

Appendix 4

Sample Noise Reduction Standards for Residential Construction

Source: "Eastern Carolina Joint Land Use Study, Prepared for Craven County, Carter County, City of Havelock, Town of Emerald Isle, Town of Bogue, Town of Atlantic, and MCAS Cherry Point by the Eastern Carolina Council, Region P council of Governments; November 2002.

Note: Standards differ by geographic region.

SOUND INSULATION IN RESIDENTIAL STRUCTURES

DEFINITION

Sound insulation refers to the use of acoustical related building materials for the reduction of noise for architectural abatement purposes. These materials apply to any areas of a structure that may be part of a sound transmission path including windows, doors, roof systems, ventilation, wall systems (exterior), and utility access points through a building envelope.

CHARACTERISTICS

The application of sound insulation techniques can involve existing and/or planned structures or buildings. Often the benefits for noise control, such as double pane windows have additional benefits in terms of energy conservation and reduced heat loss. The primary objective of an airport sound insulation program is to reduce the sound transmission through the building envelope (e.g., exterior wall, window, and roof system), thereby having lower interior noise levels. The implementation of such a program may be the adoption of a building code or performance requirements established by a public agency.

POSITIVE FEATURES

The primary benefit of a sound insulation program is to protect the noise receiver, while they are indoors. Frequently, there are associated benefits of energy conservation when there is building insulation. Such efforts have the flexibility of applying to both existing structures, as well as buildings that will be constructed. Therefore, it can be more comprehensive than a building code. Since building codes generally are applicable only to planned or new structures.

NEGATIVE FEATURES

Sound insulation controls apply directly to a structure. Therefore it does not improve the outdoor environments, when the individual is outside the home. Often times, sound insulation is considered for selected areas or buildings, rather than being a comprehensive approach.

LEGAL STANDING

Sound insulation programs are frequently mandates for certain geographical areas as a policy of a jurisdiction with matching federal and local funds involved. Since a program is adopted by a jurisdiction it does represent legal standing.

Sound Attenuation Definitions

DNL Day - Night Sound Level:

An average of the cumulative measure of the noise exposure during a 24-hour day.

Exterior Wall Rating:

EWR is a single-number rating for exterior building elements (such as walls, windows, doors, etc.) and represents the effective sound transmission loss capability, in decibels, of each element. It differs from the STC rating in that it is based on aircraft noise rather than office noise spectra. For this reason, EWR is superior to STC for describing the sound-insulating properties of exterior wall elements exposed to aircraft noise. The EWR concept was developed by Wylie Laboratories and has been used extensively in studies of residential sound insulation. It is conceptually similar to the STC rating method. Like TL and SIC, the higher the EWR value, the better the noise reduction.

Noise Reduction:

The quantitative measure of sound isolation between spaces is called Noise Reduction (NR). The NR between two spaces, such as from the exterior to the interior of a dwelling, depends on the TL of the various components in the separating wall, the area of the separating wall, and the acoustical absorption in the receiving room. This value takes more into account than just the sound transmission characteristics of the wall material. Generally, values of NR are determined in one-third octave bands. A higher NR gives a lower noise level in the receiving room, indicating greater noise insulation.

Noise Level Reduction:

NLR is used to describe the reduction of environmental noise sources, such as aircraft. It is a single-number metric based on values of A-weighted noise reduction (NR). The greater the sound insulation in a wall, the lower the noise level in the receiving room, giving a higher NLR. The NLR is useful because it is a simpler metric to use than NR; one number is easier to apply than a set of numbers in one-third octave bands. However some building materials and components are more effective at reducing low-frequency noise than other materials or components. Since aircraft noise contains a lot of low frequency sound, it is important to ensure that insulating materials and components perform well at low frequencies. NLR is a good indicator of overall wall performance but may not be appropriate when designing modifications for aircraft noise reduction, especially if a good NLR value disguises poor low frequency insulation.

Sound Transmission Class:

Since working with a series of one-third octave TL measurements can be cumbersome, a single number descriptor based on the one-third octave values has been developed. This rating method is called the Sound Transmission Class (STC). Like TL, the higher the STC rating for a construction method or component, the higher the sound insulation. Originally, STC ratings were developed as a single-number descriptor for the TL of interior office walls for typical office noise and speech spectra. Now, they are used, often incorrectly, for exterior walls as well. Most acoustical materials and components are commonly specified in terms of their STC ratings.

Sound Transmission Loss:

This is the physical measure, which describes the sound insulation value of a built construction system or component. It is a measure, on a logarithmic scale, of the ratio of the acoustic sound power incident on the tested piece to the acoustic sound power transmitted through it. The TL is expressed in decibels (dB). Generally, TL is measured as a function of frequency in one-third octave frequency bands. The higher the sound insulation, the less sound will be transmitted, resulting in a higher TL value. Values of TL are determined in acoustical laboratories under controlled testing methods prescribed by the American Society of Testing and Materials (ASTM).

Sound Insulation Objectives

The goal for residential sound insulation is to reduce the dwelling interior noise levels due to aircraft operations. Total "soundproofing" of the dwelling, such that aircraft operations are inaudible, is economically infeasible. Modest improvements over the existing characteristics (i.e. less than 5 dB) may not provide a noticeable improvement for the homeowner and hence are not cost effective. The ideal solution is to provide sound insulation, which lies between these two extremes.

Interior Noise Objectives

The DNL is the best predictor of overall long-term community reaction to noise from aircraft as well as other activities. Exterior noise exposure less than DNL 65 dB is normally considered compatible with residential land use. Noise exposure is normally incompatible above 65 dB unless stated noise reductions are achieved within the dwellings. A 25 dB NLR is required in the noise zone from 65 to 70 dB. From 70 to 75 dB, a 30 NLR is required. Above 75 dB, residential land use is generally deemed incompatible and should be discouraged.

Sometimes, the DNL noise reduction goal in habitable rooms is supplemented by a single-event noise level criterion. This Sound Exposure Level (SEL) reflects the annoyance associated with individual flyovers because of activity interference. The SEL goal is 65 dB in general living spaces and 60 dB in bedrooms and television viewing rooms. These criteria are only applied to homes within the DNL defined noise impact area, not to homes outside the 65 dB DNL contour boundaries.

To use the SEL interior noise criteria, the outside noise exposure level is compared to the interior goal. For example, if the dwelling were between the SEL contour boundaries of 85 to 90 dB, then the required NLR to achieve 60 dB in a bedroom would be 30 dB. (The conservative upper bound of the noise zone is normally used to set NLR goals.)

Room Variations

The noise level of different rooms in a house depends on the absorption within the room, as well as on the noise entering from outside. Upholstered furniture, drapes, and carpeting absorb sound while hard surfaces do not. In addition, different categories of rooms vary on how predictable their sound environments are. Living rooms, for example, tend to be consistent from one house to another because they almost always have the same types of furnishings in them. Bedrooms vary because some are guest rooms with less furniture, and some have been converted to other uses. Kitchens tend to vary widely due to the use of different wall coverings, such as cabinets and appliances, or floor coverings, such as tile or carpet. These room

variations act in addition to variation in exterior sound level and sound transmission through the outside wall.

Sound Insulation Concept

Sound Transmission

In order to effectively examine noise control measures for dwellings it is helpful to understand how sound travels from the exterior to the interior of the house. This happens in one of two basic ways: through the solid structural elements and directly through the air. Consider the sound transmission through a wall constructed with a brick exterior, stud framing, interior finish wall and absorbent material (insulation) in the cavity. The sound transmission starts with noise impinging on the wall exterior. Some of this sound energy will be reflected away and some will make the wall vibrate. The vibrating wall radiates sound into the airspace, which in turn sets the interior finish surface vibrating, with some energy lost in the airspace. This surface then radiates sound into the dwelling interior. Vibration energy also bypasses the air cavity by traveling through the studs and edge connections. Openings in the dwelling, which provide air infiltration paths through windows, vents, and leaks, allow sound to travel directly to the interior. This is a very common and often overlooked source of noise intrusion.

Flanking is a similar concept and usually refers to sound passing around a wall. Examples of common flanking paths include: air ducts, open ceiling or attic plenums, continuous sidewalls and floors, and joist and crawlspaces. The three different major paths for noise transmission into a dwelling are air infiltration through gaps and cracks, secondary elements such as windows and doors, and primary building elements such as walls and the roof.

Low-frequency sound is most efficiently transmitted through solid structural elements such as walls, roof, doors, and windows. High frequencies travel best through the air gaps. Within these broad categories, different building materials have different frequency responses to sound and varying abilities to insulate against sound.

Reducing Transmitted Sound

The amount of sound energy transmitted through a wall, roof or floor can be limited in several ways. First, all air infiltration gaps, openings, and possible flanking paths must be eliminated wherever possible. This is the single most important, but occasionally overlooked, step in noise reduction. This includes keeping windows and doors closed and putting baffles on open-air vents.

Some materials reflect more of the incident sound, converting less of it into vibration energy. The mass of the exterior and interior panels influences how much sound will pass through them. The more mass a structural element has the more energy it takes to set it into vibration, so adding weight to a wall or ceiling by attaching a gypsum board layer will make the assembly pass less sound. Then, absorption in the air cavity and resilient mounting of interior finish panels can further reduce the sound transmitted to the room. The primary approaches for improving sound isolation are:

1. Elimination of openings and flanking paths (when accessible).
2. Improvement of windows and doors.
3. Massive construction (build a wall 3 feet thick and 40 feet high around the whole house).
4. Isolation of panel elements through separation or resilient mounting.
5. Absorption.

Problem Areas

Sound intrusion problems are commonly caused by:

1. Building construction components and configurations not providing sufficient sound insulation.
2. Structural elements, such as windows, doors, walls, roofs and floors chosen and combined in an unbalanced way so that some parts are much weaker sound insulators than others.
3. Unintended openings or sound-flanking paths caused by deterioration or improper installation of construction elements.

Balanced Acoustical Design

The most important, or controlling, sound paths must be identified in order to know how to construct or modify a dwelling to meet a specified noise criteria. The ideal sound insulation design would achieve a condition where all the important sound paths transmit the same amount of acoustical energy. This eliminates any weak links in the building's insulation envelope and is commonly referred to as a balanced acoustical design.

In most cases, after leaks and gaps are sealed, the windows are the controlling sound paths. Replacing them with acoustical windows typically does more to improve the sound insulation performance than any other architectural modifications. Once this is done the other elements may become important in meeting specific noise reduction goals. Exterior doors often require improved sound insulation. Ceilings and walls, which face the exterior, may require modification as well, particularly in the higher DNL noise zone.

New Versus Old

Dwellings can vary in their sound isolation performance. Generally, air infiltration, and therefore sound infiltration, around windows and doors tends to be worse for older dwellings. Inadequate or deteriorated weather-stripping and misaligned framing usually cause this. On the other hand, most older construction techniques and materials tend to be more massive than newer lighter-weight construction. As a result, many older buildings tend to perform better with regard to sound transmission through walls, roofs, and floors than do new houses. Homeowner modifications can also degrade the dwelling's sound insulation performance. Examples include home improvements such as skylights, whole-house attic fans, through-the-wall air conditioners, and solariums. In general, it is much more efficient, and cost effective, to take acoustic performance into account when designing and building a home at the start. Remodeling an already built home is more costly and time consuming than anticipating and building for good sound insulation.

While homes, which are well insulated thermally, often perform well acoustically, thermal insulation is not always a good indicator of sound insulation. Many thermal windows, installed in new construction or added as a homeowner upgrade provide little sound insulation when compared to walls or acoustical windows and are frequently the weak link in the building envelope. However thermal treatments usually eliminate air infiltration and may serve to improve the acoustical performance of a dwelling. Thermal insulation batts are often useful in the wall cavities and attic spaces to absorb some sound.

Most homes today are constructed using double pane windows. Although the windows perform well thermally, they usually do not perform well acoustically. The panes are separated by approximately 1/2 inch of air space and thin panes of glazing are used. The thin panes of glazing allow for vibration and the vibrations are transmitted through the air space to the interior glazing and into the home.

Recommended Building Requirements

Recommended Building Requirements for a Minimum NLR of 25 dB

Compliance with the following standards shall be deemed to meet the requirements of the compatible use districts in which an NLR 25 is specified.

General:

- a. Brick veneer, masonry blocks, or stucco exterior walls shall be constructed airtight. All joints shall be grouted or caulked airtight, except weep holes for drainage.
- b. At the penetration of exterior walls by pipes, ducts, or conduits, the space between the wall and pipes, ducts, or conduits shall be caulked or filled with mortar.
- c. Window and/or through-the-wall ventilation units shall not be used.
- d. Through-the-wall/door mailboxes shall not be used.

Exterior Walls:

- a. Exterior walls other than as described in this section shall have a laboratory sound transmission class rating of at least STC-39.
- b. Masonry walls having a surface weight of at least 25 pounds per square foot do not require a furred (stud) interior wall. At least one surface of concrete block walls shall be plastered or painted with heavy "bridging" paint.
- c. Stud walls shall be at least 4" in nominal depth and shall be finished on the outside with siding-on-sheathing, stucco, or brick veneer.

(1) Interior surface of the exterior walls shall be of gypsum board or plaster at least 1/2" thick, installed on the studs.

(2) Continuous composition board, plywood, or gypsum board sheathing at least 1/2" thick shall cover the exterior side of the wall studs behind wood or metal siding. Asphalt or wood shake shingles are acceptable in lieu of siding.

(3) Sheathing panels shall be butted tightly and covered on the exterior with

overlapping building paper. The top and bottom edges of the sheathing shall be sealed.

(4) Insulation material at least 2" thick shall be installed continuously throughout the cavity space behind the exterior sheathing and between wall studs. Insulation shall be glass fiber or mineral wool.

Windows:

- a. Windows other than as described in this section shall have a laboratory sound transmission class rating of at least STC-28.
- b. Glass shall be at least 3/16" thick.
- c. All operable windows shall be weather stripped and airtight when closed so as to conform to an air infiltration test not to exceed 0.5 cubic foot per minute per foot of crack length in accordance with ASTM E-283-65-T.
- d. Glass of fixed-sash windows shall be sealed in an airtight manner with a non-hardening sealant, or a soft elastomer gasket, or glazing tape.
- e. The perimeter of window frames shall be sealed airtight to the exterior wall construction with a sealant conforming to one of the following Federal Specifications: TT-S-00227, TT-S-00230, or TT-S-00153.
- f. The total area of glass in both windows and doors in sleeping spaces shall not exceed 20% of the floor area.

Doors:

- a. Doors, other than as described in this section shall have a laboratory sound transmission class rating of at least STC-28.
- b. All exterior side-hinged doors shall be solid-core wood or insulated hollow metal at least 1-3/4" thick and shall be fully weather-stripped.
- c. Exterior sliding doors shall be weather stripped with an efficient airtight gasket system. The glass in the sliding doors shall be at least 3/16" thick.
- d. Glass in doors shall be sealed in an airtight non-hardening sealant, or in a soft elastomer gasket or glazing tape. The perimeter of doorframes shall be sealed airtight to the exterior wall construction.

Roofs:

- a. Combined roof and ceiling construction other than described in this section shall have a laboratory sound transmission class rating of at least STC-39.
- b. With an attic or rafter space at least 6" deep, and with a ceiling below, the roof shall consist of closely butted 1/2" composition board, plywood, oriented strand board or gypsum board sheathing, topped by roofing as required.
- c. If the underside of the roof is exposed, or if the attic or rafter spacing is less than 6", the roof construction shall have a surface weight of at least 25 pounds per square foot. Rafters, joists, or other framing may not be included in the surface weight calculation.
- d. Window or dome skylights shall have a Laboratory sound transmission class rating of at least STC-28.

Ceilings:

- a. Gypsum board or plaster ceilings at least 1/2" thick. Ceilings shall be

- substantially airtight, with a minimum number of penetrations.
- b. Glass fiber or mineral wool insulation at least 2" thick shall be provided above the ceiling between joists.

Floors:

Openings to any crawl spaces below the floor of the lowest occupied rooms shall not exceed 2% of the floor area of the occupied rooms.

Ventilation:

- a. A mechanical ventilation system shall be installed that will provide the minimum air circulation and fresh air supply requirements for various uses in occupied rooms without the need to open any windows, doors, or other openings to the exterior.
- b. Gravity vent openings in attic shall not exceed code minimum in number and size.
- c. If a fan is used for forced ventilation, the attic inlet and discharge openings shall be fitted with sheet metal transfer ducts of at least 20 gauge steel, which shall be lined with coated glass fiber 1" thick, and shall be at least 5 ft long with one 90 degree bend.
- d. All vent ducts connecting the interior space to the outdoors, except domestic range exhaust ducts, shall contain at least a 5 ft. length of internal sound absorbing duct lining. Each duct shall be provided with a bend in the duct such that there is no direct line of sight through the duct from the venting cross section to the room-opening cross section.
- e. Duct lining shall be coated glass fiber duct liner at least 1" thick.
- f. Domestic range exhaust ducts connecting the interior space to the outdoors shall contain a baffle plate across the exterior termination, which allows proper ventilation. The dimensions of the baffle plate should extend at least one diameter beyond the line of sight into the vent duct. The baffle plate shall be of the same material and thickness as the vent duct material.
- g. Fireplaces shall be provided with well-fitted dampers.

Recommended Building Requirements for a Minimum NLR of 30dB

Compliance with the following standards shall be deemed to meet the requirements of the compatible use districts in which an NLR 30 is specified.

General:

- a. Brick veneer, masonry blocks, or stucco exterior walls shall be constructed airtight. All joints shall be grouted or caulked airtight.
- b. At the penetration of exterior walls by pipes, ducts, or conduits, the space between the wall and pipes, ducts, or conduits shall be caulked or filled with mortar.
- c. Window and/or through-the-wall ventilation units shall not be used.
- d. Operational fireplaces shall not be used.
- e. All sleeping spaces shall be provided with either a sound absorbing ceiling or a carpeted floor.
- f. Through-the-wall/door mailboxes shall not be used.

Exterior Walls:

- a. Exterior walls, other than as described below, shall have a laboratory sound transmission class rating of at least STC-44.
- b. Masonry walls having a surface weight of at least 40 pounds per square foot do not require a furred (stud) interior wall. At least one surface of concrete block walls shall be plastered or painted with heavy "bridging" paint.
- c. Stud walls shall be at least 4" in nominal depth and shall be finished on the outside with siding-on-sheathing, stucco, or brick veneer.
 - (1) Interior surface of the exterior walls shall be of gypsum board or plaster at least 1/2" thick, installed on the studs. The gypsum board or plaster may be fastened rigidly to the studs if the exterior is brick veneer or stucco. If the exterior is siding-on-sheathing, the interior gypsum board or plaster must be fastened resiliently to the studs.
 - (2) Continuous composition board, plywood or gypsum board sheathing shall cover the exterior side of the wall studs behind wood or metal siding. The sheathing and facing shall weigh at least 4 pounds per square foot.
 - (3) Sheathing panels shall be butted tightly and covered on the exterior with overlapping building paper. The top and bottom edges of the sheathing shall be sealed.
 - (4) Insulation material at least 2" thick shall be installed continuously throughout the cavity space behind the exterior sheathing and between wall studs. Insulation shall be glass fiber or mineral wool.

Windows:

- a. Windows, other than as described in this section, shall have a laboratory sound transmission class rating of at least STC-33.
- b. Glass of double-glazed windows shall be at least 1/8" thick. Panes of glass shall be separated by a minimum 3/4" air space.
- c. Double-glazed windows shall employ fixed sash or efficiently weather-stripped operable sash. The sash shall be rigid and weather-stripped with material that is compressed air tight when the window is closed so as to conform to an infiltration test not to exceed 0.5 cubic foot per minute per foot of crack length in accordance with ASTM E-283-65-T.
- d. Glass of fixed-sash windows shall be sealed in an airtight manner with a non-hardening sealant, or a soft elastomer gasket, or glazing tape.
- e. The perimeter of window frames shall be sealed airtight to the exterior wall construction with a sealant conforming to one of the following Federal Specifications: TT-S-00227, TT-S-00230, or TT-S-00153.
- f. The total area of glass of both windows and exterior doors in sleeping spaces shall not exceed 20% of the floor area.

Doors:

- a. Doors, other than as described in this section, shall have a laboratory sound transmission class rating of at least STC-33.
- b. Double door construction is required for all door openings to the exterior. Openings fitted with side-hinged doors shall have one solid-core wood or insulated hollow metal core door at least 1-3/4" thick, separated by an airspace of at least 4" from another door, which can be a storm door. Both

- doors shall be tightly fitted and weather-stripped.
- c. The glass of double-glazed sliding doors shall be separated by minimum 3/4" airspace. Each sliding frame shall be provided with an efficiently airtight weather stripping material.
 - d. Glass of all doors shall be at least 3/16" thick. Glass of double sliding doors shall not be equal in thickness.
 - e. The perimeter of doorframes shall be sealed airtight to the exterior wall construction.
 - f. Glass of doors shall be set and sealed in an airtight, non-hardening sealant, or a soft elastomer gasket, or glazing tape.

Roofs:

- a. Combined roof and ceiling construction other than described in this section shall have laboratory sound transmission class rating of at least STC-44.
- b. With an attic or rafter space at least 6" deep, and with a ceiling below, the roof shall consist of closely butted 1/2" composition board, plywood, oriented strand board or gypsum board sheathing topped by roofing as required.
- c. If the underside of the roof is exposed, or if the attic or rafter spacing is less than 6", the roof construction shall have a surface weight of at least 40 pounds per square foot. Rafters, joists or other framing may not be included in the surface weight calculations.
- d. Window or dome skylights shall have a laboratory sound transmission class rating of at least STC-33.

Ceilings:

- a. Gypsum board or plaster ceilings at least 1/2" thick shall be provided
- b. Glass fiber or mineral wool insulation at least 2" thick shall be provided above the ceiling between joists.

Floors:

- a. The floor of the lowest occupied rooms shall be slab on fill, below grade, or over a fully enclosed basement. All door and window openings in the fully enclosed basement shall be tightly fitted.

Ventilation:

- a. A mechanical ventilation system shall be installed that will provide the minimum air circulation and fresh air supply requirements for various uses in occupied rooms without the need to open any windows, doors, or other openings to the exterior.
- b. Gravity vent openings in attic shall not exceed code minimum in number and size. The openings shall be fitted with transfer ducts at least 3 ft in length containing internal sound absorbing duct lining. Each duct shall have a lined 90-degree bend in the duct such that the line of sight is interrupted from the exterior through the duct into the attic.
- c. If a fan is used for forced ventilation, the attic inlet and discharge openings shall be fitted with sheet metal transfer ducts of at least 20 gauge steel, which shall be lined with coated glass fiber 1" thick, and shall be at least 5 ft long with one 90 degree bend.
- d. All vent ducts connecting the interior space to the outdoors, except domestic

range exhaust ducts shall contain at least a 10 ft. length of internal sound absorbing duct lining. Each duct shall be provided with a lined 90-degree bend in the duct such that there is no direct line of sight through the duct from the venting cross section to the room opening cross section.

- e. Duct lining shall be coated glass fiber duct.
- f. Domestic range exhaust ducts connecting the interior space to the outdoors shall contain a baffle plate across the exterior termination, which allows proper ventilation. The dimensions of the baffle plate should extend at least one diameter beyond the line of sight into the vent duct. The baffle plate shall be made of the same material and thickness as the vent duct material.
- g. Building heating units with flues or combustion air vents shall be located in a closet or room closed off from the occupied space by doors.
- h. Doors between occupied space and mechanical equipment areas shall be solid core wood or 20 gauge steel hollow metal at least 1-3/4" thick and shall be fully weather-stripped.

Recommended Building Requirements for a Minimum NLR of 35dB

Compliance with the following standards shall be deemed to meet the requirements of the compatible use districts in which an NLR 35 is specified

General:

- a. Brick veneer, masonry blocks or stucco exterior walls shall be constructed airtight. All joints shall be grouted or caulked airtight.
- b. At the penetration of exterior walls by pipes, ducts or conduits, the space between the wall and pipes, ducts or conduits shall be caulked or filled with mortar.
- c. Window and/or through-the-wall ventilation units shall not be used.
- d. Operational vented fireplaces shall not be used.
- e. All sleeping spaces shall be provided with either a sound absorbing ceiling or a carpeted floor.
- f. Through-the-wall/door mailboxes shall not be used.
- g. No glass or plastic skylight shall be used.

Exterior Walls:

- a. Exterior walls other than as described below shall have a laboratory sound transmission class rating of at least STC-49.
- b. Masonry walls having a surface weight of at least 75 pounds per square foot do not require a furred (stud) interior wall. At least one surface of concrete block walls shall be plastered or painted with heavy "bridging" paint.
- c. Stud walls shall be at least 4" in nominal depth and shall be finished on the outside with siding-on-sheathing, stucco, or brick veneer.

(1) Interior surface of the exterior walls shall be of gypsum board or plaster at least 1/2" thick, installed on studs, The gypsum board or plaster may be fastened rigidly to the studs if the exterior is brick veneer. If the exterior is stucco or siding-on-sheathing, the interior gypsum board or plaster must be fastened resiliently to the studs.

(2) Continuous composition board, plywood or gypsum board sheathing

shall cover the exterior side of the wall studs behind wood or metal siding. The sheathing and facing shall weigh at least 4 pounds per square foot.

- (3) Sheathing panels shall be butted tightly and covered on the exterior with overlapping building paper. The top and bottom edges of the sheathing shall be sealed.
- (4) Insulation material at least 3-1/2" thick shall be installed continuously through the cavity space behind the exterior sheathing and between wall studs. Insulation shall be glass fiber or mineral wool.

Windows:

- a. Windows other than as described in this section shall have a laboratory sound transmission class rating of at least STC-38.
- b. Glass of double-glazed windows shall be at least 1/8" thick; Panes of glass shall be separated by a minimum 3/4" air space and shall not be equal in thickness.
- c. Glass of windows shall be sealed in an airtight manner with a non-hardening sealant, or a soft elastomer gasket or glazing tape.
- d. The perimeter of window frames shall be sealed airtight to the exterior wall construction with a sealant conforming to one of the following Federal Specifications: TT-S-00227, TT-S-00230, or TT-S-00153.
- e. The total area of glass of both windows and exterior doors in sleeping spaces shall not exceed 20% of the floor area.

Doors:

- a. Doors, other than as described in this section, shall have a laboratory sound transmission class rating of at least STC-38.
- b. Double door construction is required for all door openings to the exterior. The door shall be side-hinged and shall be solid-core wood or insulated hollow metal, at least 1-3/4" thick, separated by a vestibule at least 3 ft in length. Both doors shall be tightly fitted and weather-stripped.
- c. The perimeter of doorframes shall be sealed airtight to the exterior wall construction.

Roofs:

- a. Combined roof and ceiling construction other than described in this section and Section 3-7 shall have a laboratory sound transmission class rating of at least STC-49.
- b. With an attic or rafter space at least 6" deep, and with a ceiling below, the roof shall consist of closely butted 1/2" composition board, plywood, oriented strand board or gypsum board sheathing topped by roofing as required.
- c. If the underside of the roof is exposed, or if the attic or rafter spacing is less than 6" the roof construction shall have a surface weight of at least 75 pounds per square foot. Rafters, joists or other framing may not be included in the surface weight calculation.

Ceilings:

- a. Gypsum board or plaster ceilings at least 1/2" thick shall be provided where

required by Paragraph 3-6. Ceilings shall be substantially airtight, with a minimum number of penetrations. The ceiling panels shall be mounted on resilient clips or channels. A non-hardening sealant shall be used to seal gaps between the ceiling and walls around the ceiling perimeter.

- b. Glass fiber or mineral wool insulation at least 3 1/2" thick shall be provided above the ceiling between joists.

Floors:

The floors of the lowest occupied rooms shall be slab on fill or below grade.

Ventilation:

- a. A mechanical ventilation system shall be installed that will provide the minimum air circulation and fresh air supply requirements for various uses in occupied rooms without need to open any windows, doors, or other openings to the exterior.
- b. Gravity vent openings in attic shall not exceed code minimum in number and size. The opening shall be fitted with transfer ducts at least 6 ft. in length containing internal sound absorbing duct lining. Each duct shall have a lined 90-degree bend in the duct such that there is no direct line of sight from the exterior through the duct into the attic.
- c. If a fan is used for forced ventilation, the attic inlet and discharge openings shall be fitted with sheet metal transfer ducts of at least 20 gauge steel, which shall be lined with 1" thick coated glass fiber, and shall be at least 10 ft long with one 90 degree bend.
- d. All vent ducts connecting the interior space to the outdoors, excepting domestic range exhaust ducts, shall contain at least a 10 ft length of internal sound absorbing duct lining. Each duct shall be provided with a lined 90-degree bend in the duct such that there is no direct line of sight through the duct from the venting cross section to the room-opening cross section.
- e. Duct lining shall be coated glass fiber duct liner at least 1" thick.
- f. Domestic range exhaust ducts connecting the interior space to the outdoors shall contain a baffle plate across the exterior termination, which allows proper ventilation. The dimensions of the baffle plate should extend at least one diameter beyond the line of sight into the vent duct. The baffle plate shall be of the same material and thickness as the vent duct material.
- g. Building heating units with flues or combustion air vents shall be located in a closet or room closed off from the occupied space by doors.
- h. Doors between occupied space and mechanical equipment areas shall be solid core wood or 20 gauge steel hollow metal at least 1-3/4" thick and shall be fully weather-stripped.

Methods for Exterior Wall Sound Insulation in New Homes

Typically, most wall construction consists of a 3.5-inch stud cavity with studs spaced 16 inches on center, 5/8-inch gypsum drywall on the interior, 7/16 structural sheathing on the exterior and either siding or brick veneer as the finish on the exterior. Consider using the construction techniques below:

1. Increase the wall stud cavity to 5.5-inches, spaced 24 inches on center. The increased depth of the stud cavity will allow for the installation of R-19

insulation.

2. When considering the type of insulation material, consider using cellulose insulation material. This material is of a higher density. The method of installation is a spray method that tends to completely fill the cavity without voids.
3. Prior to the installation of insulation material in the walls, seal all penetrations through the top and bottom plates. Remember if air can enter, so can sound. Seal all penetrations through the bottom plate with caulk. Seal all penetrations through the top plate with caulking materials meeting the requirements of ASTM E-136.
4. Increase the thickness of the interior wall finish from 1/2-inch to 5/8-inch gypsum wallboard.
5. Caulk around all openings through the drywall such as receptacles, switches, plumbing drains, etc.
6. Increase the thickness of the exterior sheathing material to 5/8-inch or thicker material.
7. Consider using brick veneer instead of siding material for the exterior finish. Insure at least a one-inch air space between the brick veneer and the siding.
8. If siding is to be used, avoid using vinyl siding. Choose siding with a higher density such as Hardiplank, or wood siding. Install 30-pound felt between the siding and sheathing lapped 2 inches on horizontal joints and 6 inches on vertical joints.
9. If vinyl siding is a must, install 1/4-thick fanfold insulation board between the siding and sheathing.
10. Avoid large openings or breaks in continuity in the walls, such as large windows.
11. Install bathroom vent and kitchen hood vents on the side of the home away from the flight track. Make sure that vent terminations have an automatic closure on the end. Always use metal pipe for the vent pipe.

Methods for Improving Attic and Ceiling Sound Insulation In New Homes

1. Consider using energy trusses. Energy trusses allow for the installation of ceiling insulation to a full depth along the plate lines at exterior walls.
2. Install baffles on attic vents where practical.
3. Install acoustically absorptive material to a thickness equal to R-38 to the attic space to reduce reverberant sound level buildup. Apply material evenly throughout the attic space, taking care to keep it away from eave vents and openings. Consider the use of cellulose insulation. This material fills the cavity without leaving voids in the material and is of a higher density than fiberglass.

4. Install 5/8-inch gypsum board as the interior ceiling finish.
5. Caulk around all penetrations through the ceiling membrane such as light fixtures.
6. Avoid the use of "can-type — recessed light" light fixtures.
7. Avoid the use of true exposed wood beams on the ceiling. This creates a continuous path for sound through the ceiling structure.
8. Avoid the use of whole house exhaust fans in the ceiling.

Methods for Improving Floor Sound Insulation In New Homes

1. Install R-30 insulation batts between the joists.
2. Seal all penetrations through the floor assembly such as Heating and Air Conditioning supplies; exhaust ducts such as down draft exhaust from dryers and ranges, etc.
3. Install foundation vents of the swing cover awning type instead of the horizontal slider type.
4. Consider a sealed crawlspace and insulate the foundation walls, If this method is chosen, caulk between the mudsill and the foundation.

Methods for Improving Window Sound Insulation in New Homes

1. The most effective method of reducing sound transmission by a window is by increasing thickness of the glass panes. Basically, thicker is better. Thicker glass tends to bend less, and therefore vibrates less when exposed to sound waves. Using 6mm glass combinations or laminated glass is the simplest, most cost effective method of reducing sound transmission.
2. When choosing windows for your new home remember windows are generally the weakest link in sound attenuation
3. Choose windows that are double-glazed with panes at least 3/16 inch thick. Windows shall be double glazed with panes at least three/sixteenths inch (**3/16"**) thick. Panes of glass should be separated by a minimum one-half inch (**1/2"**) airspace, and should not be equal in thickness.
4. Double glazed windows should employ fixed sash or efficiently weather-stripped, operable sash. The sash shall be rigid and weather-stripped with material that is compressed airtight when the window is closed.
5. Glass should be sealed in an airtight manner with a non-hardening sealant or a soft elastomer gasket or gasket tape.

6. The perimeter of the window frames should be sealed airtight to the exterior wall construction with a sealant. The usual installation of windows employs stuffing the void between the window and framing with fiberglass insulation. The use of a sealant on top of the insulation material acts as an air infiltration barrier. Insulation by itself is not a good air infiltration barrier. Remember, if air can pass through, so can sound.
7. Avoid large picture windows and sliding glass doors on sides of the dwelling, which face the flight track.

Methods for Improving Door Sound Insulation in New Homes

1. Double door construction should be considered for all hinged door openings to the exterior. Such doors should be side hinged and shall be solid core wood or insulated hollow metal at least one and three-fourths inch (1-3/4") thick separated by an airspace of at least three inches (3") from another door, storm door. Both doors shall be tightly fitted and weather-stripped.
2. All doors, shall be at least three-sixteenths (3/16") thick. Glass of double sliding doors shall not be of equal thickness.
3. The perimeter of doorframes shall be sealed airtight to the exterior wall construction (framing). Stuff the gap between the doorframe and the framing with insulation and seal with a non-hardening caulk. Remember, if air can pass through, so can sound.
4. Glass in doors should be sealed in an airtight non-hardening sealant or in a soft elastomer gasket or gasket tape.

Methods for Improving Sound Insulation in Existing Homes

The best time to consider sound attenuation is during the construction of new homes. Retrofitting an existing home for sound attenuation can be costly. If one is considering retrofitting for sound attenuation, it is best done during a planned renovation project. As mentioned earlier in this guide, windows are generally the weakest link in sound attenuation. Some of the simpler and easiest ways to attain sound attenuation is by a combination of the following:

1. Add insulation in the attic to an overall R-Value thickness of R-38.
2. Caulk around all penetrations through the interior finishes. (Receptacles, light fixtures, plumbing drains, etc.)
3. Install single pane storm windows over existing single pane windows.
4. Install weather-stripping on all doors.
5. Employ any of the methods described in Methods for Improving Sound Attenuation in New Homes as the project allows.

Methods of Noise and Vibration Control In Residential HVAC Systems

1. Mount the motor/fan at grade level on factory-supplied vibration isolators to minimize vibration transmitted to the house.
2. If fans or other pieces of equipment are located in the attic, use mounting bases and vibration isolators to reduce structure borne noise and vibration transmission.
3. Install flexible duct connectors to limit vibration transmitted to the ductwork or the dwelling structure.
4. Use standard sheet metal ductwork in attics and crawlspaces. Ductwork is exposed to higher levels of aircraft noise in these spaces. Do not use flexible ductwork in attic spaces since it does not have as good sound-insulating properties as standard sheet metal.
5. Supply grilles in rooms should be of the opposed-blade type and be designed for low noise.
6. A duct sound trap (muffler) should be installed just inside the fresh-air inlet opening. The sound trap will reduce any aircraft noise that passes through this opening and will eliminate the possibility of aircraft noise being transmitted via the duct path.

COMPARISON OF COMPONENTS FOR SOUND ATTENUATION

Component	Regular	Sound Attenuation
Door		
3/0 X 6/8 insulated embossed 6 panel exterior steel door	\$ 175.00	175.00
Windows		
Length X Width United Inch = UI Windows compared are 1 over 1 with grids		
Up to 64 UI	\$214.00	\$222.90
64 to 69 UI	\$231.20	\$241.10
69 to 74 UI	\$248.40	\$259.30
74 to 79 UI	\$ 265.60	\$ 277.40
79 to 84 UI	\$282.80	\$295.60
84 to 89 UI	\$ 300.20	\$ 314.00
89 to 94 UI	\$317.30	\$332.00
94 to 99 UI	\$334.50	\$350.30
99 to 104 UI	\$352.00	\$368.00
Over IO4 UI	\$3.52 per UI	\$3.68perUi
Insulation/Sound Batting Walls		
3.5 inch stud cavity: R-13 Fiberglass Batt	\$ 0.36 psf	\$0.36 psf
3.5 inch stud cavity: R-13 Cellulose Sprayed	\$ 0.70	\$0.70 psf
5.5 inch stud cavity: R-19 Fiberglass Batt	\$ 0.39	\$0.39 psf
5.5 inch stud cavity: R-19 Cellulose Sprayed	\$ 0.90	\$ 0.90 psf
Insulation/Sound Batting Ceilings		
R-30 Fiberglass Batt	\$ 0.61 psf	\$ 0.61 psf
R-38 Fiberglass Batt	\$ 0.80 psf	\$ 0.80 psf
R-30 Fiberglass Blown	\$ 0.40 psf	\$ 0.40 psf
R-38 Fiberglass Blown	\$ 0.50 psf	\$ 0.50 psf
R-30 Cellulose Sprayed	\$ 0.32 psf	\$ 0.32 psf
R-38 Cellulose Sprayed	\$ 0.42 psf	\$ 0.42 psf
Drywall		
1/2 inch X 4 ft. X 12 ft.	\$ 8.98 per sheet	\$ 8.98 per sheet
5/8 inch X 4 ft X 12 ft.	\$10.56 per sheet	\$ 10.56 per sheet
Miscellaneous		
Seal/Caulk around 3/0 X 5/0 window with non-hardening caulk assuming 3/8-inch crack		\$ 5.00 per window
Seal/Caulk around 3/0 X 6/8 doors with non-hardening caulk assuming 3/8-inch crack		\$ 6.00 per door
Insulate metal exhaust duct on exterior of duct		\$ 2.50 per foot

Values in this table are for comparison only and are not intended to be a guaranteed price quote for any product.