting" the Rez-Bar,

- When installing Rez-Bar on wall studs, point the wide flanges upwards so that the narrow flanges by which the Rez-Bar is attached to the studs are on the bottom. This will make the gypsum board tend to "pull away" from the studs when its weight is taken by the Rez-Bar, thereby preventing contact.

7.11 Tips on insulating walls

To effectively insulate a party or other wall, consider the following:

- The type of insulation used (blow-in cellulose, mineral or glass fibres, or mineral or fiberglass batts) does not substantially influence sound attenuation, however, the thickness, and to a lesser degree, the density of the insulation does,

- Wall cavities should be filled to at least 80% of their depth and preferably be completely filled,

- Since cavity insulation functions as a sound “absorber”, not a “barrier”, the entire face area of the wall does not have to be filled. For example, some minor (e.g. 10%) settlement of blow-in insulation is acceptable, small gaps in the insulation can be left around cross-bracing, electrical boxes etc.,

- It is beneficial to slightly overfill the cavity with insulation so that it will bear lightly against the gypsum board when installed and thereby provide damping. Do not however, “pack” the insulation into the cavity since, when over-compressed, it can begin to promote low-frequency sound transmission through the wall.

7.12 Seismic requirements for party walls – Shear Layers and potential conflicts with sound insulation

In recent years the seismic (earthquake resistance) requirements prescribed in the B.C. Building Code for multi-family residential buildings have increased. As a result, it has become necessary to include plywood or OSB “shear layers” in many party walls within frame buildings. Unfortunately this requirement for additional shear stiffness sometimes conflicts with the provision of effective sound insulation. To avoid or minimize these conflicts, designers and builders of multi-family residential buildings should take note of the following:

- Shear layers should not be located inside the cavity of a double stud wall as this reduces the effective width of the cavity and therefore its low frequency sound insulation capacity. Shear layers should ideally be located on the outside of one or both rows of studs. If absolutely necessary, one shear may be located inside the cavity while still marginally achieving a field rating of FSTC 50. However, if two shear layers should be located within the cavity (on the inside of each stud row), the resulting narrow gap between shear layers will further degrade the low frequency sound insulation of the wall and generally reduce its FSTC to below 50.

- Like Rez-bar, shear layers are only effective if attached directly to the building framing. Therefore, if Rez-Bar is to be used to improve the sound insulation of a single-stud party wall which also requires a shear layer, the two elements should be placed on opposite sides of the wall. While the same approach should be followed in the cases of staggered-stud and double-stud walls, Rez-Bar is of significantly less benefit when applied to such walls since there is no direct structural connection between their two surfaces, other than at their perimeters.

7.13 Floor/ceiling systems must control airborne and impact noise

Like party walls, party floor/ceiling systems must be able to effectively control airborne sound transmission (i.e., from speech, music etc.) between adjacent dwelling units However, such systems must also be able control impact noises from footsteps, noise from moving furniture, dropped objects, children playing etc. While the principals outlined above for improving the STC ratings of party walls apply equally to floors, it is quite possible to achieve adequate airborne sound insulation and still have serious problems with impact/footstep noise transmission. This is because the impact noise control capacity of floor/ceiling systems (as indicated by ***Impact Insulation Class, or IIC***) is strongly influenced by the floor’s finish (e.g. carpet, linoleum, hardwood, ceramic tile, cork etc.). By contrast, the choice of finish flooring has relatively little effect on the floor's airborne sound insulation capacity as indicated by its STC. This often unexpected outcome is regularly brought to the attention of condominium designers, builders and owners when party floors are either newly constructed with hard surfaces such as hardwood, ceramic tile or stone, or when existing carpeting is replaced with such materials.

7.14 Airborne sound insulation capacity of floors

For frame construction floor/ceiling systems to achieve a high level of airborne sound insulation (as indicated by STC) they must have the same characteristics as good party walls, namely sufficient mass (weight), plenty of absorption material in the cavity and a structural break (disconnection) between the two sides, or in the case of floors, the floor above and ceiling below. Many condominiums have solid concrete floors slabs typically 125 and 200 mm (5" to 8") thick. Even though these slab floors have no "cavity" and no structural disconnection between their upper and lower surfaces, they generally have enough mass and stiffness to achieve STC 50 or more. Wood frame party floors, however, must possess all three of the above elements in order to approach or exceed STC 50. These elements are generally not present in floors within single-family residences or within multi-storey condominium units or townhouses. In these situations, substantial improvements must therefore be made if a reasonable level of acoustic privacy is to be achieved, as might, for example, be desired between the main floor of a single family residence and a bedroom, family room or in-law suite below. The STC ratings of a variety of common floors constructions and provided in Table 7.2 while Figure 16 illustrates many of these constructions.

7.15 Impact noise insulation capacity of floors

Most condominium floors, both solid concrete and wood-frame constructions, which provide adequate airborne sound insulation will provide adequate footstep nose insulation if finished with carpet and underlay. In all-concrete buildings, normal footstep noise is virtually inaudible in spaces located below carpeted rooms, while in wood-frame buildings, only a low-frequency "thudding" sound is sometimes audible, particularly from "heavy walkers" or if the floor has no concrete topping layer or is exceptionally flexible (e.g., has long joist spans). However, when the carpet and underlay are removed and replaced with hardwood, tile, cork or vinyl flooring, footstep noise becomes much louder as well as "brighter" in character, i.e., it is no longer a dull thudding but contains middle and high-frequency components as well. This is generally found unacceptable to people living below, particularly in "high-end" buildings or in areas were background noise levels from traffic and other exterior sources are very low.

Many "resilient" underlay materials (see Appendix C) are marketed as a means of controlling the noise created by footsteps on hard-surfaced floors such as hardwood and tile. While these these sheet or mastic underlay products are quite effective at reducing the "brightness" (i.e. taking out the high frequency components) of impact sounds, they are generally quite thin and, when applied over the entire floor area, are not sufficiently resilient or "soft" to provide effective isolation against the mid and lower frequency components of impact noise. As such, their performance cannot approach that of carpet and underlay. Developers, designers and contractors as well as condominium owners and strata councils, should consider this limitation before installing, or permitting installation of, hard-surfaced finish floors in areas having occupied spaces below.

Floor #	Floor Type(s)	STC[1]	IIC[1,2]	Subjective Impact Insulation Performance
1	Basic single-family residence floor: ▪ 16 mm plywood or OSB sub-floor, ▪ wood joists, ▪ 16 mm gypsum board ceiling	33	28	Totally unacceptable for party floor or for situations where moderate sound isolation is required within a single residence
2	Same as Floor #1, except two layers of 16 mm gypsum board on ceiling	36	31	Still totally unacceptable for party floor or moderate isolation
3	Same as Floor #1 except two layers of 16 mm gypsum board on ceiling floor and cavity insulated[3]	37	33	Still totally unacceptable for party floor or moderate isolation
4	Same as Floor #1 except cavity insulated[3] and <u>single</u> gypsum board ceiling suspended from Rez Bar at 600 mm (24") spacing	49	42	More than twice as effective as Floor# 1 but IIC still not adequate for party floor or moderate isolation,
5	Same as Floor #1 except cavity insulated[3] and <u>double</u> gypsum board ceiling suspended from Rez Bar at 600 mm (24") intervals	55	49	About four times as effective as Floor #1, IIC adequate for most spaces within same dwelling
6	Same as Floor #5 except sub-floor has two layers of 16 mm plywood, OSB or wood	58	51	Adequate for most spaces within same dwelling
7	Typical wood-frame multi-family building floor: ▪ 38 mm concrete topping, ▪ 16 mm plywood or OSB sub-floor, ▪ wood joists, no insulation in cavity ▪ 16 mm gypsum board ceiling	46	25	Totally unacceptable for party floor
8	Same as Floor #7 except floor cavity insulated[3]	48	28	Totally unacceptable for party floor
9	Same as Floor #7 except floor cavity insulated[3] and <u>single</u> gypsum board ceiling suspended from Rez Bar at 600 mm (24") spacing	65	38	Totally unacceptable for party floor
10	Same as Floor #7 except floor cavity insulated[3] and <u>double</u> gypsum board ceiling suspended from Rez Bar at 600 mm (24") spacing	70	46	Still unacceptable for party floor
11	Basic concrete multi-family building floor ▪ 125 to 200 mm (5" to 8") reinforced concrete slab	52 to 55	27 to 35	Totally unacceptable for party floor

1. Unless otherwise indicated, these lab-rated STC's and IIC's were obtained from the 1998 B.C. Building Code,. Note that when tested in the field, the resulting FSTC's and FIIC's can be significantly lower.
2. These IIC ratings are from floors tested without any finish flooring,
3. Based on 150 mm (6") of fiberglass, mineral or cellulose fibre insulation or 90 mm (3.5") of spray-applied cellulose fibre

Table 7.2; The Airborne Sound Insulation (STC) and Impact Sound Insulation (IIC) Ratings of Various <u>Bare</u> Floor Constructions. Note; the addition of rugs or carpet with underlay to such floors will generally improve their IIC's by from 25 to 50 points.

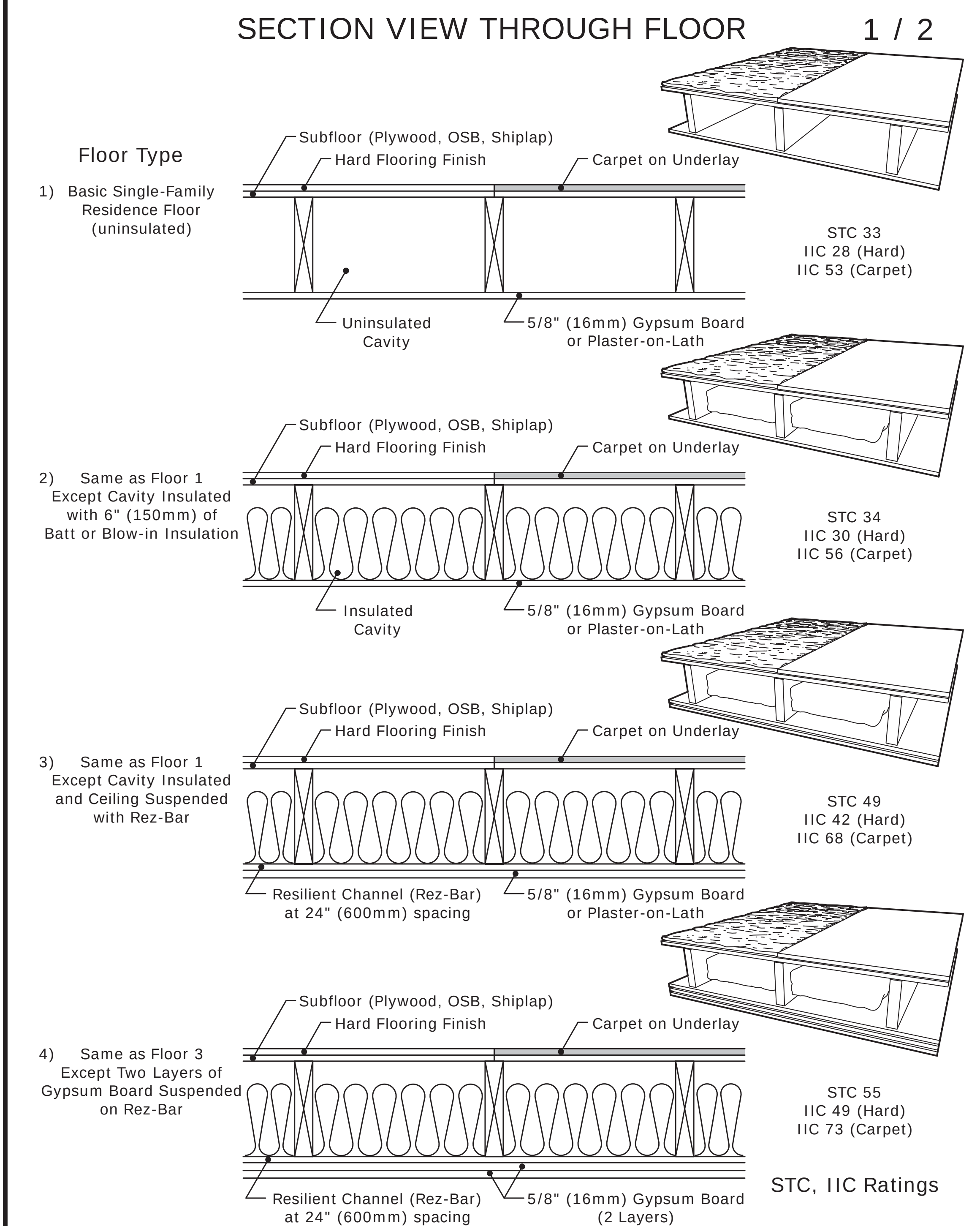


Figure 16A: STC and IIC Ratings of Various Floors

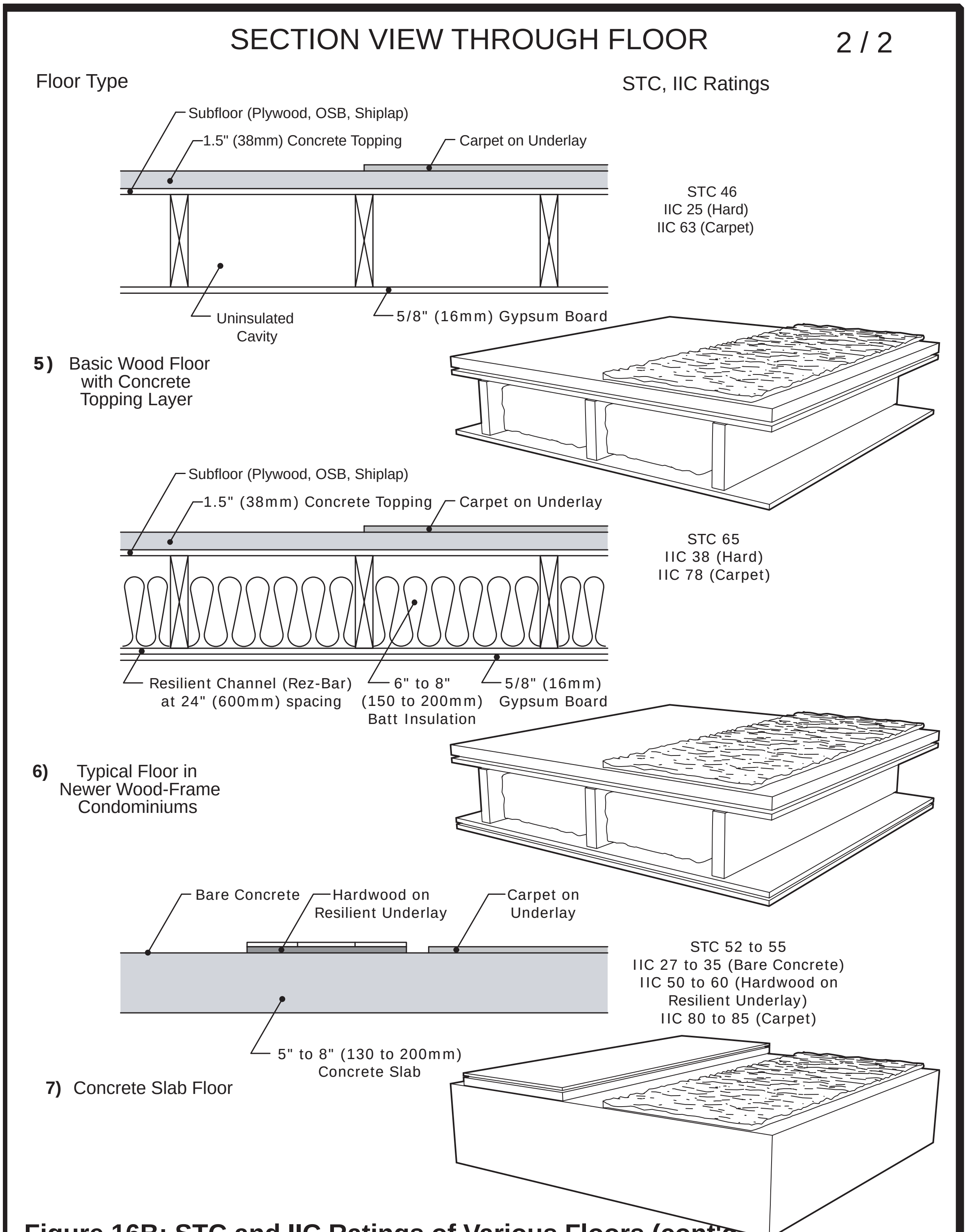


Figure 16B: STC and IIC Ratings of Various Floors (cont'd)

7.16 The Impact Insulation Class (IIC) Rating of Floors

The Impact Insulation Class (IIC) provides a single-number rating of a floor's general ability to suppress impact noise. IIC is based on the level of noise that is generated in the room below when a standard "Tapping Machine" is operated on the surface of the test floor above. While the tapping machine does not accurately replicate the sound of normal footsteps, it does produce a comparable standardized impact force which permits the rating and comparison of various floor assemblies and finishes. The lower the impact noise level created in the room below the test floor, the better the floor and the higher its IIC.

7.17 What IIC Rating is required to adequately control impact noise?

Table 7.2 lists the IIC's typically attained by various floor constructions and the subjective impact insulation performance that is provided by each. Note that these IIC's are for "bare floors" (i.e., no finish floor coverings are included). The BC Building Code does not yet (as of the 1998 edition) require that party floors in multi-family residences provide a certain minimum IIC rating. However, it does recommend that designers/builders concerned with preventing occupant complaints should design floors to minimize impact noise transmission. The IIC rating required to provide generally acceptable impact noise insulation depends on the sensitivity of the situation (quality of building, expectations of occupants and background noise environment). The scale shown in Table 7.3 below provides some guidance in selecting an appropriate IIC target for a given situation.

Party Floor IIC	**Impressions of Impact/Footstep Noise Heard**
Less than 45	Normal walking clearly audible below, other impacts, chair movements, dropped objects audible, unsuitable for multi-family units or where moderate isolation is required within same dwelling unit
45 to 55	Normal walking (in hard shoes) still clearly audible, may be adequate between spaces within same dwelling unit, not suitable for most multiple-family buildings,
55 to 60	Normal walking noise still clearly audible when background noise levels are fairly low; may be adequate for multi-family buildings in less critical situations
60 to 70	Normal walking audible only during very low background noise situations, adequate for most multi-family buildings
70 to 80	Normal walking largely inaudible, generally adequate for even most sensitive, (high quality, low background noise) situations,
80 or higher	Virtually no audible impact noise transmitted from walking, small dropped objects etc.

Table 7.3; Impressions of Impact/Footstep Noises as Heard in Rooms Directly Below Party Floors having Various IIC Ratings.

7.18 What IIC ratings are practically achievable and how?

The 1998 B.C. Building Code recommends that party floors be designed to achieve an IIC of 55 when bare (no finish floor covering), the intent being that, even if a hard finish floor is selected, a minimally acceptable rating of about IIC 55 will be achieved. If a more resilient finish (such as cork, cushioned vinyl, hardwood or tile on resilient underlay, or carpet) should be used, a higher IIC would be obtained. However, Table 7.2 has shown that it is not possible to achieve a bare-floor rating of IIC 55 with common floor constructions. There are essentially four ways in which the impact insulation performance of bare or hard-surfaced floors can be improved so as to achieve IIC 55 or higher. These are listed in approximate order of increasing effectiveness:

1. Use a semi-resilient finish floor

   There are some flooring materials, such as cork and cushioned vinyl, which, due to their somewhat resilient surfaces, possess some built-in capacity to control impact noise. However, on their own, these materials are not effective enough to be used in high traffic areas, particularly where people are likely to wear street shoes. These materials may then be appropriate for use in small areas where limited walking occurs such as entries, bathrooms, utility rooms and small kitchen areas.

2. Use a Resilient Underlay

   Many resilient underlay products (e.g., foam rubber or vinyl, cork, crumb rubber matting, urethane foam and expanded nylon webbing) are available commercially (see Appendix C). These products come in sheet form and can be laid beneath hardwood flooring or pre-applied (adhered) to the underside of engineered hardwood floor (EHF) systems. Special grouts or mastics are also available which can be used to bond tile or stone to the sub-floor and which remain resilient after application. Such resilient underlay materials certainly improve the IIC ratings of floors compared to the case where the hard finish flooring is applied directly over plywood/OSB sub-floors, concrete topping layers or concrete slab floors. However, because these materials are typically only about 9 mm (3/8" thick) and cover the entire floor surface, their resilience (ability to compress under load) is limited. As a result, the IIC improvement achieved is usually only 10 to 15 points thereby typically increasing impact ratings from IIC 35 to 45 into the IIC 50 to 60 range. Only the upper end of this range is considered marginally acceptable for party floors.

   These materials work best when they are "preloaded" with additional weight, such as provided by a 38 to 50 mm (1.5" to 2.0") concrete topping layer. Some of these products, such as "Enkasonic" and "Acousti-tech", are designed to permit concrete to be poured directly on top of them.

3. Construct a "Floating Floor"

   The impact noise insulation performance of hard-surfaced floors can be improved much more with a true "floating floor". Here the floated portion of the floor needs to be quite heavy (e.g. a concrete topping layer on a plywood sub-floor or, alternatively multiple layers of plywood, particle board, OSB or gypsum board) and must be supported by truly resilient elements such a individual rubber "pucks" spaced at appropriate intervals. In order to achieve the best performance from a floating floor, the design services of a noise control expert should be obtained (see Appendix C).

4. Construct an independently-supported ceiling below the floor

   Where sufficient headroom is available, a structurally independent ceiling may be constructed 150 to 200 mm (6” to 8”) or more below the floor joists or existing gypsum/plaster ceiling. Such a ceiling should be supported by a separate row of “joists” which would span the entire room and be supported only at the walls. This approach can be very effective, particularly if the cavity created above the new ceiling is well insulated.

5. Use Carpeting, Rugs and Runners

   As an example of the effect which carpeting can have on impact noise transmission through floors, the application of carpet and underlay to a 150 mm (6”) concrete slab floor can increase its FIIC rating from a dismal 27 to 35 to an extremely effective 75 to 85. The impact noise levels created by the standard tapping machine are corresponding reduced from a “loud and clear” 70 to 75 dBA to a normally inaudible 25 to 30 dBA (or roughly 1/32nd to 1/64th as loud). Improvements achieved with wood frame floors are not quite as dramatic since frame floors are generally flexible enough to permit some low-frequency “thudding” to come through even when carpeted. However, increases in FIIC of 25 to 30 points (from FIIC 35 to 45 to FIIC 65 to 75) are typical.

   Clearly carpeting is the most effective/practical way to control noise from footsteps and other impacts. If, for some reason (allergies, cleaning, style), wall to wall carpet is undesirable, consider area rugs and runners in activity zones and high traffic areas.

7.19 How to reduce the general “noisiness” of indoor spaces

Some spaces seem to amplify even modest noises (pubic address announcements, children’s laughter or a dropped book) into uncomfortable experiences. Typically, the worst examples include train or bus stations, cathedrals, indoor swimming pools, hockey arenas or gymnasia. Here the combination of large room volume and the predominance of hard, sound-reflecting surfaces permit sound waves to bounce around, or “reverberate” for relatively long periods of time (sometimes up to 5 or 6 seconds) after the source of sound has been shut off. This reverberant sound then combines with more recently-created sound with the result that overall sound levels build up and up. Announcements from public address systems or instructions from coaches are often unintelligible under such conditions. To lesser degrees, this reverberant sound build-up can occur within residences, particularly within vaulted entryways and open floor plans featuring hard-surfaced floors and lots of glass and gypsum board. It is even noticeable in normal-sized rectangular rooms when they are empty and uncarpeted – an effect that can become quite obvious when moving into a new house or apartment or emptying out an old one.

The best way to avoid or correct such situations is to include large areas of sound absorptive materials within the rooms of concern. Obvious choices include carpeting, rugs, upholstered furniture, large pillows and heavy draperies but may also include more creative solutions such as fabric wall hangings (quilts, duvets or banners) or simply lots of “stuff” such as shelves full of books, plants, and knick knacks. While quite costly, acoustic wall panels are available in a wide range of colours and designs. It will be found that the initial significant addition of sound absorptive material to an otherwise bare room, such as an area rug, a bed, or overstuffed couch and chair, will produce a dramatic reduction in the “noisiness” of the room, and that further such additions will yield progressively smaller improvements.

Section 8 NOISE CONTROL GUIDELINES FOR MULTIFAMILY DWELLINGS

8.1 General

These guidelines are intended to assist both the project design team, the general contractor and trades people in providing, to the extent practical, a satisfactory acoustic environment for future residents of the Second Street Condominiums by minimizing intrusive noise from building systems and appliances and maximizing acoustic privacy between residential units. Adherence to these guidelines, combined with inspections by the acoustical consultant at key stages in the construction process will prevent any significant acoustical problems from arising after the building is occupied.

8.2 Mechanical Systems and Appliances

1. Appliances such as garburators, dishwashers, clothes washers and dryers should be located on interior or corridor walls within spaces which are located above other less sensitive spaces such as kitchens, laundries, storage, baths.

2. Where such appliances must be located above noise-sensitive spaces (living rooms, bedrooms, dens etc.), they should be vibration isolated from the floor, walls or other supporting structures,

3. Bathroom and kitchen exhaust fans should be selected for low noise output (maximum 2.5 Sones or 55 dBA),

4. Ducts from the kitchen and bathroom fans of one suite should not traverse another suite on the way to the exterior wall or roof. They should pass between the insulation in the ceiling space and the floor structure above without rigidly contacting either the gypsum board ceiling below or the floor structure above,

5. Where mechanical rooms share common walls or floors with occupied spaces (suites, offices, activity rooms etc.) steps should be taken to limit both airborne and structure borne fan, pump or chiller noise reaching these sensitive spaces to appropriate levels, such as the Noise Criteria (NC) or Room Criteria (RC) levels recommended by ASHRAE,

6. Levels of exhaust fan and air handling unit noise reaching the outside of the building should be controlled so as not to exceed relevant municipal noise bylaw limits at the nearest adjacent residential premises.

8.3 Plumbing

1. Keep water supply pressure to suites low - less than 35 psi,

2. Keep water flow velocity low - less than 6 fps in branch lines and 10 fps in mains,

3. Piping Lay-out::

   - locate supply and drain piping in interior walls within suite or in corridor walls,
   - if possible avoid party walls,
   - avoid walls and ceilings common to living room and dining room,
   - supply each suite with a separate branch line from main,
   - common (to multiple units) caste iron waste pipes are acceptable; caste iron waste pipes are preferred over plastic.

4. Piping Installation:

   - attach piping only to the wall of the suite its serves - do not attach to wall of adjacent suite,
   - plastic supply piping need not be isolated from framing where it passes through studs but avoid direct contact with gypsum board walls,
   - fill all wall cavities carrying supply mains or waste pipes with fibreglass batt insulation,
   - support waste piping at floor level only and prevent direct contact with flooring using neoprene pads, non-setting caulking etc.,
   - prevent direct contact between supply/waste pipes and hanger straps using neoprene gasketing, heavy felt or corrugated cardboard,

5. Toilets:

   - prevent direct rigid contact between toilet bowls/mounting rings and the floor below using 3/16" neoprene pad,
   - select toilets with centrifugal flushing action and bowls having relatively small water surface areas and large exposed porcelain areas.

6. Bathtubs:

   - to reduce splashing/squeaking noises transmitted to suite below, the space between bathtub and floor should be filled with fibreglass batt insulation,
   - gypsum board wall sheets behind bathtubs should extend all the way to the floor.

8.4 Electrical

- Do not locate pairs of electrical/cable/phone outlets/switches on opposite sides of a party wall within same stud space - offset by at least 3 feet/two stud spaces,
- Use quiet type light switches throughout - particularly on party walls,
- Minimize size of any ceiling penetrations and seal any gaps around fixtures,
- Do not locate cable T.V. outlets on party walls,
- Install transformers in basement, preferably on grade, vibration isolate larger units,
- Install all distribution panels on interior walls - not on party walls.

8.5 Cabinets/Doors/Drawers

- Where possible, avoid placing kitchen cupboards/cabinets on party walls,
- Use soft foam rubber bumper strips on all cupboard doors/drawers as well as resilient (soft rubber or plastic) drawer rollers and shelf liners,
- Suite entry doors should be solid-core,
- Avoid use of door knockers,
- Interior doors should be fitted with rubber-tipped door stops to reduce impacts with walls,
- Select sliding/folding closet doors for smooth, quiet operation - avoid sheet metal doors.

8.6 Rods/Rollers

- Do not locate paper rollers on party walls, use resilient inserts at roller supports,
- Shower rods and clothes closet rods should be vibration isolated (rubber cups) from their mounting brackets, particularly if locate close to a party wall. Wooden clothes closet rods are preferred.

8.7 Party Walls

See Sections 7.4 to 7.12.

8.8 Party Floors

See Sections 7.13 to 7.18.

Section 9 CONDOMINIUM RESIDENTS "DO'S & DON'T'S" FOR MINIMIZING NOISE DISTURBANCE

9.1 Introduction

The party walls and floors of most condominiums currently constructed in B.C. are designed to meet or exceed the 1998 B.C. Building Code's requirements for the control of airborne sound transmission (i.e., speech, TV, music). In addition, special measures are often taken to minimize the transmission of footstep noise through the floors in non-carpeted areas. However, within concrete as well as wood-frame condominium buildings, particularly where background noise levels (such as created by arterial road or highway traffic) are very low, the normal activities of residents may create noises which, while of low intensity, are audible to their neighbours in adjacent units and may, for some, be a source of disturbance or annoyance.

Due to the necessary structural (framing) connections between adjacent units, a certain amount of sound transmission is inevitable within multi-family dwellings. This is particularly true of "structure-borne" noise. This type of noise often originates as vibration created in one unit by, for example, the closing of a cupboard door or drawer or the dropping or dragging of a hard object on or across the floor. This vibration is transmitted through the building structure (wood framing and wall and floor sheathing) into adjoining units where it is ultimately radiated as sound (noise) from walls and floors. The generation of these noises, and therefore the potential creation of disturbance/annoyance, may be minimized in two ways:

1. *by making a number of minor physical modifications to your unit,*
2. *by becoming aware of those routine activities which may cause disturbance to your neighbours and going about them in a manner which minimizes the noise created.*

Towards this end, the following list of ***"Do's and Don'ts"*** are provided to assist condominium residents in maintaining a noise environment within their buildings that will hopefully be found acceptable to all.

9.2 Physical Modifications to Minimize Noise Generation

The following minor modifications to your condominium should be considered in order to minimize the amount of noise which generated by everyday activities within the building:

1. The inside edges of all cupboard doors and drawers should be fitted with closure bumpers that are thick and resilient enough to prevent any significant noise upon closing. The hard vinyl "bumps" often provided with the doors/drawers are not soft enough for this purpose. There should be two bumper pads added to each door/drawer, ideally made of peel-and-stick foam neoprene or vinyl, at least ¼" to 3/8" thick and about 1" long by 3/8" to ½" wide,
2. Similar bumpers pads should be installed on the jambs of interior doors that are frequently opened and closed such as bathrooms and closets,

3. The surfaces of kitchen cupboards and drawers containing heavy objects like canned foods, pots and pans, large plates and dishes etc should be lined with cushioned-vinyl shelf liner. Similarly, resilient rubber or vinyl mats may be used on countertops and in sinks to reduce the noise created by pots, dishes, kitchen utensils and small appliances,

4. The bottoms of kitchen chair legs should be fitted with felt casters or other devices to facilitate sliding and reduce “chair squawk” - particularly problematic on tile and hardwood floors,

5. Placing mats, area rugs or runners in entries, corridors, kitchens and other “high-traffic” areas which have hard-surfaced floors. Note that the current popularity of hard-surfaced flooring (hardwood and tile), both in new units and as replacements for existing carpeting, is creating problems due to footsteps and other impact noises being clearly audible in the units below. Methods of minimizing this type of noise transmission are described in Section 6. Individual condominium owners or strata councils considering whether or not to install, or permit installation of, hard-surfaced flooring in their buildings should consult a noise control expert.

6. Fitting the ends of toilet paper dispenser rods with resilient (rubber or vinyl sleeves or cups) to avoid metal-to-metal contact - alternatively, consider using the vertical “stacking” type of paper dispenser that rests on the floor.

9.3 Minimizing Noise Disturbance Through Mutual Awareness and Consideration

1. Wear only slippers or soft-soled shoes indoors, particularly if floors are hard-surfaced,

2. Use noisy appliances such as vacuums, dishwashers, clothes washers/dryers and garburators only during the daytime or early evening,

3. Use minimum required effort when closing doors, cupboards and drawers,

4. When preparing foods requiring chopping or pounding, or when using blenders, mixers, electric can openers or other kitchen appliances, place a resilient mat over the work area,

5. When having young children or pets as guests, be aware of your neighbours, particularly those directly below.

REFERENCES

1. "City Noise – Report of the Urban Noise Task Force", City of Vancouver, April 1997,
2. "Road and Rail Noise: Effects on Housing" Canada Mortgage and Housing Corporation, NHA 5156 08/86, Ottawa, 1986,
3. "Guidelines for Community Noise", World Health Organization, Geneva, 1999,
4. "Occupational Health Safety Regulation", B.C. Regulation 296/97, Part 7, Noise, Vibration, Radiation and Temperature, Workers' Compensation Board of B.C.,
5. "SOUND ADVICE – A guide to hearing conservation programs", Workers' Compensation Board of B.C., ISBN – 7726-2980-3.

APPENDIX A

FUNDAMENTALS OF SOUND AND NOISE

A.1 What is Sound and How is it Created?

Vibrating surfaces such as engine housings, drum heads or loudspeakers and rapidly moving fluids such as turbulent water and jet engine exhausts produce minute fluctuations in the pressure of the surrounding air. These pressure fluctuations spread out from the source in the form of expanding waves in the air, much as a water wave on a pond spreads out from the point where a pebble has been dropped in – their intensity steadily decreasing with distance from the source. Our ears, acting like microphones, sense these tiny air pressure fluctuations and create equally tiny electrical signals that our brain then interprets as sound.

A.2 The Sound Pressure Level or "Decibel" Scale

The ear is capable of sensing sound, or "hearing", over an enormous range of intensities - from the faintest rustling of leaves or gentle breathing to the roar of a nearby jet aircraft. The jet may produce sound that is one million times more intense than the gentle breathing. Therefore, similar to the "Richter" scale which compresses the entire range of earthquake magnitudes into a 1 to 10 scale, the "***Sound Pressure Level***" or "***Decibel***" scale was developed to represent the even greater range of audible sound intensities within a compressed, or "logarithmic", scale. Within this scale, a Sound Pressure Level (SPL) of 0 decibels (dB) represents the threshold of hearing in the healthy ear's most sensitive frequency range, while the thresholds of tickling or painful sensations in the ear occur at 120 to 130 dB.

A.3 The Frequency or "Pitch" Sensitivity of the Ear - "A"-weighted Decibels

The ear is also sensitive to a very wide range of sound frequencies, or pitches. For a healthy ear, this range normally extends from 20 to 30 cycles per second, or Hertz (Hz.) - which is sub-woofer country - to about 18,000 to 20,000 Hz. which is approaching dog whistle territory. Our ears are most sensitive to sounds in the 500 to 7,000 Hz. range and progressively less sensitive to lower or higher pitched sounds. To mimic the ear's sensitivity, sound measurement instruments (sound level meters) contain an electronic filter known as the A-weighting. Most sound measurements made in the community or workplace employ the A-weighting. The resulting sound levels are called A-weighted sound levels and are expressed in units of A-weighted decibels, or dBA.

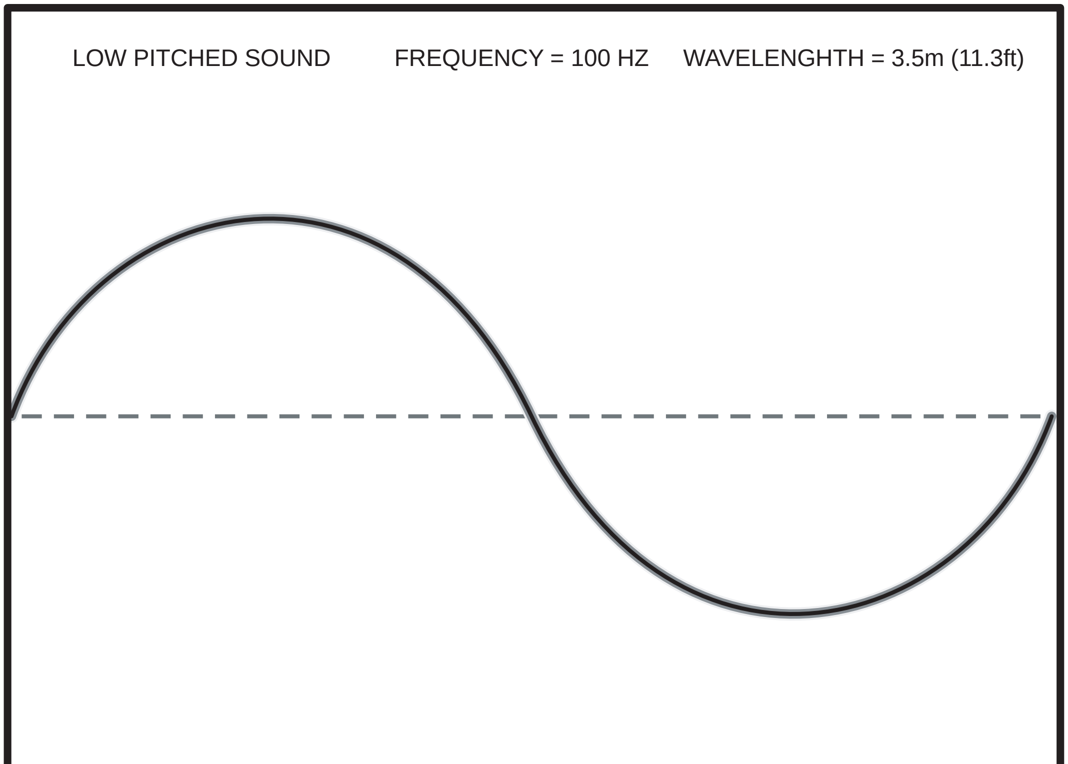


Figure A.1: An example of the frequency and wavelength of a low-pitched sound

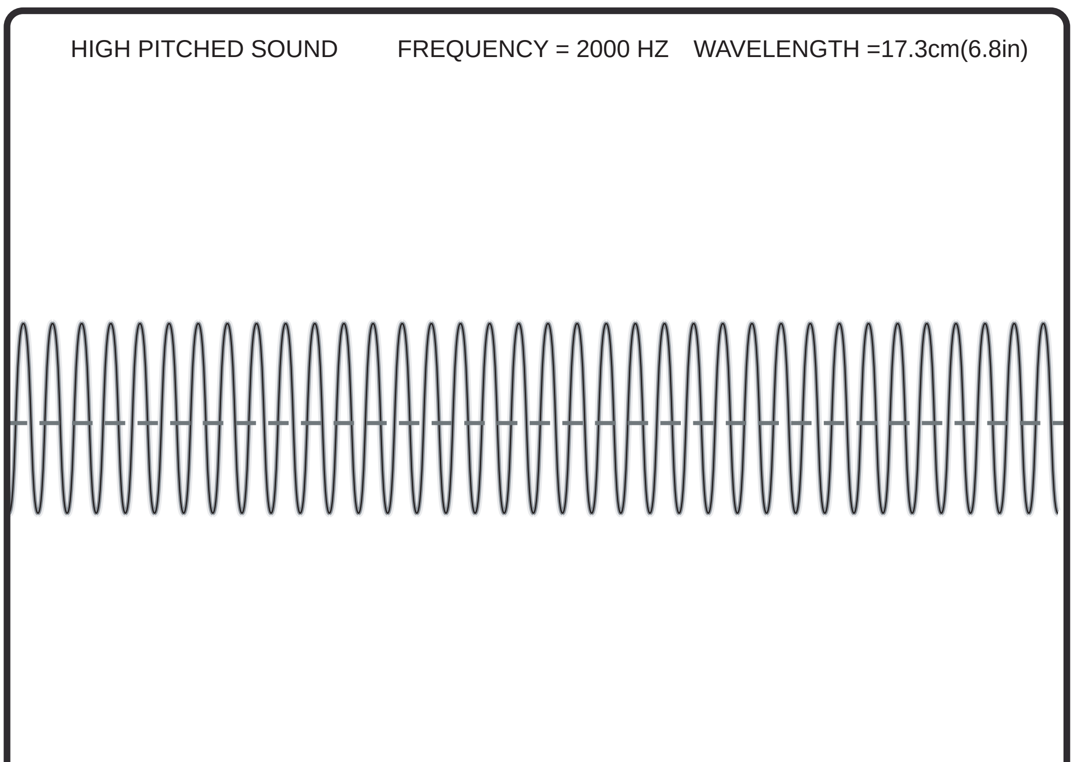


Figure A.2: An example of the frequency and wavelength of a high-pitched sound

A.4 The Speed of Sound, Wavelength and its Effects on Sound Behaviour

As mentioned above sound travels as pressure waves through the air. The wavelength of a sound is the distance that sound travels during one pressure cycle (i.e. the time taken for an air pressure fluctuation to go from maximum to minimum and back to maximum again). Since the speed of sound is the same (about 345 m/sec. or 1130 ft/sec.) for sound of all frequencies, the wavelength decreases as the frequency increases. Figure A.1 illustrates two sound waves, one with a relatively low pitch (frequency of 100 Hz.) and one with a relatively high pitch (frequency of 2,000 Hz.). It is seen that the wavelength of a 100 Hz. sound is about 3.5 m (11.3 ft) while that of a 2,000 Hz. sound is only 17.3 cm (6.8 in.). Sound with long wavelengths (i.e., low-pitched sounds) tend to diffract (bend) around everyday objects much more readily that short wavelength sound so that it is more difficult to shield receiver locations from low-frequency sounds using noise walls or other barriers. Low-pitched sounds also pass through solid materials much more readily than high pitched ones so that it is more difficult to contain them. High-pitched sounds, however, because of their short wavelengths, can squeeze through small cracks and gaps much more easily than low-pitched sounds.

A.5 What levels of noise are we typically exposed to in our-day to day lives?

In our day-to-day lives we are rarely exposed to sound levels near either end of our huge (0 to 130 dBA) audible range. More typically we encounter noise levels between about 20 and 30 dB (a faint whisper or nighttime background noise in a quiet suburban bedroom) and 100 dBA (unmuffled motorcycle or jackhammer operating nearby). Typical noise levels experienced include 40 to 50 dB in a general office situation, 60 dB when talking normally to someone 1 to 2 m away and 65 to 75 dB when riding in a car at highway speeds and 85 to 95 dBA while cutting the grass with power mower. Roughly speaking, ***each 10 dB increase*** in sound level corresponds to a “***doubling of subjective loudness***” so that, for example, jackhammer noise at 110 dB would typically be judged to be 2 x 2 x 2 x 2 = 16 times as loud as the inside of a car at 70 dB.

A.6 How is Sound Measured?

Sound is measured with instruments called "***Sound Level Meters***", or SLM’s, which consist of a microphone in conjunction with an electronic amplifier and filter, a display meter and commonly today, a digital memory for logging sound level data over time. These meters are calibrated before each use. Some SLM’s measure only the overall sound level (i.e., including all sound frequencies) as expressed in dBA while others, known as analyzers, can separate the noise into its various frequency components much in the way the ear does.

A.7 What is Noise?

The words "sound" and "noise" are often used interchangeably. However, from the viewpoint of its effects on people in the community or the workplace, sound is considered to be noise when it is "unwanted" - either because it interferes with essential human activities (such as speech, sleep, concentration or relaxation) or causes annoyance. While subjective loudness depends essentially on the intensity and frequency of a sound, "noisiness" depends on these as well as other physical characteristics of the sound as well as many personal, subjective factors related to the noise receiver(s).

A.8 Some Sounds are "More Noisy" Than Others

The physical attributes of a sound (its nature and time patterns) which can increase its inherent "noisiness" or its ability to cause disturbance and annoyance include:

- its frequency content - of particular importance (sensitivity) is the range between 500 and 7,000 Hz.,
- the presence of pure tones, (e.g. the "whine" or "hum" of a pump or fan, the "squeal" of tires or brakes),
- the presence of impulsive sound components (e.g. material handling, construction or industrial impacts, gunfire, sonic booms) - sounds which have very sudden onsets and which rise substantially above the background noise level are judged to be more noisy,
- the intermittency, irregularity or rhythmic nature of the sound,
- the duration of the noise - for intermittent sounds, judged noisiness increases with duration of the noise,
- time of day or night, day of week and season of year during which noise occurs.
- sounds which carry unwanted information (e.g. speech through walls) or create feelings of fear or apprehension (e.g. an approaching aircraft or barking dog),
- Some community noise regulations acknowledge the inherently greater noisiness of sounds having the above characteristics by setting specific limits for various types of noises or by applying correction factors or penalties to the measured levels of such sounds.

A.9 Personal Factors Influencing Perceived Noisiness and Negative Response to Noise

Personal, subjective factors and individual and community attitudes can strongly influence how noisy or annoying a given intrusive noise is judged to be and the levels of negative community reaction that it might be expected to generate. These factors generally include:

- age and state of health, activities engaged in, ambient noise levels within household(s),
- previous experience with the type of noise in question,
- perceptions regarding the necessity or usefulness of the activity creating the noise,
- attitudes towards, and involvement with, the noise maker.

A.10 Negative Effects of Noise on People

A.10.1 <u>Hearing Loss and Stress-Related Disease From Noise at High Intensities</u>

At high enough intensities, noise can cause temporary and permanent hearing loss. This can happen suddenly (e.g. from an explosion or when a rifle is fired very close to the ear) or very gradually over a lifetime as with most occupational noise exposure. This latter type of noise exposure is the concern of the Worker's Compensation Board of B.C. The WCB's limit for an 8-hour daily exposure is 85 dBA (energy average or "equivalent sound level"). Each 3 dBA increase in average noise level above 85 dBA requires that daily exposure time be cut in half. These limits are intended to prevent gradual hearing loss over a working life sufficient to cause problems with speech intelligibility.

In most residential communities, noise levels rarely exceed WCB limits. However, the general din of our mechanized world has been observed to have negative effects on hearing and health in general. The U.S. Environmental Protection Agency, in its "Levels Document" of 1974, recommended a 24-hour equivalent sound level of 70 dBA as the threshold for hearing loss and stress-related diseases from overall lifetime noise exposure at work and at home.

Noise levels due to exterior sources within the community are typically 10 to 15 dBA lower inside the home than outside assuming windows are open slightly. Since most people spend the large majority of their time at home inside, levels of 80 to 85 dBA outside would typically be required to achieve average noise exposures of 70 dBA inside the home.

A.10.2 Interference With Speech Communication

When levels of intrusive noise approach or exceed normal speech sound levels, they can "mask" the speech sounds and cause loss of intelligibility. The practical noise level thresholds for the onset of interference with the speech communication (i.e., some individual words begin to be misunderstood at normal vocal effort and separation distance) are taken to be 45 dBA for steady noises (eg. heat pumps) and 55 dBA for intermittent peak levels (e.g. truck or aircraft nose events). However, higher noise levels are required to begin to significantly interfere with the understanding of the meaning of whole sentences. For example, outdoor equivalent noise levels of 57 to 62 dBA will typically cause from 2% to 7% loss of outdoor sentence intelligibility at 2 m separation distance. Upon going indoors, these noise levels would typically be reduced by 10 to 15 dBA to 42 to 52 dBA and the sentence intelligibility loss would be reduced to virtually 0%.

A.10.3 Interference with Sleep

Intrusive noise can interfere with sleep and rest by delaying falling asleep and by causing shifts to lighter sleep stages or actual awakenings. Within residences with normal nighttime background noise levels, the thresholds for the onset of such disturbance by intrusive noise are about 30 dBA for relatively continuous noises and 45 dBA for intermittent noises. Above these thresholds, the likelihood of sleep quality (depth) degradation or arousal increases with both the level and the duration of the intrusive noise. Again assuming the house façade provides 10 to 15 dBA of noise reduction with windows open slightly, these two indoor sleep disturbance thresholds would correspond to outdoor levels of 40 to 45 and 55 to 60 dBA respectively.

A.10.4 Annoyance due to Noise

Annoyance with intrusive noise is often, to a large degree, a by-product of its direct interference with activities like speech, sleep, relaxation or concentration. In some cases however, annoyance may occur even when noise levels are neither high enough nor durations long enough to cause significant activity interference.

The ability of a given noise to cause annoyance in a given situation depends on all the physical noise characteristics and subjective receiver variables described above. The consideration of these factors will improve the ability to anticipate average degrees of annoyance within noise exposed populations - methods have been developed to try to predict the reaction of communities to intrusive noises of various types. However, it is not possible to predict with any certainty the annoyance and negative reaction of individuals or small groups to an intrusive noise. For this reason, municipal noise regulations based solely on the receipt of complaints and general reports of disturbance allow neither the municipality nor the noise maker to be confident that mitigation efforts (short of achieving inaudibility) will prevent further violations under such regulations.

APPENDIX B

OPTIMIZING THE SOUND INSULATION

PERFORMANCE OF A RESIDENTIAL FACADE

B.1 Quantifying the Sound Insulation Capacity of Exterior Building Elements; Outdoor-Indoor Transmission Class (OITC)

When considering how best to reduce the overall levels of traffic or aircraft noise entering our home, it is useful to have a simple, quantitative measure by which we can compare the amounts of insulation provided against such noises by various types of exterior walls, windows, doors and roofs. Such a measure is provided by the Outdoor-Indoor Transmission Class, or OITC (Reference B-1). *For our purposes, OITC may be considered to be the amount (in decibels) by which sound levels created by typical transportation sources such as arterial traffic and aircraft are reduced in passing through the particular building element.* Note that in calculating OITC, lower sound frequencies are included and the noise spectrum (frequency content) assumed is representative of transportation sources. As a result, OITC ratings are numerically smaller than the STC ratings (see Section 6.5.4) provided by the same wall or window structure.

As when trying to reduce heating costs by adding thermal insulation, little improvement in sound insulation can be gained by treating exterior walls when the rooms involved have old, leaky single-paned windows. Similarly, the benefits of installing superior new windows will not be fully realized if the adjacent walls do not provide adequate sound insulation. It is best then to balance the sound insulation performance of all major facade elements and the OITC allows this to be done. The following sections present the OITC's of various window, wall and door constructions and show how to balance the sound insulation provided by these elements.

B.2 Sound Insulation of Various Common Window Types

Table B.1 below shows the OITC's (Reference B-2) of various standard and custom window types. Note that OITC results are presented for windows that are open slightly, closed without weather stripping, closed with weather stripping and fixed (i.e., unopenable and therefore assumed totally sealed). Of course if windows must be opened, even slightly (as for ventilation in summer) the sound insulation achievable is very limited. It is important, for both energy conservation and noise control, that openable windows be fitted with airtight perimeter seals.

Note that each 10 point (decibel) increase in OITC corresponds roughly to a halving of the loudness of the noise heard inside the house. Traffic noise levels inside a house with windows providing OITC 37 will then be roughly one-quarter as loud as inside a house with windows that provide only OITC 17. Comparing Window 6 with Windows 3 and 4 in Table B.1, it is seen that typical factory double-glazed window units do not provide substantially better insulation against traffic noise than do single-glazed windows with effective seals. To significantly improve window performance we must either use heavier glass in the double-glazed units, use much wider airspaces between glazing layers and/or use laminated glass (usually two layers of glass bonded together by a thin plastic inter-layer). Note also that "triple-glazed" windows do not provide significantly greater noise reduction than double-glazed units unless the spacing between at least two of the layers is much greater than the usual 6 to 13 mm. Adding a widely-spaced storm window (Window No. 14) is a particularly effective means of increasing OITC.

Window No.	Window Type / Condition	OITC
1	Any window type, open slightly	10 to 15
2	Single-glazed (3 mm glass), openable window (no weather stripping)	17
3	Single-glazed (3 mm glass), openable window (good weather stripping)	19
4	Single-glazed (3 mm glass), fixed	21
5	Single-glazed (6 mm glass), fixed	23
6	Typical Openable Factory Double-glazed Units (3 mm glass–13 mm airspace–3 mm glass)	23-25
7	Double-glazed (3 mm glass–13 mm airspace–3 mm glass), fixed	24-26
8	Double-glazed (3 mm glass–25 mm airspace–3 mm glass), fixed	25-27
9	Double-glazed (3 mm glass–50 mm airspace–3 mm glass), fixed	27-29
10	Double-glazed (3 mm glass–100 mm airspace–3 mm glass), fixed	29-31
11	Double-glazed (6 mm glass–50 mm airspace–6 mm glass), fixed	29-31
12	Laminated Glass (6 mm), fixed	30
13	Laminated Glass (13 mm), fixed	33
14	Typical Factory Doubled-glazed Units with Storm Window added at 76 mm spacing	30 - 32

Table B.1; OITC's of Various Standard and Custom Window Types.

B.3 Sound Insulation of Various Exterior Walls

Table B.2 provides OITC's for a variety of exterior residential wall constructions. Many of these exterior walls (Reference B-2) have the same basic construction, namely: 11 mm wood exterior sheathing (plywood or oriented strand board [OSB]), 89 or 140 mm wood studs at 406 mm spacing, 89 or 152 mm glass fibre insulation and interior sheeting of 13 mm gypsum wall board (GWB). Various external claddings treatments are then applied to the basic wall and the effects on OITC noted. It is clear that for typical single wood stud constructions, OITC is strongly dependent on the overall weight of the wall. It is also seen that the basic exterior wall, with or without lightweight vinyl or aluminum siding, at OITC 24 to 25 rates much the same as the single-glazed windows and factory double-glazed windows listed in Table B.1. Only when the weight of these walls is increased significantly with cement stucco or brick cladding, are worthwhile improvements in OITC achieved. A second approach to improving wall performance is to eliminate or weaken the rigid connections through the wall created by the wood studs. This can be done by either building a staggered stud wall (studs are alternatively attached to one side of the wall and then the other) or by attaching the interior GWB layer(s) to the studs using resilient channels, or "Rez-Bar.

Ext. Wall No.	Exterior Wall Type	OITC
1	Basic wall[1] (89 mm wood studs)	24
2	Basic wall (89 mm wood studs) plus 1 mm vinyl siding[2]	24
3	Basic wall (140 mm wood studs)	25
4	Basic wall (140 mm wood studs) plus 1 mm vinyl siding[2]	25
5	Basic wall (140 mm wood studs) plus 1 mm vinyl siding and a second layer of 13 mm GWB on interior surface	27
6	Basic wall (140 mm wood studs) plus 1 mm vinyl siding on 19 mm wood furring at 406 mm spacing	25
7	Basic wall (140 mm wood studs) plus 25 mm expanded polystyrene (Styrofoam) and 1 mm vinyl siding	26
8	Basic wall (140 mm wood studs) plus 0.6 mm aluminum[2] siding	25
9	Basic wall (140 mm wood studs) plus 0.7 mm building paper, 25 mm expanded polystyrene and 6 mm acrylic stucco (exterior insulation/finish)	27
10	Basic wall (140 mm wood studs) plus 0.7 mm building paper and 9.5 mm cement stucco[3]	29
11	Basic wall (140 mm wood studs) plus 0.7 mm building paper and 19 mm cement stucco[3]	32-33
12	Basic wall (140 mm wood studs), 0.7 mm building paper and 9.5 mm cement stucco on outside plus 13 mm resilient channel at 610 m spacing between studs and two layers of 13 mm GWB on inside	41
13	Basic wall (140 mm wood studs) plus 16 mm airspace and 89 mm brick	40
14	Basic wall but with 140 mm staggered wood studs and 1 mm vinyl siding	33
15	Basic wall but with 140 mm staggered wood studs, I mm vinyl siding plus a second layer of 13 mm GWB on interior surface	39
16	Basic wall but with 140 mm staggered wood studs, I mm vinyl siding plus a second layer of 11 mm OSB on the exterior surface and a second layer of 13 mm GWB on the interior surface	43
17	Basic wall (140 mm wood studs), 1 mm vinyl siding plus 13 mm resilient channel (610 m spacing) located between studs and 13 mm GWB	32
18	Basic wall (140 mm wood studs), 1 mm vinyl siding plus 13 mm resilient channel (610 m spacing) located between studs and two layers of 13 mm GWB	34

1. The "basic" exterior wall consists of 11 mm wood exterior sheathing (plywood or oriented strand board [OSB]), 89 or 140 mm wood studs at 406 mm spacing, 89 or 152 mm glass fibre insulation and interior sheeting of 13 mm gypsum wall board.

2 Walls finished with wood siding (shiplap) would be expected to provide slightly higher OITC values (about 1 or 2 points) than vinyl or aluminum siding.

3. Cement stucco finishes on older Vancouver houses and apartments are usually thicker than 9.5 mm. With a more typical 19 mm stucco layer, the OITC would be expected to be increased by a further 3 to 4 points.

Table B.2; OITC's provided by Various Exterior Wall Constructions

B.4 Effects of Vents in Walls

The location of a kitchen or bathroom exhaust vent opening in an exterior wall can significantly compromise its sound insulation. For example, if such a vent should pass directly through the wall (without any additional ductwork within which noise attenuation could occur) it could reduce the OITC of an otherwise good wall by 10 points or more. Therefore, such vents should be located on a quiet side of the house or in a sheltered location. If this is not possible, they may be fitted with external baffles to shield the vent opening from traffic noise and/or with acoustically lined hoods and connecting ductwork.

B.5 Sound Insulation of Exterior Doors

A solid wooden or insulated steel door (typically 45 to 55 mm thick) can provide about OITC 25 to 28 if its perimeter is well sealed but only about 18 to 21 if it is not sealed. Doors located within walls exposed to noise from traffic or other sources should then be of solid wood or insulated steel construction with well-sealed perimeters. Adding a second “storm door” of insulated steel, solid wood or heavy-glazed construction, [e.g. 6 mm (¼”), laminated or plate glass] spaced out from the first door by 100 to 150 mm (4” to 6”) will substantially increase sound insulation into the OITC 40 to 45 range. An entry vestibule, or “mud room”, involving two widely separated solid core doors (at least one, and preferable both, weather stripped) will be even more effective for insulation against both heat loss and noise penetration.

B.6 Sound Insulation of Roofs

Because of the relatively large depths of the cavities typically found between roofs and the ceilings below, the transmission of traffic noise through insulated roof spaces is generally not a significant concern. However, roof transmission can be of concern for those living near airports or under flight paths. Table B.3 describes several common roof constructions and provides their lab-tested OITC ratings (Source; Reference B-2).

B.7 Obtaining a Balanced Noise Insulation Design

To obtain a balanced, and therefore cost-effective, residential facade design, it is necessary to construct the various façade elements so that their “effective OITC’s” are similar. To obtain the “effective OITC” of a façade element we start with its rated OITC (as provided in Tables B.1, B.2 and B.3) and “adjust” this value to reflect the relative size of the element compared to that of the entire noise-exposed façade. Table B.4 shows that, if a certain overall façade OITC is required to adequately insulate against traffic noise, then smaller façade elements, such as doors or windows, may have significantly lower OITC’s provided the large proportion of the façade (typically, but not always, the walls) meets or, preferably somewhat exceeds, the overall target OITC.

B.8 How much sound insulation does my residence need to provide?

To determine how much sound insulation your residence should be providing, you need to know two things:

1. What levels of traffic (or other) noise do I you want to achieve inside my house?

2. What is the average level of traffic (or other) noise at the façade of my house now? Is it likely to increase? If so, by how much?

Roof No.	Roof Type	OITC
1	Flat roof or cathedral ceiling with 3 mm (1/8") asphalt shingles on 11 mm (0.43") OSB, 203 mm (8") glass fibre insulation between 235 mm (9.3") deep wood joists[1], single layer of 13 mm (1/2") gypsum board on ceiling	30
2	Same as Roof No. 1 except that the single gypsum board layer ceiling is mounted to joists using Resilient Channels (Rez-Bar)	40
3	Same as Roof No. 1 except that two layers of ceiling gypsum board are mounted to joists using Resilient Channels (Rez-Bar)	43
4	Flat roof or cathedral ceiling with 3 mm (1/8") asphalt shingles on 11 mm (0.43") OSB, 264 mm (10.5") glass fibre insulation, 356 mm (14") deep wood trusses, single layer of gypsum board on the ceiling	32
5	Same as Roof No. 4 except that ceiling consists of two layers of gypsum attached to trusses with Resilient Channels	44
6	Sloped roof with 3 mm (1/8") asphalt shingles on 11 mm (0.43") OSB, 152 mm (6") glass fibre insulation between 1626 mm (64") deep raised heel wood trusses, single layer of gypsum board on ceiling	39
7	Same as Roof No. 6 except that 264 mm (10.5") glass fibre installed between trusses.	41
8	Same as Roof No. 6 except that 264 mm (10.5") glass fibre installed between trusses and second layer of 13 mm (1/2") gypsum board applied to ceiling.	43
9	Same as Roof No. 6 except that 264 mm (10.5") glass fibre installed between trusses and single layer of 13 mm (1/2") gypsum board applied to ceiling with Resilient Channels.	42

1. All wood joists and trusses are spaced at 406 mm (16") on centre.

Table B.3; OITC's provided by Various Roof/Ceiling Constructions

B.9 Recommended Indoor Noise Levels - CMHC

The levels of traffic noise found to be acceptable within residences will vary form person to person depending on their nature and lifestyle. However, the noise levels found to be generally acceptable and to prevent any significant interference with essential activities (speech and sleep) have been defined by the Canada Mortgage and Housing Corporation (Reference B-3) and are widely used as guidelines in Canada. The CMHC's target noise levels for various indoor spaces – expressed in terms of the 24-hour Equivalent Sound Level[1], or $L_{eq}(24)$ – are as follows:

Bedrooms	35 dBA
Living, dining and recreation rooms	40 dBA
Kitchens, bathrooms, hallways, utility rooms	45 dBA
Outdoor Recreation areas	55 dBA

[1] The Equivalent Sound Level is that steady sound level which, over a given time period (here 24 hours), would result in the same total sound energy exposure as would the actual "time-varying" sound level in the community.

Area of Façade Element as Percentage of Entire Area of Exposed Façade[1]	Effective OITC Adjustment (Amount by which OITC of Façade Element may fall short of Overall Façade Target OITC)
1%	15
2%	12
3%	10
4%	9
5%	8
6%	7
8%	6
10%	5
15%	4
20 - 25%	3
30 – 40%	2
40 - 50%	1
50% or more	0

1. Here "Exposed Façade" refers to the total area of the exterior surface of a given room which is directly exposed to the noise source (e.g. traffic).

Table B.4; Allowable Adjustments to the OITC's of Smaller Façade Elements (windows, doors) based on their Size (area) as a Percentage of the Entire Façade Area.

B.10 Estimating the Level of Traffic Noise at Your Residence

B.10.1 Daily Average Noise Levels from Traffic on Typical Urban Roads - Speed Limit 50 kmph

Table 3.1 herein indicated that daily average noise levels in cities typically range from 45 to 50 dBA in quiet suburban areas well removed from major roads or industry to 65 to 75 dBA at residences fronting directly on major arterial roads or highways or near airports. While the most accurate way to determine the noise exposures in your neighbourhood would be to measure them[2], if your noise environment is clearly dominated by local street or arterial road traffic, it is possible to estimate the daily average noise exposures at your residence using Table B.5[3].

The noise levels shown in Table B.5 are expected to be obtained under the following conditions:

- freely-flowing traffic on a level road (i.e., no grade),
- posted speed of 50 kmph,
- heavy vehicle mix (percentage heavy trucks and busses in traffic) of 1.5% or less,
- hard ground between the roadway and the residence in question.

[2] Noise levels may be measured with devices called "sound level meters". Inexpensive meters, adequate for getting a general impression of noise levels in the neighbourhood, may be purchased at consumer electronics stores such as Radio Shack. More accurate and moderately expensive ones may be purchased through industrial safety and supply outlets such as Acklands-Grainger. To have noise exposures assessed accurately over longer time periods, the services of an acoustical consultant may be obtained (see Appendix C).

[3] The content of Table B.5 and much of the following method for estimating traffic noise levels is based on the procedure contained in the CMHC's "Road and Rail Noise; Effects on Housing" (Ref. B-3).

Table B.5, which is based on the CMHC's highway noise prediction procedure (Reference B-3), shows the approximate daily average noise exposures - expressed in terms of the $L_{eq}(24)$ - at a residential façade as a function of daily traffic volume and the setback distance of the façade from the centre of the road.

Average Daily Traffic Volume (vehicles/day)	Setback Distance from Centre of Roadway to Residence (m)										
	10	13	16	20	25	30	40	50	60	80	100
1,000	52	51	50	49	48	47	46	45	44	43	42
1,250	53	52	51	50	49	48	47	46	45	44	43
1,600	54	53	52	51	50	49	48	47	46	45	44
2,000	55	54	53	52	51	50	49	48	47	46	45
2,500	56	55	54	53	52	51	50	49	48	47	46
3,150	57	56	55	54	53	52	51	50	49	48	47
4,000	58	57	56	55	54	53	52	51	50	49	48
5,000	59	58	57	56	55	54	53	52	51	50	49
6,300	60	59	58	57	56	55	54	53	52	51	50
8,000	61	60	59	58	57	56	55	54	53	52	51
10,000	62	61	60	59	58	57	56	55	54	53	52
12,500	63	62	61	60	59	58	57	56	55	54	53
16,000	64	63	62	61	60	59	58	57	56	55	54
20,000	65	64	63	62	61	60	59	58	57	56	55
25,000	66	65	64	63	62	61	60	59	58	57	56
31,500	67	66	65	64	63	62	61	60	59	58	57
40,000	68	67	66	65	64	63	62	61	60	59	58
50,000	69	68	67	66	65	64	63	62	61	60	59
63,000	70	69	68	67	66	65	64	63	62	61	60
80,000	71	70	69	68	67	66	65	64	63	62	61
100,000	72	71	70	69	68	67	66	65	64	63	62
125,000	73	72	71	70	69	68	67	66	65	64	63
160,000	74	73	72	71	70	69	68	67	66	65	64
200,000	75	74	73	72	71	70	69	68	67	66	65
250,000	76	75	74	73	72	71	70	69	68	67	66

Table B.5; Daily Average Noise Levels [$L_{eq}(24)$'s] Produced at Various Distances over "Hard Ground" from the Centre of a Level Road by Various Volumes of Freely-flowing Traffic. Posted Speed; 50 kmph, Heavy Vehicle Mix; 1.5% or Less.

B.10.2 Daily Traffic Volumes on Vancouver Streets

Table B.6 below provides the 2003 daily traffic volumes and heavy vehicle mixes for a sample of Vancouver's major arterials. These values can be used in Table B.5 to estimate traffic noise levels along these and similar streets. Traffic volumes and truck mixes for other arterials may be obtained form the City's Traffic Management Branch. In particular, truck mixes may be derived from the "Truck Traffic Study 2001-2002" produced by the City's Strategic Transportation Planning office as well as TransLink's 1999 Lower Mainland Truck and Freight Study.

No.	Arterial Street / Road Name	Arterial Street / Road Section	Daily 2-Way Volume (vpd)	Heavy Vehicle Mix
1	First Avenue	Clark Drive to Commercial Drive	43,000	-
		Nanaimo Street to Renfrew Street	52,000	-
2	Hastings St.	Victoria Drive to Nanaimo Street	59,500	0.5%
3	12th Avenue	Cambie Street to Main Street	24,000	-
4	Broadway/ Lougheed Hwy	Renfrew Street to Rupert Street	43,000	1.5%
4	Grandview Hwy	Renfrew Street to Rupert Street	52,000	-
5	King Edward	Cambie Street and Main Street	27,000	-
6	41st Avenue	Knight Street and Victoria Drive	40,500	1.5%
7	49th Avenue	Main Street and Fraser Street	24,300	-
8	Marine Way	Fraser Street and Knight Street	60,500	2.5%
		Kerr Road and Boundary Road	66,700	2.5%
9	Cassiar Street	1st Avenue to Adanac Street	74,300	-
10	Renfrew Street	1st Avenue to Hastings Street	20,500	-
11	Commercial Dr.	Lougheed Hwy to 1st Avenue	20,000	-
12	Clark Drive	1st Avenue to Adanac Street	34,300	5%
13	Knight Street	33rd Avenue to 41st Avenue	39,500	5.5%
14		57th Avenue to Marine Way	55,000	6.0%
15	Fraser Street	33rd Avenue to 41st Avenue	24,000	-
16	Main Street	16th Avenue to King Edward Ave.	33,000	1%
17	Cambie Street	49th Avenue to 57th Avenue	45,000	1%
18	Oak Street	41st Avenue to 49th Avenue	60,000	0.5%
19	Granville Street	33rd Avenue to 49th Avenue	52,000	0.5%
20	Arbutus Street	33rd Avenue to King Edward Ave.	29,000	-

Table B.6; Posted Speeds, Daily (24-hour Two-way) Traffic Volumes and Heavy Vehicle Mix on Selected Vancouver Arterial Streets, 2003

B.10.3 Adjusting the Daily Average Noise Level to Reflect the Situation at your Residence

Where traffic conditions are not quite as described above, adjustments may be made to the daily average noise levels given in Table B.5 The following series of tables provide the appropriate adjustments to account for the effects of different posted speeds, of larger numbers of heavy vehicles, of grades, of soft ground conditions and of “stop and go” traffic conditions.

B.10.4 Speed Adjustment

Average traffic noise levels increase with average vehicle speed. If the road past your residence has a posted speed other than 50 kmph, Table B.7 can be used to adjust the 50 kmph noise levels shown in Table B.5.

Posted Speed (kmph)	30	40	50	60	70	80	90
Traffic Noise Adjustment (dBA)	-4	-2	0	+2	+3.5	+5	+6.5

Table B.7; Average Traffic Noise Level adjustments for Posted Speeds other than 50 kmph.

B.10.5 Heavy Vehicle Mix Adjustment

The more heavy vehicles (trucks with 3 or more axles and busses) in the traffic flow, the higher the noise levels generated. Table B.8 provides adjustments that may be applied to the average noise levels contained in Table B.5 when the heavy vehicle mix is greater than 1.5%.

Heavy Vehicle Mix (%)	0.0 - 0.5	0.5 to 1.5	1.6 – 3.5	3.6 – 6.0	6.1 – 9.2	9.3 - 13
Traffic Noise Adjustment (dBA)	0	+0.5	+1	+2	+3	+4

Table B.8; Average Traffic Noise Level Adjustments for Various Heavy Vehicle Mixes.

B.10.6 Grade Adjustment

The steeper the grade of a road, the more noise generated by the engines and exhausts of vehicles traveling uphill, particularly for heavy vehicles (trucks and busses). Table B.9 provides adjustments that may be applied to the average noise levels contained in Table B.5 when the road in question is not level.

Percentage Heavy Vehicles	Average Road Grade				
	1%	**2%**	**3%**	**4%**	**5% or more**
0 to 7%	0	+1	+1	+1	+2
8 to 12%	+1	+1	+2	+2	+3
13-17%	+1	+1	+2	+3	+3

Table B.9; Average Traffic Noise Level adjustments for Roads with Grades other than 0% (i.e., level road).

B.10.7 Soft Ground Adjustment

If the ground between the roadway and your residence is “acoustically soft” (that is, it is not hard and reflective like pavement or water, but rather soft and porous like lawn or garden) then it will help to reduce the traffic noise reaching your house, particularly at the ground floor level. Table

B.10 provides adjustments that may be applied to the average noise levels contained in Table B.5 when all or most of the ground between your house and the road is “soft”.

Floor Level (Height above Ground, m)	Setback Distance from Centre of Roadway to Residence (m)										
	10	13	16	20	25	30	40	50	60	80	100
1st Floor (0.5 to 2.5)	0	0	0	-1	-2	-3	-4	-5	-6	-7	-8
2nd Floor (2.6 to 5.0)	0	0	0	-0.5	-1	-2	-3	-4	-5	-6	-7
3rd Floor (5.1 to 8.0)	0	0	0	0	0	-1	-2	-3	-4	-5	-6

Table B.10; Average Traffic Noise Level Adjustments for Acoustically Soft Ground Conditions

B.10.8 Adjustment for “Stop-and-Go” Traffic

On most city streets with posted speeds of about 50 kmph or less, the creation of “stop-and-go” traffic due to a stop sign or stoplight, will tend to increase traffic noise exposures at nearby residences by about 2 dBA at locations within about 60 m of the stop sign/light and by about 1 dBA at locations between 60 and 150 m of the stop sign/light. For roads with higher posted speeds (about 65 kmph or higher), stop signs and stop lights actually reduce overall noise exposures by from 1 to 2 dBA due to the associated reduction in average vehicle speed. For posted speeds between 55 and 65 kmph, no “stop-and-go” adjustment is required.

Traffic congestion, such as commonly found on Vancouver streets, results in average vehicle speeds being well below the typical posted speeds of 50 to 60 kmph. As indicated in Table B.7, where traffic conditions remain free flowing, each 10 kmph reduction in average speed below 50 kmph reduces average noise levels by about 2 dBA. However, in situations where there are many heavy trucks and/or a grade involved, the effects of the “stop and go” traffic conditions associated with congestion (i.e., frequent acceleration and braking), will generally offset the beneficial effects of the reduced average speed.

B.10.9 Calculating the Adjusted Daily Average Noise Exposure - **An Example**

As an example of the traffic noise estimation procedure outlined above, consider a home located 25 m (over largely soft ground) from the centre of a four-lane arterial road carrying 40,000 vehicles per day (vpd) with 5% heavy vehicles at a posted speed of 70 kmph. Consider also that the road is on a slight (2%) grade and is within 60 m of a stoplight. The adjusted daily noise exposure at a second floor bedroom window facing the road may be calculated as follows:

Step 1; Select basic average daily noise level from Table B.5. Find intersection of “40,000 vpd traffic volume” row and “25 m” setback distance” column, obtain 64 dBA,

Step 2; Select posted speed adjustment from Table B.7. Enter “70 kmph” column, obtain adjustment of + 3.5 dBA, Step 3; Select adjustment for 5% Heavy vehicles from Table B.8. Enter “3.6 - 6.0%” column, obtain adjustment of +2 dBA,

Step 4; Select grade adjustment from Table B.9. Find intersection of “0 to 7% heavy vehicles” row and “2% grade” column, obtain adjustment of +1 dBA,

Step 5; Select Soft Ground Adjustment from Table B.10. Find intersection of “2nd Floor” row and “25 m setback distance column”, obtain adjustment of –1 dBA,

Step 6; Select stop-and-go traffic adjustment (Section B.10.8). Since the house is within 60 m of a stoplight and the posted speed is 70 kmph, the appropriate adjustment is -1 dBA,

Step 7; Apply all five adjustments to the basic daily noise level to obtain the “adjusted” average daily noise level:

Adjusted Average Daily Noise Level, $L_{eq}(24)$ = 64 + 3.5 + 2 + 1 - 1 - 1 dBA,

= 64 + 4.5 dBA

= 68.5 dBA

B.11 What OITC would be required to meet the CMHC’s 35 dBA objective for a bedroom?

The actual noise levels experienced within a room when its exterior façade is exposed to noise as from traffic or other sources depends on how much sound absorbing material is present in the room. If the room is quite bare (uncarpeted and sparsely furnished), noise levels will be higher, while if the room is carpeted and fully furnished, they will be noticeably lower. However, for our purposes an average room has been assumed, so that the noise level inside the room (at least close to the façade facing the road) can be conservatively approximated by subtracting the façade OITC from the predicted average traffic noise levels outside the room. In the above example, the 24-hour average traffic noise exposure at the second floor bedroom window was estimated to be 68.5 dBA. Therefore, in order to approach the CMHC’s objective of $L_{eq}(24)$ 35 dBA inside the bedroom, the second floor façade (wall and window combined) would need to provide an OITC of approximately 68.5 minus 35 = 33.5. Since average traffic noise levels are usually considerable lower during the nighttime than the day, the above OITC objective is somewhat conservative (i.e., contains a margin of safety) for spaces such as bedrooms which are generally occupied only at night.

B.12 How would the façade need to be constructed to meet the CMHC’s 35 dBA objective?

Referring back to Table B.2 it is seen that there are several exterior wall constructions that will provide OITC’s in the 33 to 34 range. These include Wall Type 11 which is a standard 140 mm (2” x 6”) wood stud wall with 19 mm of cement stucco. Note that the OITC provided by an 89 mm (2” x 4”) stud wall with 19 mm cement stucco would be expected to be only about 1 point less than that of the above 140 mm wall. Wall Types 14 (staggered 140 mm wood studs) and 18 (140 mm wood studs with resilient channels supporting two layers of 13 mm gypsum board) would also be appropriate for this situation.

Assuming that the window is quite small (roughly 10% of the entire bedroom façade area), Table B.4 shows that the effective OITC of the window should be no more than 5 points lower than that of the wall, that is, at least OITC 28 to 29. Table B.1 shows that standard double-glazed windows (Window Types 6 and 7) fall short of this objective. However, Window Type 8 (a fixed double-glazed window with 3 mm glass–25 mm airspace–3 mm glass) would meet this objective provide as would Window Type 14 (typical factory doubled-glazed units with storm window at 76 mm spacing). If, however, the window was larger and represented, for example, 20 to 25 % of the entire façade area, then it would need to provide an effective OITC of 30 to 31.

Appendix B - References

B-1 ASTM 1332 "Standard Classification for Determination of Outdoor-Indoor Transmission Class", American Society for Testing and Materials, Philadelphia,

B-2 "Laboratory Measurements of the Sound Insulation of Building Façade Elements", National Research Council, Institute for Research in Construction, Internal Report, IRC IR-818, October 2000.

B-3 "Road and Rail Noise: Effects on Housing", Canada Mortgage and Housing Corporation, Document No. NHA 5156 08/86,

APPENDIX C

SOURCES OF NOISE CONTROL

PRODUCTS, MATERIALS AND SERVICES

Noise Control Products and Materials

General Noise and Vibration Control Material and Systems Suppliers

- Vibra-Sonic Control Ltd., Burnaby, Phone, 604 294-9495,
- Western Noise Control, Edmonton, Phone; 1-800 661-7241,
- Benton & Overbury Ltd., North Vancouver, Delta, Surrey,
- H.L. Blachford Ltd., Mississauga, Ontario, Phone; (905) 823-3200.

Hearing Protection Devises (HPD's) – Ear Muffs and Plugs

- most building supply stores,
- industrial and safety supply stores (Acklands-Grainger Inc., Fleck Bros.),
- contact Workers Compensation Board for lists of HPD's and information on use,
- NIOSH Compendium of Hearing Protection Devices www.cdc.gov/niosh/95-105.html

Sound Absorption/Insulation Materials

Fibreglass or mineral fibre batts and semi-rigid panels:

- most building supply stores,
- speciality building supply stores (Winroc Corp., Richmond, Phone; 604-430-1463)
- industrial supply stores (Benton & Overbury Ltd. Steels Industrial Products Ltd.),

Installation of Loose fill (blow-in) insulations:

- some major building supply stores,
- most thermal insulation contractors

Acoustic Duct Liners and Duct Silencers

- Johns-Manville “Permacote Linacoustic” duct liner; Steels Industrial Products Ltd.)
- Crossroads C&I, duct systems insulations, Burnaby, Phone; 604 421-1221,
- Vibro-Acoustics Ltd., Scarborough Ontario, duct silencers Phone; 1-800-565-8401,
- Owens Corning, Phone; 1-800.438-7465, wwww.owenscorning.com,
-

Acoustic Wall Panels

- Benton & Overbury Ltd.,
- Western Noise Control, Edmonton, Phone; 1-800 661-7241

Acoustic Curtains

- Vibra-Sonic Control Ltd., Burnaby, Phone, 604 294-9495,
- Western Noise Control, Edmonton, Phone; 1-800 661-7241

Acoustic Doors

- Vibra-Sonic Control Ltd., Burnaby, Phone, 604 294-9495,
- Western Noise Control, Edmonton, Phone; 1-800 661-7241
- Overly Manufacturing Company, Greenburg Pa, Phone; (412) 834-7300.

Window and Door Weather stripping and Perimeter Seals

- weather stripping - most building supply or hardware stores,
- acoustical doors seals – Pemko Canada, Abbotsford, Phone; 877 535-7888,
- McGregor & Thompson Hardware Ltd. Phone; (604)253-8252.

Acoustical Sealants (non-setting caulking, e.g. Tremco)

- general building supply and drywall supply stores,

Resilient Channels

- most drywall supply outlets (e.g. Winroc Corp. Richmond, Phone; 604-430-1463)

Resilient Floor Underlays

- most hardwood flooring and wood finishing stores (e.g. The Finishing Touch),
- Acousti-tech products; Toll Free: 1.866.889.0001, email info@acousti-tech.com
- Enkasonic; Structure All Sealants Inc., Richmond Phone 604 275-0858, BC Erosion Control Products Inc., Vancouver, Phone; 604 327-0540,
- Dura-son, Dura Undercushions Ltd., Montreal Tel.: (514) **737-6561**/(800) 295-4126, Fax: (514) 342-7940 email, info@dura-undercushions.com

Masking Noise

- Tapes and CD’s of masking sounds – Music and consumer electronic stores,
- Masking Noise systems (ceiling installed) Sound-Rite Acoustics Inc., Vancouver,

Phone; 604 642-0505.

Sound Level Meters

- basic, inexpensive - commercial electronics stores (e.g., Radio Shack),
- moderate price – industrial and safety supply store (e.g. Acklands-Grainger Inc., Fleck Bros.),
- higher priced, more accurate, some with logging capabilities:
  Instrumentation Sales and Rentals, Ontario, Phone 1-800 268-4928 ext. 23, website www.isre.com.
  Scantek Inc., USA, various brands of meters, website;
  www.scantekinc.com/soundmeters.htm
  Onno Sokki, USA/Canada, Phone; 630 627-9700, website;
  www.onosokki.co.jp/English/english.htm

Noise Control Services

Noise Control Consultants – professional engineering services in acoustical design and noise assessment and control:

- BKL Consultants Ltd., North Vancouver, Phone; 604 988-2508,
- Brown Strachan Associates, Vancouver, Phone; 604 689-0514,
- Wakefield Acoustics Ltd., Victoria, Phone 250 370-9302.

Noise Control Contractors – supply and installation of insulation, acoustical ceiling tiles and other acoustical products, construction of effective party walls etc.

- for listing of noise control and acoustics-related contractors in B.C see;
  http://bc.finditincanada.ca/app/data/Acoustical+Contractors.html

Government Services – environmental/community noise related issues, control of noise entering homes and within buildings;

- Canada Mortgage and Housing Corporation, website; www.cmhc-schl.gc.ca,
- Health Canada, Consumer and Clinical Radiation Protection, Healthy Environments and Consumer Safety Branch, www.hc-sc.gc.ca/hecs-sesc/hecs/
- National Research Council, Institute for Research in Construction, Ottawa, website, http://irc.nrc-cnrc.gc.ca/

APPENDIX D

REFERENCES AND RESOURCE MATERIALS

ON NOISE AND NOISE CONTROL

Documents, Reports

6. "Sound Insulation Issues", J.S. Bradley, National Research Council, Institute for Research in Construction, Ottawa, NRCC-47054, April 2004,
7. "Laboratory Measurements of the Sound Insulation of Building Façade Elements", J.S. Bradley and J.A. Birta, National Research Council, Institute for Research in Construction, Ottawa, Interim Report IRC IR-818, October 2000,
8. "Guidelines for Community Noise", World Health Organization, Geneva, 1999,
9. "Sound Insulating Homes Against Aircraft Noise", J.S. Bradley, National Research Council, Institute for Research in Construction, Ottawa, NRCC-46396, August 1998,
10. "What You Can Do about Noise in British Columbia", Right to Quiet Society, Vancouver, B.C., April 1998,
11. "Acoustics and Noise Control Handbook for Architects and Builders", Leland K. Irvine and Roy L. Richards, Krieger Publishing Company, Malabar Florida, 1998,
12. "City Noise – Report of the Urban Noise Task Force", City of Vancouver, April 1997,
13. "Revised Policy for Mitigating the Effects of Traffic Noise from Freeways and Expressways", Province of British Columbia, Ministry of Transportation and Highways, Highway Environment Branch, November 1993,
14. "National Guidelines for Environmental Noise Control", Health and Welfare Canada, Environmental Health Directorate, Health Protection Branch, Cat No. H49-37/1989E, March 1989,
15. "Road and Rail Noise: Effects on Housing" Canada Mortgage and Housing Corporation, NHA 5156 08/86, Ottawa, 1986,
16. "Insulation of Buildings Against Highway Noise", U.S. Department of Transportation, Federal Highway Administration, FHWA-TS-77-202, Reprinted February 1979,
17. "Guide to the Soundproofing of Existing Homes Against Exterior Noise", U.S. Department of Transportation, Federal Highway Administration, October, 1977,
18. "Information on Levels of Environmental Noise Requisite to Protect Public Health and Welfare with an Adequate Margin of Safety", U.S. Environmental Protection Agency, NTIS Doc. No. PB-239429/AS, March, 1974.

Acoustics and Noise Organizations and Websites

1. Acoustical Society of America www.asa.aip.org
2. Canadian Acoustical Association www.caa-aca.ca
3. Health Canada, Consumer and Clinical Radiation Protection, Healthy Environments and Consumer Safety Branch, 775 Brookfield Rd., 6301B, Ottawa, Ontario, K1A 1C1, www.hc-sc.gc.ca/hecs-sesc/hecs/
4. Institute of Noise Control Engineering (INCE) www.inceusa.org,
5. Institute for Research in Construction, National Research Council, C http://irc.nrc-cnrc.gc.ca,
6. National Hearing Conservation Association www.hearingconservation.org,
7. National Council of Acoustical Consultants www.ncac.com,
8. Noise & Acoustics www.quiet.uk,
9. Noise Pollution Clearing House www.nonoise.org,
10. Right to Quiet Society www.quiet.org,
11. www.noisenet.org,

APPENDIX E

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