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FINAL

NEW CONSTRUCTION ACOUSTICAL DESIGN GUIDE

Prepared for

MCAS Cherry Point

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1.0 Introduction

1.1 Background

Residences located near military airfields experience many economic and transportation benefits of the facility, but are unfortunately exposed to significant amounts of aircraft noise. However, using proper construction techniques and materials minimizes the impact of aircraft noise and reduces interference with regular indoor activities. This New Construction Acoustical Design Guide can assist builders, planning officials, building inspectors, and homeowners in incorporating specific noise level reduction features into the designs of new homes in the Marine Corps Air Station (MCAS) Cherry Point area. These features will help to ensure that new homes in the area provide an adequate noise level reduction to protect occupants from undesirable noise impacts.

For homes located in areas with high noise levels, standard building methods, even those that are designed for thermal efficiency, are normally inadequate to protect inhabitants from external noise. For this reason, building design and construction methods may have to be modified for noise-sensitive rooms such as bedrooms, kitchens, living rooms, and family rooms. These spaces are referred to as the habitable rooms in a house. Standard design and construction methods can typically be used for non-habitable rooms, such as garages, mudrooms, and breezeways unless they open directly to habitable rooms without interior doors in between the rooms.

This Design Guide provides recommendations for the design of dwellings in the vicinity of the airfield that may be constructed in the future. It is meant to be used in conjunction with noise overlay zones developed by the surrounding communities through the joint land use study process. This Guide was developed for new homes; different materials and techniques would be appropriate when renovating houses to achieve the noise level reduction goals. Construction guidelines are presented for the noise level reductions (NLRs) of 20, 25, 30, and 35 decibels.

The recommendations contained in this Guide were developed considering the unique characteristics of the aircraft that currently use MCAS Cherry Point. As a result, the recommendations would not be the same as those developed for communities near civilian airfields.

1.2 How to Use this Guide

This guide has been developed to be used by a variety of different professionals, as well as by interested homeowners. This guide is recommended for the following people:

- Planning Officials

- Plan Reviewers
- Building Inspectors
- Builders
- Homebuyers/Homeowners

Sections 2.0 Through 3.0

The main design guide sections include a brief overview of sound transmission paths into a home, a discussion of basic design principles, and subsections for each building element including walls, windows, doors, ceilings, attics, floors, basements, crawlspaces, and ventilation systems. The building element subsections include text, tables, and design detail drawings to illustrate various options for noise control.

Section 4.0

Specific design requirements are presented in a selection chart. Designs that achieve noise level reductions (NLR) of 20, 25, 30 and 35 dB are listed. The table in Section 4.0 tells the sound ratings of building materials that are needed to achieve the NLR design goals. Additional details are provided in Appendix A.

Section 5.0

This section discusses some of the assumptions used in developing the proposed design methods, as well as factors that would affect the accuracy of NLR predictions.

Appendices

The first appendix provides a description of design and construction methods necessary to achieve NLRs of 20, 25, 30, and 35 dB. It supplements and details the design requirements presented in Section 4.0. Once the reader is familiar with this Guide, Appendix A can be used as a stand-alone reference in implementing the designs. Appendices B and C will be useful to builders, as they provide information on many acoustical product manufacturers and certified test laboratories. Appendix D is a glossary that will be useful to all parties.

General Notes

This Guide seeks to provide clear, unambiguous direction that is practical and can be implemented with minimum additional cost. However, construction quality is especially important for maintaining the acoustical integrity of a design. For example, even a good window, if not installed properly, will allow a significant amount of noise into the building. High-quality construction standards are absolutely essential for these techniques to work effectively.

The design packages in Section 4.0 and Appendix A address typical home sizes and styles. The noise analysis used here makes assumptions about the number of exterior doors and the size of the windows with respect to the floor area. Unusual homes may require more specialized analysis to ensure compliance. For example, very small rooms with normal windows have a larger window-to-floor space ratio and may allow more noise intrusion than average sized rooms. Similarly, rooms with very large windows or a room with several windows and exterior doors may also allow more noise to enter. Unusually large windows would require better acoustical performance than is indicated in this report in order to meet the noise level reduction goals. Homes with large wrap-around porches may provide shielding from noise that the Guide will not anticipate. For these reasons, homes with unique features or with dimensions that differ significantly from the average may require the services of an acoustics consultant in order to ensure adequate noise reduction.

Individuals differ in their response to noise. In an aircraft noise-affected neighborhood, a number of residents are very annoyed by aircraft overflights, while quite a few others are not. If properly implemented, the recommendations in this Guide will reduce noise inside the home to levels that most people will find acceptable. The aircraft will still be discernible; sound insulation is not sound elimination. People will know that a plane is passing overhead but, with the techniques outlined in this Guide, the noise should not be so loud that it interferes with normal daily indoor activities. Those individuals, however, who are most sensitive to noise, may continue to be annoyed. Nevertheless, the number of people who perceive unacceptable indoor noise levels can be significantly reduced by the use of proper construction techniques.

House Types

In the MCAS Cherry Point area new homes could include:

- Single-family homes
- Modular single-family homes
- Manufactured ("HUD Code") single-family homes
- Townhouses
- Apartments (rental or condominium)

The recommendations in this guide apply to all of these types of homes, except to HUD Code homes. There are Federal requirements for the construction and safety of manufactured homes. The National Manufactured Housing Construction and Safety Standards Act of 1974 (Title VI of Pub. L. 93-383, 88 Stat. 700, 42 U.S.C. 5401, et seq.) required the U.S. Departments of Housing and Urban Development (HUD) to establish construction and safety standards for manufactured homes. The resulting Manufactured Home Construction and Safety Standards, generally referred to as the "HUD Code" (24 CFR 3280), regulate the design and construction of all manufactured homes in the U.S. A manufactured home (formerly known as a trailer or mobile home) by definition must have "continued transportability." In contrast, a modular home is assembled from panels and is installed on a site-built permanent foundation. Therefore, modular homes do not have continued transportability and are not covered by the HUD Code (see 24 CFR 3280.7). A manufacturer may elect to construct a structure that is both a manufactured and a modular home (see CFR 3282.12).

Only the HUD Code can be used to limit the construction of manufactured homes, with certain exceptions related to wind loads and foundation design. States and localities cannot preempt Federal requirements with respect to the construction and safety of a manufactured home. A locality can require that all other types of housing be built to attain certain noise level reduction goals, but they cannot for manufactured homes. A locality can only prohibit the use of manufactured homes in certain locations such as in a specified noise zone.

Manufactured homes and some modular homes use thinner gypsum board and particular types of mechanical systems. In addition, where it is necessary to use additional layers of gypsum board on walls or ceilings, there is a question of whether the structure can carry the extra weight. This may make it impossible or cost prohibitive to meet the noise reduction goals for manufactured homes and some modular homes.

Therefore, this Guide does not cover sound insulating manufactured homes. Modular homes should be treated no different than traditional single-family homes.

2.0 Noise Control Basics

2.1 Units Used in Acoustics

A number of different metrics (measures) have been developed to express various aspects of acoustics. It is important to understand several of them in order to make the best use of this Guide.

Aircraft noise is generally expressed in terms of its A-weighted sound level, in units called "decibels." Strictly speaking, the decibel unit should be abbreviated only by "dB"; however, for clarity "dBA" and "dB(A)" are often used to highlight the fact that the sound level measurement has been A-weighted (this weighting system is described below).

The noise exposure in areas around airfields is expressed in terms of the Day-Night Average Sound Level, which is abbreviated by "DNL" in text and "L_{dn}" in equations. DNL is a measure of the average A-weighted sound level of all aircraft flights occurring in a 24-hour period with nighttime operations being counted more heavily as described below. The unit of DNL is also the decibel.

The sound insulation properties of building construction materials are described by Sound Transmission Loss (TL) or Sound Transmission Class (STC). These measures of sound insulation are also described below.

Day-Night Average Sound Level (DNL) and Noise Contours

Aircraft noise exposure in a community is usually described in terms of noise contour maps. These indicate bands or zones around airfields where the average noise level can be expected to fall within the ranges specified by the contour lines. Most noise contour maps show contour levels of DNL 65 dB and above in 5 dB increments.

The acoustic metric used at MCAS Cherry Point is the Day-Night Average Sound Level (DNL or L_{dn}). As noted above, this is a cumulative measure of the noise exposure during a 24-hour calendar day. A 10 dB penalty is added to noise events occurring between 10:00 p.m. and 7:00 a.m. to reflect their greater intrusiveness and potential for disturbing sleep. The DNL is the result of averaging the A-weighted sound pressure level over 24 hours for aircraft activities taking place on an average busy day. The average busy day is determined by analyzing flight activity over a full year. This gives an indication of the year-round average noise exposure for the community.

Sound Transmission Loss (TL)[1]

This is the physical measure that describes the sound insulation value of a building element such as a window or wall. Values of TL are determined in acoustical laboratories under controlled testing methods prescribed by the American Society for Testing and Materials (ASTM). The TL is expressed in decibels (dB), and the greater the sound insulation, the higher the TL value and the less sound will be transmitted through the building material. TL values are determined for different frequency ranges and give an indication of how a building product or assembly responds differently to sounds at different frequencies.

Sound Transmission Class (STC)[2]

Since working with a series of TL measurements for different frequencies can be cumbersome, a single-number descriptor based on the TL values has been developed. This rating method is called the Sound Transmission Class (STC). As with the TL, the greater 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 or apartment walls for typical office noise and speech spectra. Now, they are used for exterior building components as well. Most acoustical materials and components are commonly specified in terms of their STC ratings.

2.2 Aircraft Noise

Interference with Activities

The problem of aircraft noise has been recognized and studied in this country since the 1950s. Opinion surveys indicate that interference with telephone usage, listening to television and radio, and conversations invoke the most complaints. However, after a home has been sound insulated, residents notice improvements in their ability to carry out these normal activities as well as to fall asleep and concentrate.

Fears of permanent hearing damage from flyovers have been shown to be unfounded. A large number of studies on the physical health effects of aircraft noise exposure have led to the general conclusion that residences near airfields are not exposed to high enough sound levels to warrant concern. The principal effect of aircraft noise on airfield neighbors is annoyance, caused by interference with daily activities.

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1 Tests to determine TL are described in American Society for Testing and Materials (ASTM) Standard E90.

2 STC is described in ASTM Standard E413.

Aircraft Noise Characteristics

Noise intrusion from aircraft activities is perceived as more disturbing than other kinds of noise because of two primary characteristics. Unlike many other community noise sources, such as highway noise, which tend to be fairly constant, aircraft noise consists of sporadic individual noise events with a distinct rise and fall pattern. People do not, in general, respond to these events as just another component of the "background noise" of their day-to-day lives. Some people get used to the noise, but many others feel that each individual flyover event is recognizable and disturbing.

The noise level experienced at a particular dwelling will depend on its location relative to the aircraft flight paths and the mode of ongoing aircraft operations (arrivals or departures). For homes very near the airfield, the second quality that makes aircraft noise more intrusive is its higher level, or loudness, than other types of community noise.

Aircraft Sound Spectrum

The noise produced by modern aircraft contains acoustical energy over a wide frequency range. The audible noise includes many sounds from a low-frequency "rumble" to a high-frequency "whine." The exact character depends on the aircraft type and the operation performed (takeoff, landing, or ground run-up). Low-frequency noise (below 500 Hz) penetrates walls, roofs, doors, and windows much more efficiently than does high-frequency noise. Higher frequencies (above 1,000 Hz), however, are carried through cracks and vents better. Also, people hear higher frequency sound better, the human ear being more sensitive above 1,000 Hz than below.

Since aircraft noise differs somewhat from other types of community noise, it is important to identify the characteristics of the noise that sound insulation is protecting against. Most materials and construction methods are more effective at insulating in one part of the frequency spectrum than in others. Knowing the noise characteristics helps in choosing the best materials for sound insulation. This Guide has been designed specifically to protect against noise from the types of aircraft that use MCAS Cherry Point rather than noise from civilian aircraft, highway traffic, or other types of noise sources.

Most of the sound energy from military aircraft operations is found at middle frequencies. This is different from civilian aircraft that have more equal sound at low and middle frequencies. Section 2.4 discusses the process by which sound is transmitted into a dwelling interior.

2.3 Sound Insulation to Reduce Noise

Total "soundproofing" of the dwelling, such that aircraft operations are not heard, is usually not practical or cost-effective. The goal for residential sound insulation is to *reduce* the dwelling interior noise levels due to aircraft operations to an acceptable level, that is, a level where it no longer interferes with daily activities.

Interior Noise Objectives

The U.S. Department of the Navy has established land use compatibility criteria for exposure to aircraft noise. The land-use compatibility table states that residential use is discouraged in the 65-69 dB DNL zone, and strongly discouraged in the 70-74 dB DNL zone. The table recommends that a home exposed to a DNL of 65 to 69 dB should provide at least 25 dB of NLR, a home exposed to a DNL of 70 to 74 dB should provide at least 30 dB of NLR, and a home exposed to a DNL of 75 to 79 dB should provide at least 35 dB of NLR. The use of other NLR goals may be appropriate in many cases, especially if a noise metric other than DNL is used in the community. The table assumes that typical homes can provide an NLR of 20 dB; separate recommendations are provided for homes exposed to a DNL of 60 to 64 dB in order to ensure that an NLR of 20 dB is provided.

Room Variations

The noise level of different rooms in a house depends on the amount of sound 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. The exterior sound level is transmitted through the outside walls (depending on their construction) and is further modified by the absorption inside the room (from the various furnishings) to determine what the interior noise level will be. *The calculations contained in this report are based on the assumption that all rooms would be furnished; noise levels in unfurnished rooms would be higher.*

Expected Dwelling Noise Level Reduction

An acoustically well-insulated home with windows and doors kept closed can provide 30 to 35 dB of NLR whereas more typical, unmodified designs might provide 20 to 25 dB of NLR. Experience has proven that the objectives discussed here are reasonable when construction materials and methods follow the guidelines presented in Sections 3.0 and 4.0. Providing more than 40 dB of noise level reduction is not usually practical for a typical residence. Of course, sound insulation will not have any effect on outdoor activities. The advantage of sound insulation is that it provides a refuge from external aircraft noise levels.

In general, it is more efficient and cost effective to take acoustic performance into account at the start when designing and building a home. Remodeling a pre-existing home is far more costly and time consuming than anticipating and building using good sound insulation techniques. This Guide was developed for new homes; different materials and techniques would be appropriate when renovating houses to achieve the NLR goals.

2.4 Basic Sound Insulation Concepts

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. Figure 2-1 illustrates the sound transmission through a wall constructed with a brick exterior, stud framing, interior finish wall, and absorbent material in the cavity.

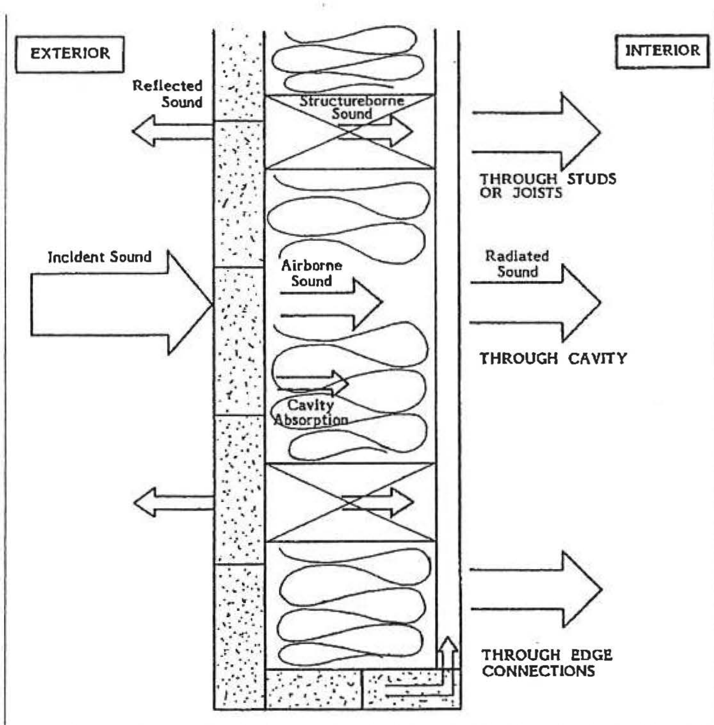

Figure 2-1. Pictorial Representation of Sound Transmission Through Built Construction

The sound transmission starts with noise at 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 finish surface then radiates sound into the dwelling interior. As the figure shows, some vibrational 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 into the interior. This is a very common, and often overlooked, source of noise intrusion. Basically, any way that air enters a home, sound will also enter.

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 side walls and floors, joist and crawlspaces.

Figure 2-2 displays the three different major paths for noise transmission into a dwelling: air infiltration through gaps and cracks, secondary elements such as windows and doors, and primary building elements such as walls and the roof.

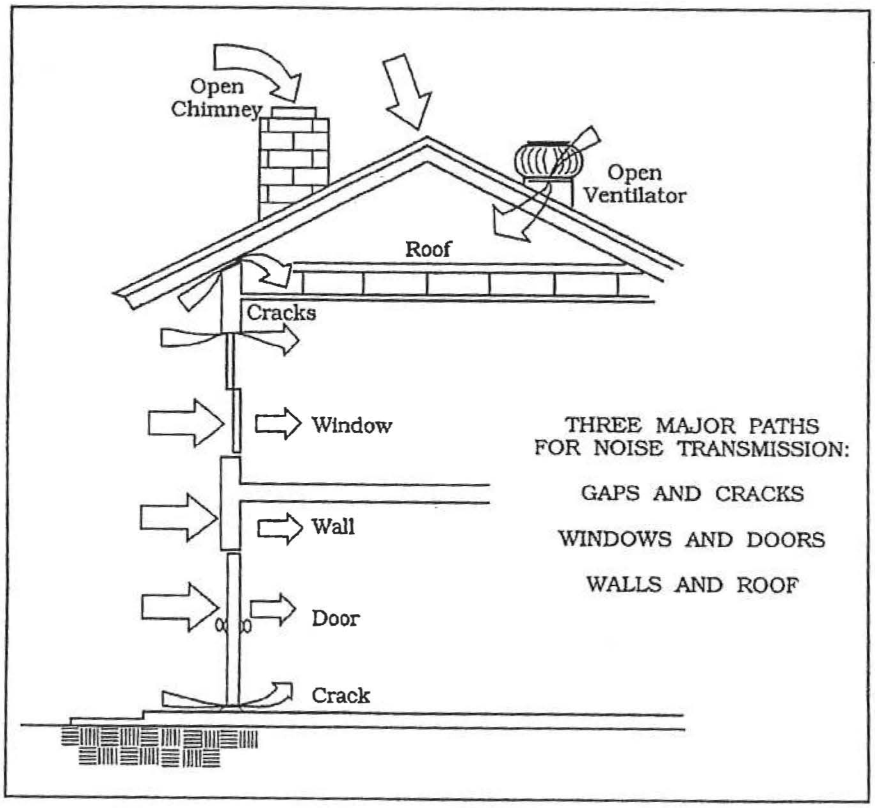

Figure 2-2. Sound Transmission Paths Into Dwelling Interiors

Low-frequency sound is most efficiently transmitted through solid structural elements such as walls, roofs, doors, and windows. High frequencies travel best through the air gaps.

Within these broad categories, different building materials have different responses based on the frequency of the incident 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 level 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 vibrational 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 using heavier building elements generally blocks more noise. Then, absorption in the air cavity, resilient mounting of interior finish panels, and mounting the exterior and interior panels on different studs can further reduce the sound transmitted to the room. The primary approaches for improving sound isolation are:

1. Elimination of openings and flanking paths.
2. Using higher STC windows and doors.
3. Adding mass to walls or ceilings.
4. Isolation of panel elements through increasing their separation, mounting the interior and exterior panels on different studs, or resiliently mounting the interior panels.
5. Adding absorptive materials between the studs or joists.

Acoustical Design

The most important, or controlling, sound paths must be identified in order to know how to modify a dwelling design to meet a specified noise criterion. The ideal sound insulation design would focus on those elements that transmit the most acoustical energy into a room. This eliminates any weak links in the building's insulation envelope.

Windows generally allow more noise intrusion than walls; as more of the wall area is taken up with windows, the overall noise protection decreases. This effect is significant even for massive wall materials, such as brick. Intuition suggests that a brick wall would protect better against sound than siding and this is true when these materials alone are compared. But, putting a weak window or an especially large window into a brick wall will cause the overall construction to perform very poorly since noise enters through the weakest path. On the other hand, installing a high-STC window in a wood-framed sided wall will give much better noise level reduction than building a weak window into a brick wall.

The STC rating, defined in Section 2.1, is a measure of the material's ability to insulate against sound; the higher the STC rating, the better the insulator. Proper use of STC ratings will be discussed in more detail in Section 3.1. Table 2-1 gives a brief list of typical STC ratings for common building elements. Much of the variability for walls and roofs is due to the type of interior finish, the type of studs or joists, and whether there is insulation in the stud or joist cavities. The ratings in Table 2-1 cannot be used directly to estimate noise level reduction because they do not account for the presence of other elements or the areas of each element.

In most cases, after making sure that openings remain sealed, the windows are the controlling sound paths. Using acoustical windows typically does more to improve the sound insulation performance than any other design modification. Exterior doors typically require higher STC ratings. Depending on the noise level reduction goal, other elements may become important. Ceilings and exterior walls may require special construction as well, particularly in the higher DNL noise zones. Treatments for these paths and others are discussed in Sections 3.2 through 3.8 of this Guide.

Table 2-1. Typical STC Ratings for Common New Construction Elements

LARGE ELEMENTS		
EXTERIOR WALLS		STC (dB)[1]
	Vinyl Siding on Wood Frame	36-37
	Insulated Concrete Forms	42-55
ROOFS		
	Vented Attic with Flat Ceiling	49-53
	Vaulted Ceiling	41-45
FLOORS		
	Elevated House on Pylons	App. 43
	Vented Crawlspace	App. 48
SMALL ELEMENTS		
WINDOWS		
	Double Pane Glass	24-29
DOORS		
	Swinging Steel or Fiberglass	23-25
	Swinging Steel or fiberglass with Storm	29-33
	Sliding Glass	25-29

[1] A higher STC value indicates greater sound insulation.

Problem Areas

Sound intrusion problems are commonly caused by:

1. Building construction components and configurations not providing sufficient sound insulation.
2. Building 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 improper installation of construction elements.

Thermal Insulation

While homes that are well insulated thermally often perform well acoustically, thermal insulation is not always a good indicator of sound insulation. Many thermal windows 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 for that reason. The presence of insulation in walls or ceilings is far more important than the type of the insulation.

Shielding

The last concept to consider is shielding. This refers to the fact that the side of the dwelling that faces away from the flight path and does not have an open line-of-sight to it will be protected somewhat from the noise. The shielding may be as much as 10 dB in some cases, though values on the order of 5 dB are more common. Sides of the house facing directly toward the flight path are unshielded. Sides that face the flight track at an angle may benefit from some minor shielding effects. Sometimes, however, sound is reflected off nearby buildings in such a way as to counteract the shielding benefits. Shielding must be examined on a case-by-case basis and the possibility of aircraft straying from the usual flight path must be taken into account before assuming a consistent shielding effect. Considering shielding is not useful when predicting indoor noise levels at homes near MCAS Cherry Point, because the aircraft typically fly all around houses instead of only on one side.

3.0 Building Elements

This section provides specific guidelines for modifying standard construction designs and practices to meet the need for aircraft sound insulation in new homes. A general discussion of construction materials and methods is given in Section 3.1. Sections 3.2 through 3.8 address techniques for use with weatherstripping, windows, doors, walls and ceilings, attics, floors, HVAC systems, and other miscellaneous elements.

In high wind (velocity) zones the building code requires using windows and doors that are rated for impact resistance. Any acoustically rated windows or doors must also be able to meet these criteria.

The recommendations apply to all habitable rooms, as well as to rooms that are open to habitable rooms.

3.1 Evaluating Construction Materials and Methods

Informed Use of STC Ratings

STC ratings are the most common measures of acoustical performance given by manufacturers of building materials. For this reason, it is important to understand how to use STC ratings to evaluate construction materials and systems.

Two different construction methods or components may have identical STC ratings and yet may block aircraft noise differently because or their response at different frequencies. One method or component may perform better than another at some important frequencies. Selecting a construction method or component from a group only on the basis of the highest STC rating may not provide the intended sound insulation. This is because the STC rating does not take into account the strong low-frequency nature of both civilian and military aircraft noise. This guide has taken the ability of typical products to block aircraft noise into account. The recommended materials listed in Section 4.0 (and their STC ratings) were evaluated for frequency response prior to formulating the design packages.

Combining Building Elements

As mentioned earlier, the acoustical performance of the building depends on the combined performances of each of the elements. The final result depends on the transmission loss (or STC) and the relative surface areas of the elements. If any of the components has poor insulation properties the overall performance can be seriously weakened. This is why it is important to focus on the weaker elements and to consider the relative areas of the components.

As a rule-of-thumb, if a weaker element will be included in the assembly, its size should be kept to a minimum. For example, if a pane of glass is to be used for a vision panel in a door, it should be kept small and should be constructed of insulated glass. Similarly, very large windows degrade the noise level reduction of an otherwise effective concrete wall. If a cathedral ceiling is included, it should be designed so that there is a larger-than-standard air space between the ceiling and the roofing system, and this space must be insulated. Sensible compromises can be made to preserve the noise level reduction of the home without sacrificing aesthetics, provided the principles explained in this Guide are employed.

3.2 Sealing and Weatherstripping

Good weatherstripping and caulking around windows and doors is crucial to effective sound insulation. The STC rating of the overall assembly can vary by as much as 2 to 4 dB, depending on perimeter infiltration. For these assemblies, any perimeter leakage will degrade the performance of the window or door and can be the controlling factor in the noise isolation. This is generally not an issue with new construction, but homeowners must understand the importance of maintaining weatherstripping in good condition.

For acoustical purposes, compressible neoprene weatherstripping is preferred over felt or other fibrous types. Neoprene is not as porous and compresses better against the window or doorframe. Also, felt and fibrous weatherstripping materials tend to deteriorate more quickly than neoprene and must be replaced more often.

3.3 Windows

Options Overview

The exterior windows are usually one of the weakest elements in the dwelling's sound insulation performance. Improving the acoustical properties of the windows is one of the simplest ways of lowering the overall sound transmission into the house. Design modification options include using thicker glass and wider airspaces between the panes of glass. Specialized acoustical windows provide maximum sound insulation, and should be used in the loudest environments, as specified in Section 4.0.

Acoustical Performance

The thicker, high-quality insulated glass units should be ¾ inch to 1 inch thick and, for the best noise level reduction, should incorporate at least one lite (pane) of laminated glass, preferably ¼ inch thick. Laminated glass provides significantly better transmission loss than standard, float glass. Tempered glass is also acoustically superior to standard glass, but is not nearly as effective as laminated glass. Off-the-shelf thermopane units are typically available with ratings ranging from STC 24 to 29, and upgraded acoustical units with thicker glass may provide ratings as high as STC 30 to 36.

Acoustical windows differ significantly from ordinary residential windows. The design of an acoustical window has a greater frame depth, the glass lites are heavier, the frame extrusions may be thicker, and the weatherstripping and seals are more substantial. All of these measures are necessary to provide the high degree of sound insulation required for the window assembly.

In order to achieve ratings above approximately STC 36 it is typically necessary to use either a double pane window with a storm unit attached (often referred to as a "combination" window), or an assembly of two single or double pane windows connected together (often referred to as a "dual" window). Figure 3-1 shows a typical acoustical combination window installation with the most important features highlighted. Figure 3-2 shows schematically the features of an acoustical dual window. Combination and dual acoustical windows with STC ratings of 37 to 46 are available in a variety of styles and finishes, including aluminum and vinyl, and special windows with STC ratings in the 50s are available from a few manufacturers. Information on specialized acoustical windows is available in Appendix A. They are considerably more expensive than typical residential windows.

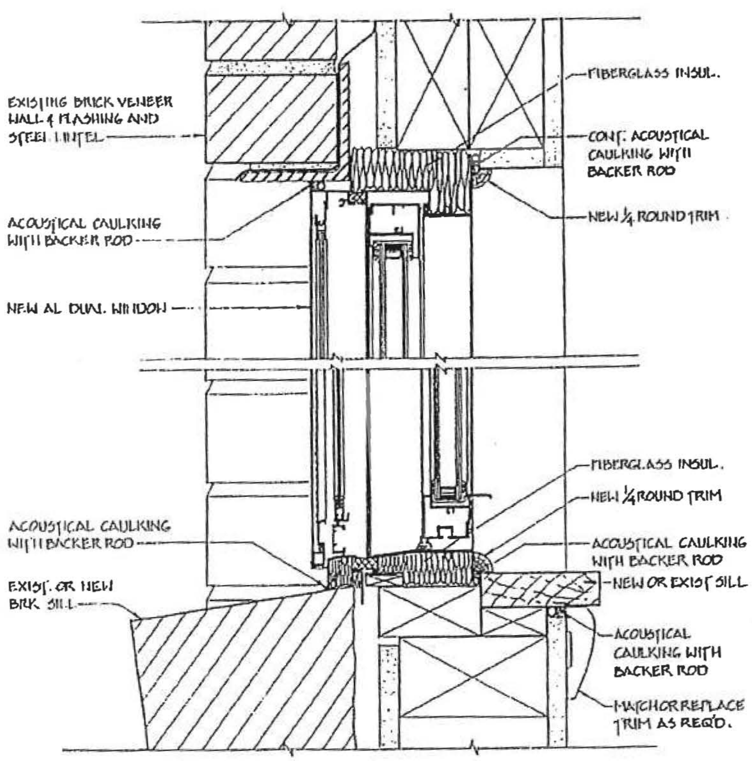

Figure 3-1. Typical Combination Window Installation Detail

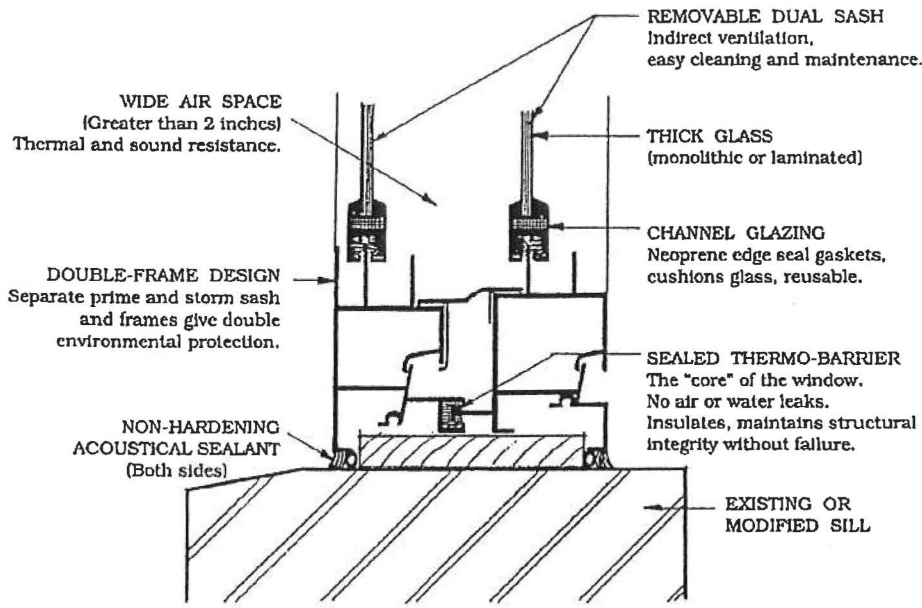

Figure 3-2. Typical Dual Acoustical Window

Thermal Performance

Insulated glass windows are recognized to block the transmission of heat (in winter or summer) much more effectively than single pane glazing. Increasing the thickness of the glass and the airspace, as recommended for noise level reduction, further improves their thermal performance.

Because of the above-mentioned design features, plus the common inclusion of thermal barriers at the frames, acoustical windows perform exceptionally well as thermal barriers. They allow approximately one-tenth the air infiltration of a typical 20-year-old double-hung wood window with single pane glass. The R-value (a measure of thermal resistance) for acoustical windows is R-4. For comparison, the R-values of most off-the-shelf single pane and double pane windows are R-1 and R-3, respectively.

Installation Considerations

For the windows to provide the required noise reduction they must remain tightly closed. Ways to maintain ventilation will be discussed in Section 3.8. It is important to note, however, that this requirement precludes the use of jalousie or louvered windows in a sound insulation design. Double-hung, single-hung, horizontal rolling/sliding, casement, fixed, and awning/hopper windows are all acceptable for noise reduction, provided they have the required STC rating. However, it must be noted that the STC ratings vary a few points between these various operational types for a given window manufacturer or model. Fixed windows normally have the highest STC rating, sliding/rolling windows have the next highest, hung windows have slightly lower ratings, while casement and awning/hopper windows tend to have the lowest STC ratings.

Other considerations when preparing window specifications include maintainability, warranty, manufacturer's service, and proper installation. It is possible to install the best acoustical window improperly. If it does not fit tightly enough, air infiltration will significantly reduce the effectiveness. Starting with a too-small window unit and filling in the void around the window with a low-mass material such as fiberglass is unacceptable. Continuous wood blocking infill is recommended with fiberglass insulation filling small voids.

3.4 Doors

Options Overview

Doors are comparable to windows in the amount of sound they allow to enter the dwelling. Many typical residential doors require modification or substitution to provide the necessary protection from aircraft noise. As with windows, there are specialized acoustical units available, as well as acoustical storm doors. The following factors are important in evaluating doors for sound insulation:

- Door composition: insulated metal or fiberglass, sliding glass; core material, additional internal insulation, etc.
- Door weight (can be estimated by pull-weight).
- Presence and type of fixed window panels.
- Quality of seals and weatherstripping and how tightly they seal.

The options for improving the noise level reduction of residential doors include:

- Installation of a tightly fitting storm door with thick (or laminated) glass; or use of a specialty acoustical storm door.
- Installation of a secondary French door.
- Use of thicker glass in sliding glass doors or specialty acoustical sliding glass doors.

Standard Doors

STC requirements are outlined in Section 4.0 for each type of door (swinging and sliding doors).

Glass panels in the primary door can reduce the STC rating by several points, depending on the thickness of the lite and the surface area. The thinner the glass and the larger the area it covers, the more it decreases the sound insulation of the door. When vision panels are required, it is best to keep them small and use insulated glass units with thick glass.

Swinging Storm Doors

External storm doors are sometimes used in the MCAS Cherry Point area and can improve the STC rating by approximately 5 to 9 points and up to 19 points with special acoustical storm doors. In order for storm doors to be effective for sound insulation, they should incorporate thick glass (ideally 1/4-inch-thick laminated glass in high noise zones) and have a heavy core. Storm doors must be mounted year-round to provide an acoustical benefit. Replacing the glass panel with a screen insert in the summer months will reduce the sound insulation of the home considerably but many homeowners may wish to exercise this option for periods when aircraft activity is light. A list of acoustical storm door suppliers is included in Appendix B.

Acoustical Swinging Doors

Acoustical doors, with a typical rating of STC 29 to 43, are similar in appearance to standard entrance doors. However, due to the high cost of acoustical doors, it is often preferable instead to use more typical residential doors with acoustical storm doors.

Because of their specialized construction and superior sealing design they provide a very noticeable improvement in noise reduction. Whether metal or wood, the internal construction of acoustical doors differs substantially from standard doors. Layering of materials, along with added absorption and mass, increases their weight to approximately 12 to 14 pounds per square foot.

To eliminate sound flanking between the closed door and the jamb, acoustic doors are designed with special fixed acoustical seals at the sides and top. A drop seal along the bottom activated by a cam rod when the door is closed is sometimes used to make tight contact with the threshold. In other cases, fixed bottom seals that contact a raised threshold or saddle are used. Also, because of their extra weight, acoustical doors usually require reinforcement of the door frame and heavy-duty mounting hardware and hinges. Manufacturers often provide customized frames with their acoustical doors.

Sliding Glass Doors

There are two options for improving the sound-insulating properties of sliding glass doors: using acoustical units, or using primary and secondary doors. The disadvantages of acoustical sliding glass doors are that they are very expensive, very heavy, and can have a high threshold. The disadvantages of using primary and secondary sliding glass doors is having to open two doors to leave the building, and that the two frames would not fit in the width of a typical 2x4 stud wall. This same secondary door concept can be used with French doors. Of course, the installer must ensure that there is no conflict in the operation and opening hardware of the two door sets. Good weatherstripping should be installed on both doors.

Installing a secondary door generally requires building a second frame positioned to mount the door approximately 3 to 4 inches away from the primary door. This dual-door assembly has proven successful in that it raises the STC rating by 14 to 16 points (when the secondary door has an STC 29 rating and utilizes 1/4" laminated glass, and there is at least 3.5" airspace between the primary and secondary door). Figure 3-3 shows a system of two sliding glass doors with the secondary door mounted outside of the typical door position.

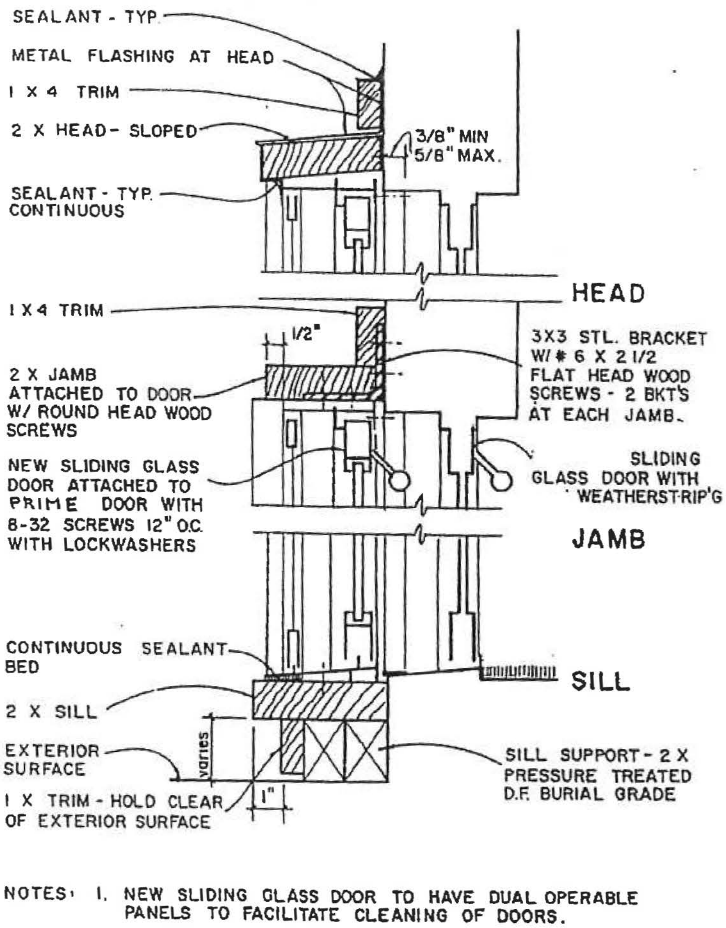

Figure 3-3. Secondary Sliding Glass Door Detail

Door Sidelights and Window and Door Transoms

Door sidelights and window and door transoms should not be neglected. However, there rarely are acoustical tests available for the window or door assembly that includes the applicable transoms or sidelights. Therefore, we recommend treating them as separate windows, even if they are attached to a door.

Installation Considerations

As with windows, it is of critical importance to ensure that the door fits well, that all gaps and leaks are sealed, and that the door remains closed. High-quality acoustical weatherstripping is recommended to ensure the noise reduction of the door. Sound attenuation through standard doors can be improved by fitting them with special acoustical seals, including drop seals mounted to the back or fully mortised in the door's bottom rail, and compressible bulb-type neoprene gaskets at the jambs (sides) and head (top). If the door does not fit squarely into the frame it will not seal properly and unnecessary noise infiltration will result. In all cases, avoid openings such as mail slots in doors or the use of pet doors.

3.5 Walls

Determining Wall Designs

Depending on the dwelling's exterior construction and materials, it may be necessary to use specialized designs for walls. Generally, walls that have vinyl or cement board siding require improvements such as staggered studs or resilient channels in the highest noise impact zones. Dwellings that use insulating concrete forms or other masonry systems typically do not.

For the purposes of this design guide, walls in the MCAS Cherry Point area can be classified as one of the two following types:

- Insulated Concrete Form (ICF) Construction: At least four-inch thick normal weight concrete between approximately 1-3/4" to 2" insulating forms, with 1/2" gypsumboard at interior. The entire wall must have concrete, not just a portion of it, for this designation to apply. If siding or a skim coat of stucco is applied over insulated concrete forms, the wall is still designated an insulated concrete form wall.
- Siding on Wood-Frame Construction: All types of siding including vinyl and cement board. Construction includes siding on 1/2" nominal OSB or plywood sheathing on 2x4 or 2x6 wood studs spaced 16" on center with batt insulation, and 1/2" gypsumboard at the interior. If a portion of the wall is ICF and a portion wood-framed, consider the wall to be sided on wood-frame construction.

The rare instances of Exterior Insulating Finish Systems (EIFS) on wood framing should be designated "Siding on Wood-Frame Construction" for the purposes of this Guide. The rare instances of Stucco on concrete masonry should be designated "Insulated Concrete Form Construction" for the purposes of this Guide.

When studs are spaced 24" on center the acoustical performance may be slightly better than for other sided wood-framed walls. Conversely, when the stud spacing is 8" or 12" on center the acoustical performance may be worse; using this stud spacing is common for the first floor of a three-floor home, in high-wind (velocity) zones, or when windows or doors comprise a large proportion of the wall.

It is sometimes necessary for structural reasons to use a layer of plywood or OSB at the interior surface of the wood studs behind the gypsum board. This should not adversely affect the STC rating.

Specific Interior Wall Designs for Siding on Wood-Frame Construction

One technique for increasing the mass and resiliency of the wall or ceiling is to attach the gypsumboard to the studs with 1/2-inch, resilient, vibration-isolation channels ("resilient channels", or "RC"). This will provide an STC rating improvement of 7 points over that for a typical wood frame construction. The resilient-mounting channels should be attached to the studs so that they run horizontally for walls (and perpendicular to the joists for ceilings). This minimizes the vibration transmission from the supporting studs (or joists) to the channels and the wallboard. The spacing of the channels should be no closer together than specified by the channel manufacturer; typically this is 24" on center. The screws used to attach the gypsum board to the channels must be short enough that they do not contact the studs. The common installation error of using too long screws allows vibration to travel from the stud to the gypsumboard, rendering the system ineffective. An alternative to this design is to use a new product called resilient sound isolation clips with rigid steel channels. This product is available from PAC International. It is more costly than resilient channels and uses more wall thickness but provides significantly better acoustical performance.

A second technique involves using the resilient channels mentioned above, and changing the wall construction from 2 x 4 studs to 2 x 6 studs. This will increase the STC by 11 points over typical siding on 2x4 stud construction, and will allow space for R-19 insulation.

The third, and most effective, option is to construct the interior wall on a set of staggered studs so that the interior and exterior finish surfaces are not rigidly connected to each other except through the top and bottom plates. This system uses two rows of studs: one row of studs spaced 16" on center supporting the sheathing, and a second row spaced 16" on center supporting the interior wall finish. The end result is that there are studs each 8" on center. Figure 3-4 shows how to implement this construction. This modification provides acoustical decoupling and separation between the exterior and the interior of the room, resulting in a 13-point increase in the STC rating over standard siding on 2x4 studs. A larger space between the interior and exterior panels will yield a greater STC improvement. Section 4.0 references a staggered 2 x 4 stud construction on a 2 x 6 base plate. If it is necessary to have 2x6 studs for strength, a variation on this design is to use 2x6 studs staggered on a 2x8 base. Such a design should provide a generally similar acoustical performance as the 2x4 studs staggered on a 2x6 base. With any staggered stud design it might be necessary to provide additional fire stopping.

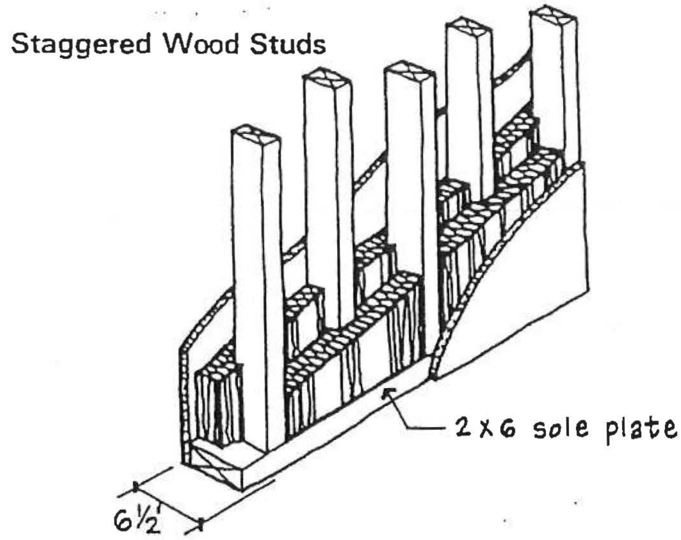

Figure 3-4. Staggered Wood Stud Construction

To absorb sound, fiberglass batts are placed between the studs in the wall cavity. Thermal insulation of at least R-11 should be used to ensure a thick enough layer. Batts or blankets should be held firmly in place between studs, with fasteners if necessary, to prevent sagging; however, packing the insulation such that it is compressed may slightly *reduce* its acoustical (and thermal) performance. Blown-in insulation is not recommended in walls for acoustical purposes because of the tendency to compact over time.

Specific Interior Wall Designs for Insulating Concrete Form (ICF) Construction

The primary way to improve the STC rating of an ICF wall is to select a wider wall that allows a wider pour of concrete. The typical wall was assumed to have a 4" thick pour of concrete. The next thicker wall considered was with a 6" thick pour of concrete. The STC ratings of this assembly will vary based on the thickness of the forms and the type of exterior finish.

The wall construction designs referenced above are summarized in Table 3-1. In this table O.C is the on-center spacing of the studs.

Table 3-1. Acoustical Wall Designs and STC Ratings

	Exterior Side	Structure	Interior Side	STC Rating
Resilient Channel on 2x4 studs	Siding, Wood sheathing	2x4 16" O.C. with batt insulation	RC on studs, 1 layer ½" gypsumboard	43
Resilient Channel on 2x6 studs	Siding, Wood sheathing	2x6 16" O.C. with batt insulation	RC on studs, 1 layer ½" gypsumboard	47
Staggered 2x4 on 2x6 base	Siding, Wood sheathing	2x4 16" O.C. for each row (staggered on 2x6 base plate) with batt insulation	1 layer ½" gypsumboard (attached only to interior-side studs)	50
Staggered 2x6 on 2x8 base	Siding, Wood sheathing	2x6 16" O.C. for each row (staggered on 2x8 base plate) with batt insulation	1 layer ½" gypsumboard (attached only to interior-side studs)	Approx. 50
ICF with 4" Concrete	1-3/4" Form	4" normal weight concrete	1/2" Gypsumboard on 1-3/4" Form	High 40s
ICF with 6" Concrete	1-3/4" Form	6" normal weight concrete	1/2" Gypsumboard on 1-3/4" Form	Low 50s

3.6 Ceilings and Roofs

Improved ceilings are sometimes necessary where there is a roof over noise-sensitive rooms such as bedrooms, kitchens, living rooms, family rooms, etc. There is no need to modify the ceiling of any first-floor rooms where they are completely covered by a second story room. Non-habitable rooms, such as garages and mudrooms in breezeways, are generally not given improved ceilings unless they open directly to habitable rooms without interior doors in between the rooms.

Specific Interior Ceiling Modifications

The ceilings of top-floor rooms may need to be modified to provide increased noise protection. The same methods that are used in wall constructions can be used for ceilings. The standard roof construction in the MCAS Cherry Point area is assumed to be: asphalt shingles or standing seam metal roofing, plywood or OSB roof deck, ridge and soffit vents, engineered wood trusses at least 14" deep throughout the span, 10" minimum thickness of blown-in or batt insulation, and 1/2" gypsumboard at the interior. This design is designated "vented attic" construction and has an STC 45 rating.Resilient channels mounted perpendicular to the bottom of the ceiling joists with one layer of ½" gypsumboard attached to the channels will increase the rating to approximtately STC 55.

With some vaulted ceilings the roof framing is less than 14" deep and the STC rating is significantly lower. One such design is shingles, wood roof deck, 2x10 rafters with batt insulation, and 1/2" gypsumboard. This design has a rating of only STC 33. To provide good acoustical performance the roof framing should be at least 14" deep (throughout the span), when sound insulation is being considered.

Attic access panels, pull-down stairs, and whole-house ceiling fans should have movable or operable covers consisting of 3/4" plywood, or other equally massive material, with continuous neoprene perimeter seals.

Attic Vents

Attics typically have open-air vents at the gable ends or a combination of ridge and soffit vents. Soffit vents are shielded by the roof and generally need no modification. Off-the-shelf acoustical louvers can be applied to baffle the sound passing through gable-end vents. Built-in-place baffles could be used under ridge vents to reduce noise intrusion. These consist of 3/4" plywood covered with 1" thick rigid fiberglass insulation; the plywood panels are oriented in such a way that noise (and air) must be reflected on at least one fiberglass-lined surface before it can move into the attic.

Attic Insulation

When considering the upgrade of thermal insulation to reduce noise levels it is important to understand what the insulation will do. Thermal insulation materials will act to absorb sound that is reverberating in the attic or in the space between flat panels. It does not prevent noise from entering the space. That is, it has no appreciable acoustic "insulating" properties but acts as an absorbent instead. To keep sound out, barriers must be used which increase the mass of the roof or ceiling. As a sound absorbent, fiberglass batts and blown-in fiberglass or mineral fiber can be applied between the rafters or ceiling joists.

The sound absorption of a material should not be confused with noise level reduction (NLR). There is no direct relationship between a material's sound absorptive properties and the overall NLR.

A simple method for determining the proper thickness of sound-absorbent materials is to use the concept of the material's thermal rating (R-value). This R-rating is a commonly used and well-known rating for building products. The R-values and thickness for several common insulation materials are given in Table 3-2. The value of the sound absorption at lower frequencies depends on the thickness of the material. For noise sources with a significant low-frequency component, such as aircraft flyovers, the thickness is the most important parameter. Thicker materials provide better low-frequency sound absorption.

Table 3-2. Material Thickness and R-Value for Common Insulating Materials

Material	Thickness, Inches		
	R-11	R-19	R-30
Roll or Batt Fiberglass	3.5	5.25	9
Blown-In Fiberglass	5	8	13
Mineral Fiber	4	6.5	11

Skylights

Skylights are rare in the MCAS Cherry Point area for new homes. There are possible measures to improve the sound insulation of skylights such as using products with high STC ratings or using secondary interior glass panels with acoustical seals. For the purposes of this guide it is assumed that skylights will not be provided.

3.7 Floors and Crawl Spaces

Options Overview

Dwellings in the MCAS Cherry Point will usually have one of these three types of floor systems at the ground level:

- Concrete slab
- Crawlspace
- Pylon foundations (e.g., for a beach house)

Since noise control measures are concerned with the external building envelope, floors between stories in a home are not addressed.

There are three stages of floor design improvements for sound insulation:

- Eliminating, sealing or baffling any openings.
- Installing insulation between the floor joists.
- Attaching a barrier panel to the underside of the floor joists or between the perimeter of the house and the ground (a skirt).

Concrete slabs require no treatment. Crawl spaces and pylon foundations will be discussed below.

Crawl Spaces

One common floor system for new residences consists of wood joist construction over a vented crawl space. Typically, the crawl space has 8" nominal concrete block walls. The simplest way to improve the acoustical performance of a house that has a crawl space with masonry walls is to install off-the-shelf noise control louvers to the under-floor vents (see Appendix B); this is similar to the design discussed above for roof vents. These louvers provide a noticeable quieting in the rest of the house. If crawl spaces do not have masonry walls, a massive barrier panel can be used as a skirt connecting the bottom of the walls to the ground. 2" thick precast concrete panels would be ideal. Alternatively, 2x4 pressure-treated wood studs with ¾" pressure-treated plywood on each side could be used, as long as the joints between the plywood are covered with batten strips. Where double-swing doors are required in flood plains use a similar construction to improve sound insulation.

Pylon Foundations

Many beach houses are elevated one story using 8x8 wood posts called pylons. This design allows some aircraft noise to enter the house through the floor. The typical floor construction in the MCAS Cherry Point area is 3/4" plywood on joists (open web wood trusses, plywood joists, or 2x10 joists), with R-19 batt insulation, and 3/8" plywood covering the bottom of the joists. This assembly has a poor STC rating. However, it will receive a significant amount of shielding from the aircraft flight path by the house. Although it is difficult to quantify this shielding effect, it is likely on the order of 10 STC points. The resulting effective rating is STC 43 if 2x10 joists are used, and higher if deeper structural members are used.

3.8 Mechanical Systems and Building Penetrations

In order to maintain the noise reduction benefits of improving windows and doors and sealing leakage paths, it is important to keep these openings closed. While an acoustically well insulated home can provide 30 to 35 dB of noise reduction, this figure drops to 15 dB whenever the windows and doors are open. Heating, ventilation, and air-conditioning (HVAC) systems do not directly affect the sound insulation performance (except when they have vents to the outdoors), but they enable residents to keep the windows and doors shut year-round and benefit from the sound insulation modifications. The following information is not referenced in Section 4.0 but the ventilation features discussed here are strongly recommended.

HVAC Systems

In the MCAS Cherry Point area the furnaces are typically located in attics. This location unfortunately allows some noise to enter the home through penetrations of the ceiling. This furnace location is acceptable provided ducts in the attic receive special treatments (see

Appendix A). Flexible ductwork should not be used in attics and crawl spaces; heavier sheet metal ducts will provide better sound insulation.

Do not use in-window, through-wall, or through-floor air-conditioners, ventilators, or heaters, i.e., units for which air ducts pass through the building envelope (windows, walls, or floors). On the other hand it is acceptable if only natural gas or refrigerant pipes pass through the building envelope, since these will not allow noise to enter the building. The preferred air-conditioning system is a split system utilizing an outdoor condensing unit.

Ducts to the outside, whether air intake or air exhaust, and all air ducts in the attic or crawl space can be lined with 1-inch acoustical internal lining material, or have at least two 90-degree (right angle) elbows (turns) thereby breaking the line-of-sight to the outside as shown in Figure 3-6. It must be noted that there is concern than this fibrous acoustical lining material will affect air quality. Installing a duct sound attenuator (silencer) is an alternative to this technique; there are silencers available that do not contain fibrous lining. To prevent moisture and grease buildup exhaust fans (bathroom, dryer, kitchen, and range) must not have internal sound lining or silencers that use fibrous lining; the use of the 90-degree elbows and/or fiber-free silencers are appropriate in these cases. These measures ensure that the ventilation system is not bringing additional aircraft noise into the house.

Combustion Air Intake

Fuel-burning appliances such as gas furnaces, gas hot water heaters, and gas dryers can introduce carbon monoxide into the house. To minimize this concern, especially in sound-insulated houses, it is useful to introduce air from the outdoors to the area near the appliance. This is often required in building codes as well. This can be accomplished with small fans called combustion air enforcers.

Combustion Air Exhausts

The exhaust ducts for fuel-burning appliances such as water heaters, furnaces, and gas dryers can also be paths for aircraft noise to enter the home. These ducts should be located in closets and never in living spaces. These ducts should also have at least two 90-degree elbows as discussed above for HVAC ducts.

Dryers

Dryer exhaust ducts can also be paths for aircraft noise to enter the home. Dryers must not be located in living spaces. If they are located near bedrooms they should be in enclosed closets. Always use rigid metal dryer ducts instead of flexible ducts to minimize aircraft noise entering the house.

Fresh Air

It is assumed that all new homes in the MCAS Cherry Point area will have central air-conditioning. Whether the air needs to be heated, cooled, dehumidified, or simply circulated and replenished depends on the season. Refreshing the air supply and moving it around is important for health and comfort no matter what the outside temperature. A fresh-air intake could be installed on an air-handling system to provide the required percentage of fresh makeup air combined with the recirculating air. However, when the system is not operating during mild weather no fresh air would be provided. Therefore, fresh-air systems should have a fresh-air intake and allow for ventilation alone when the residents do not want heating or cooling.

In order to ensure that fresh air is provided year-round, the preferred solution is to use active ventilators. The building code does not require these systems unless the house is considered "unusually tight" and meets three conditions. However, for acoustical purposes the use of active ventilation is recommended, especially in high noise zones. To heat the air in winter these systems typically incorporate an electrically operated heating coil or heat recovery feature.

Whatever ventilation system is used, penetrations of the building envelope must be minimized and located as far as possible from habitable areas of the house.

HVAC Noise and Vibration Control

It is important to limit the amount of noise the HVAC system generates and the noise it carries in from the outside. Provide vibration isolation mounting for all equipment and locate it so that the structure-borne sound and vibration are kept to a minimum.

Kitchen and Bath Fans

Most kitchen and bathroom designs for new homes already incorporate fans for ventilation purposes. If the bathroom exhaust ventilators have ducts to the outside, they should be ducted through the attic as opposed to through a wall. A ducting scheme that incorporates at least one and preferably two right-angle turns is effective at reducing noise infiltration and there should be no direct line-of-sight through the duct from the outside to the inside. In other words, if the duct grilles or covers were removed, it should not be possible to see daylight through the duct. All ducts in the attic should be rigid metal and not flexible; noise may pass through these elements to other rooms of the house. Refer to the manufacturer for allowable duct lengths, numbers of elbows, and sizes of ducts. Kitchen ranges should have re-circulating fans utilizing a charcoal filter instead of a vented range fan.

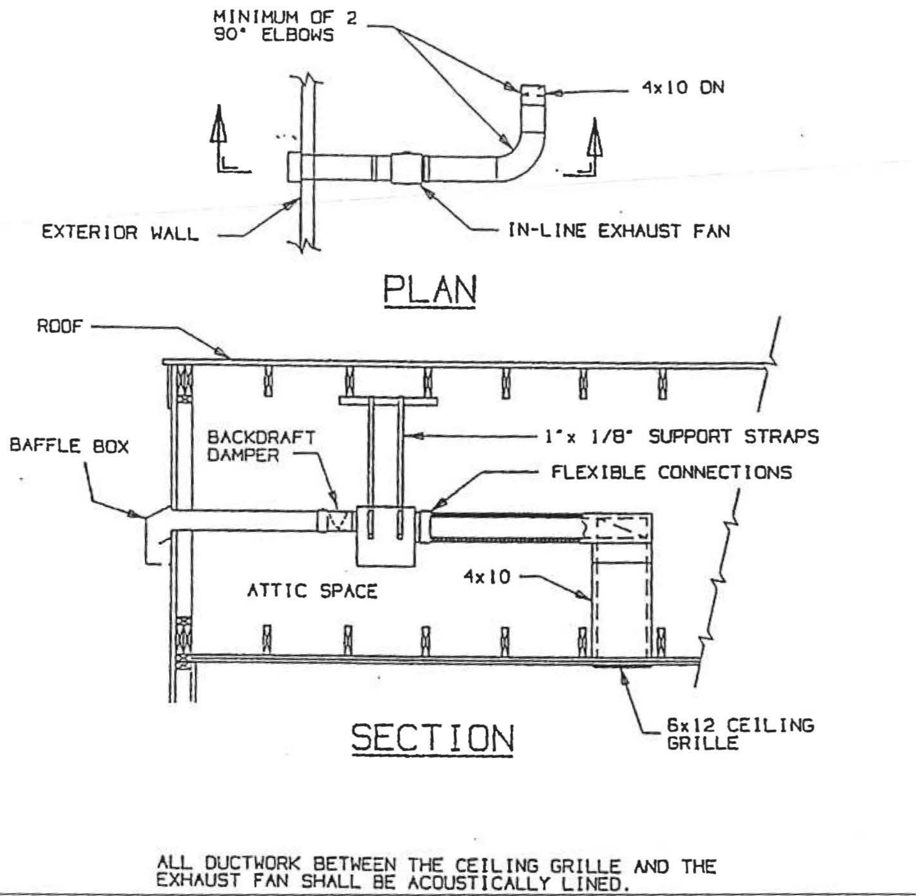

Figure 3-5. Controlling Noise Entering Through Ducts in Attic Space

Fireplaces and Wood Stoves

Some homes in the MCAS Cherry Point area will have prefabricated fuel-burning fireplaces; wood stoves are rare. Ventless units are strongly recommended. For the purposes of this Guide, it is assumed that no vented fireplaces or wood stoves will be allowed.

Whole-house Fans

Some homes in the MCAS Cherry Point area will have whole-house fans. These fans are located in the ceiling of the top floor of the house, usually over a hallway. They allow a significant amount of sound to enter the house. Their use is discouraged in high noise zones.

4.0 Material Selection Chart

The following selection chart is to be used to determine the acoustical design needs of the walls, windows, doors, roof, and floor of each noise-sensitive room of a dwelling. Additional requirements are provided in Appendix A; this material selection chart is supplemental to Appendix A. These recommendations also apply to non-habitable rooms that do not have a door separating them from habitable rooms. For each room, design recommendations are determined by following the chart from left to right. First, the required noise level reduction (NLR) must be determined for the dwelling based on its location in a certain noise contour zone. Second, the type of exterior walls must be selected. If the wall has Insulated Concrete Forms (ICF) use the "ICF" designation, even if the wall also has wood framing at the interior. Use the "Wood Frame" designation if one of the exterior walls or a portion of one of the walls is wood framed. Third, the number of exterior walls must be selected. Count partial walls as full walls. Count two-story walls as two walls. For example, a room with two two-story exterior walls is considered to have four exterior walls. Fourth, calculate the ratio of the area of windows and doors to the total exterior façade area (including the gross wall/window/door area) of the room. The last five columns contain the recommended modifications for the walls, windows, doors, roof, and floor that must be used to achieve the desired noise level reduction.

The wall modifications apply only to exterior walls. Recommended modifications for wood frame walls are either to use single-leaf resilient channels to hang the gypsumboard ("RC"), to use staggered 2x4 studs on 2x6 plates ("stag"), or to use staggered studs with two layers of 1/2" minimum gypsumboard. If the studs must be 2x6 for structural reasons, and the table calls for staggered studs, use 2x6 studs staggered on 2x8 plates.

The door and window modifications only apply to doors and windows that open to the exterior or to partially enclosed spaces such as screened-in porches or garages. The table lists the minimum allowable STC rating.

The roof modifications apply to the roof/ceiling assembly of rooms on the top floor of the house (a room below an attic is considered to be on the top floor). The modifications are either to use two layers of 1/2" minimum gypsumboard, or to hang the gypsumboard using single-leaf resilient channels.

The floor modifications only apply to houses elevated on pylons (e.g., beach houses). The recommended modification for some houses is to use floor framing members that are at least 14" deep with at least 10" thick insulation at with 1/2" minimum plywood or OSB at the bottom chords of the trusses ("deep").Table 4-1.

Table 4-1. Material Selection Chart and Corresponding STC Ratings

NLR	Wall Type	Exterior Walls	Window + Door Ratio	Recommended Modification				
				Wall	Window	Door	Roof	Floor
20	Wd Frame			None	STC 28	None	None	None
	ICF	1		None	None	None	None	
		2+	<75%	None	None	None	None	
			>= 75%	None	STC 28	None	None	
25	Wood Frame	1	<25%	None	STC 26	None	None	None
			25-40%	None	STC 28	None	None	None
			>40%	None	STC 30	STC 29	None	None
		2+	<20%	None	STC 28	None	None	None
			20-35%	None	STC 30	STC 29	None	None
			>35%	None	STC 32	STC 29	None	None
	ICF	1	<40%	None	STC 26	None	None	
			>= 40%	None	STC 30	STC 29	None	
		2+	<20%	None	STC 26	None	None	
			20-30%	None	STC 28	None	None	
			30-75%	None	STC 30	STC 29	None	
			>75%	None	STC 32	STC 29	None	
30	Wood Frame	1	<20%	None	STC 32	STC 31	2 gyp	Deep
			20-30%	None	STC 34	STC 34	2 gyp	Deep
			30-50%	RC	STC 32	STC 31	2 gyp	Deep
			>50%	RC	STC 34	STC 34	2 gyp	Deep
		2	<20%	RC	STC 34	STC 31	2 gyp	Deep
			>= 20%	RC	STC 34	STC 34	2 gyp	Deep
		3+	<20%	RC	STC 34	STC 31	2 gyp	Deep
			20-70%	RC	STC 34	STC 34	2 gyp	Deep
			>70%	RC	STC 36	STC 34	2 gyp	Deep
	ICF	1	<20%	None	STC 30	STC 29	2 gyp	
			20-50%	None	STC 32	STC 31	2 gyp	
			>50%	None	STC 34	STC 34	2 gyp	
		2	<20%	None	STC 34	STC 31	2 gyp	
			>= 20%	None	STC 34	STC 34	2 gyp	
		3+	<20%	None	STC 34	STC 31	2 gyp	
			20-70%	None	STC 34	STC 34	2 gyp	
			>70%	None	STC 36	STC 34	2 gyp	
35	Wood Frame	1	<25%	RC	STC 36	STC 34	RC	Deep
			>= 25%	Stag	STC 40	STC 40	RC	Deep
		2+	<15%	RC	STC 38	STC 37	RC	Deep
			15-20%	Stag	STC 38	STC 37	RC	Deep
			20-30%	Stag	STC 42	STC 37	RC	Deep
			>30%	Stag, 2 gyp	STC 42	STC 40	RC	Deep
	ICF	1	<15%	None	STC 34	STC 34	RC	
			15-25%	None	STC 36	STC 34	RC	
			25-50%	None	STC 38	STC 37	RC	
			>50%	None	STC 40	STC 40	RC	
		2+	<15%	None	STC 40	STC 37	RC	
			15-20%	None	STC 40	STC 40	RC	
			20-30%	None	STC 44	STC 40	RC	
			>30%	None	STC 44	STC 43	RC	

5.0 Limitations

There are many variables affecting the acoustical performance of a room. The recommendations contained in this Guide are based on assumptions of typical parameters. If the actual building design and construction used don't match these assumptions the noise level reduction will be different. Due to the interrelationship between each of these variables there are no upper limits on individual parameters.

In developing recommendations, typical types of rooms were considered. Conditions that would tend to reduce the acoustical performance include:

1. Using a greater area of windows or doors.
2. Having a greater area of exterior walls.
3. Using *smaller* rooms.
4. Adding wall penetrations such as through-wall air-conditioners, heaters, or fans.
5. Using hard room finishes such as ceramic tile or wood floors, and using few furnishings.

The modifications recommended in this Guide are packages designed to work together. That is, improvements to the windows, doors, and mechanical systems complement improvements to the walls and roof. There are always alternative packages of modifications that would be acceptable from an acoustical standpoint. The goal of this Guide was to present one package of modifications for each situation that is reasonable and cost-effective.

The determination of which rooms these recommendations apply to is not always simple. Generally, they apply to living spaces (kitchens, living rooms, family rooms, bedrooms, offices, dens, sun rooms, etc.) and do not apply to closets, typical bathrooms, most hallways, garages, utility rooms, and screened-in porches. Some large bathrooms, open foyers, or all spaces that are relatively open to a living space should be sound insulated.

The recommendations contained in this Guide are based on calculations using a large number of assumptions and averages of acoustical data for many products. Due to the large variability in acoustical performance of different buildings, and the imprecision of acoustical calculations the author does not guarantee that the acoustical objectives will be met. There is also no margin for error embedded into these recommendations, except to the extent that houses are grouped in ranges of 5-dB outdoor noise exposure. If a margin of error were desired it would be appropriate to use the recommendations for the next higher noise zone or consult a qualified acoustical consultant.

Likewise, the author does not guarantee that the recommended measures will comply with building codes.

APPENDIX A

NOISE LEVEL REDUCTION DESIGN REQUIREMENTS

Appendix A
New Construction: Noise Level Reduction Design Requirements

SECTION 1: PURPOSE

Exterior noise may be isolated and reduced in homes through construction techniques that selectively increase the insulating quality of the exterior of occupied structures. The noise level reduction values specified are 20, 25, 30, and 35 dB.

SECTION 2: GENERAL REQUIREMENTS

A. The Noise Level Reduction (NLR) requirements specified herein may be achieved by any suitable combination of building designs, choices of building materials, and execution of construction details in accordance with established architectural and acoustical principles. The NLR requirements should be applied to all occupied rooms having one or more exterior walls or exterior ceiling. A room without any exterior walls, and which has an occupied space above its entire area, will not be subject to these requirements.

B. Compliance with the construction standards herein is sufficient to comply with the NLR requirements specified in the various noise zones. These standards are applicable to plans and specifications for any proposed residence. A variety of assumptions were necessary to develop these standards. If the plans and specifications do not indicate compliance with the construction standards herein, the applicant shall provide a written statement from a qualified acoustical consultant certifying that the construction of the building as indicated in the plans and specifications will result in a NLR for appropriate occupied rooms at least as great as the NLR requirement specified herein

C. An "exterior" door or window opens to the exterior or to a partially enclosed space such as a screened-in porch. In this standard whenever the words "doors" or "windows" are used it shall be assumed that the standard provision applies only to exterior doors and exterior windows, unless the word "interior" is specifically used for that provision.

D. Sound Transmission Class (STC) ratings for windows and doors are valid only if they are determined by laboratory (not field) tests performed by an independent laboratory for the product. A rating estimated for glass alone is not an acceptable substitute for STC tests of windows or doors, except for determining the rating of sidelights and transoms. Likewise, ratings estimated for door leafs alone are not an acceptable substitute for STC ratings of doors. The installed products must have the same composition and overall configuration such as storm panels, glass type (laminated, tempered, or float glass), glass thickness, spacing between panes of insulated glass, door core, gaskets, weatherstripping, door bottom seals, thresholds, etc., and the same overall configuration as the tested assembly. The overall configuration includes the operational type (casement, double hung, fixed, slider, etc.) in the case of windows, and the general size of glazing (1/8-, 1/4-, 1/2-, or full-view) in the case of doors. Issues that do not affect the acoustical performance such as glass obscuration, internal window muntins, door and window hardware, screens, and applied door moldings can be neglected.

E. Door sidelights and door and window transoms shall be considered "windows" and shall meet the provisions for windows. For these products it is acceptable to reference the laboratory STC rating of the glass alone. However, for the adjacent windows and doors it is still necessary to reference STC tests for the entire assembly, not just the glass or door leaf.

F. For this standard it can be assumed that the rating of a prime-and-storm window combination is STC 36 provided the rating of the storm window alone is at least STC 29 and the airspace between the prime and storm window is at least 1-3/4".

G. For this standard it can be assumed that the rating of a prime-and-storm door combination is STC 37 provided the rating of the storm door alone is at least STC 30 and the airspace between the prime and storm door is at least 2".

H. In order to achieve the STC ratings specified herein special measures are necessary to install doors and windows. These include the use of non-hardening (acoustical) caulk at all hidden surfaces, flexible caulk at all exposed surfaces, and solid continuous blocking to fill all voids over 1/4" around windows and doors.

I. The phrase "Total Exterior Wall Area" as used in this standard includes the exterior wall area of the room as well as the area of all windows and doors contained within the exterior walls.

J. The phrase "Roof" as used in this standard shall refer to a ceiling attached to the bottom edge of roof structural members that are at least 14" deep (the depth is the clear distance between the ceiling gypsumboard and the roof deck) for the portion of the structural member over a living space. The use of shallower roof framing is not allowed without a written statement from a qualified acoustical consultant (see section B above). The best acoustical performance is achieved when there are horizontal ceilings, an accessible attic space above, and a sloped roof.

K. The phrase "Exposed Floor" in this standard shall refer to the floor of a house elevated above the ground without the use of a crawl space. This includes primarily beach houses on pylons.

L. It is difficult to predict the acoustical performance of open plan spaces. Adjacent living spaces that are fully open to each other shalled be grouped and treated as one room. When the rooms are only partially open to each other group them if the partitions separating the rooms are more than 30% open.

M. The number of exterior walls is a parameter that affects the acoustical performance of the room. If the exterior wall is over 14 feet tall it shall count as two exterior walls. Partial walls count as one exterior wall.

SECTION 3: BUILDING REQUIREMENTS FOR A MINIMUM NLR OF 20 dB.

A. Exterior Walls

1. The interior surface of exterior walls shall be gypsum board at least 1/2 inch thick, or an alternative material of equal surface mass.

2. For wood-framed walls: Fiberglass, mineral fiber, or cellulose batt or blanket insulation shall be installed continuously and completely throughout the stud cavity. Batts or blankets should be held firmly in place between the studs, with fasteners if necessary, to prevent sagging; however, packing the insulation such that it is compressed may *slightly reduce* its acoustical (and thermal) performance.

3. Insulated concrete form (ICF) walls, where present, shall contain at least 4" thick normal weight concrete throughout the surface of the wall.

B. Windows

1. 1.Windows in rooms that have at least one wood-framed exterior wall shall have a laboratory sound transmission class rating of at least STC 28.

2. For rooms that have all ICF exterior walls: If the exterior windows and doors together comprise 75% or more of the Total Exterior Wall Area the windows shall have a laboratory sound transmission class rating of at least STC 28.

C. Doors

1. Exterior doors, and interior doors between occupied spaces and attached garages, unfinished attics, and other non-habitable spaces with an exterior wall or ceiling, shall be fully weatherstripped.

D. Roof-Ceiling Assembly

1. Gypsum board ceilings at least 1/2 inch thick shall be provided. Ceilings shall be substantially airtight with a minimum number of penetrations.

2. Fiberglass, mineral fiber, or cellulose insulation shall be installed continuously and completely throughout the ceiling joist cavity to a depth of at least 10 inches.

3. Roof framing members shall be at least 14" deep for their entire span.

4. Attic access panels shall be constructed of 3/4" thick plywood and shall have continuous neoprene perimeter bulb seals. Pull-down attic stairs shall have moveable or operable covers.

5. Skylights shall not be provided.

E. Floors, Foundations and Basements

1. For houses elevated on pylons: Use plywood or OSB at least 1/2" thick at the underside of the floor joists with at least 10" thick fiberglass, mineral fiber, or cellulose insulation.

2. If crawl spaces do not have masonry walls, a massive barrier panel must be used as a skirt connecting the bottom of the walls to the ground. 2" thick precast concrete panels are ideal barrier skirts. Alternatively, 2x4 pressure-treated wood studs with ¾" pressure-treated plywood on each side may be used, as long as the joints between the plywood are covered with batten strips.

F. Ventilation and Wall Penetrations

1. In-window, through-wall, or through-floor air-conditioning, ventilating, or heating units shall not be used.

2. Through-the-wall/door mailboxes or mail slots shall not be used.

3. 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, as specified in the North Carolina state building code, without the need to open any windows, doors, or other openings to the exterior.

4. Gravity vent openings in attics shall not exceed the code minimum in number and size.

5. If an attic 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 at least 5 feet long with at least one 90° bend.

6. All vent ducts, including those for bathroom exhaust fans and dryers, connecting the interior space to the outdoors shall contain at least two 90° bends.

7. Vented domestic range fans shall be not used.

8. Vented fireplaces, wood stoves, or gas-powered prefabricated units shall not be used.

9. Vented fuel-burning driven appliances (e.g., gas dryers, gas fireplaces, oil or gas furnaces, and gas water heaters) shall not be located in living spaces (e.g, kitchens, living rooms, bedrooms, etc.). Vent ducts for fuel-burning appliances in non-living spaces (e.g., closets and attics) shall have double-wall sheet metal construction.

10. Whole-house fans shall not be provided.

11. Dryer shall be located in closets or other non-habitable spaces. Dryer ducts shall be rigid metal.

SECTION 4: BUILDING REQUIREMENTS FOR A MINIMUM NLR OF 25 dB.

A. Exterior walls

1. In-window, through-wall, or through-floor air-conditioning, ventilating, or heating units shall not be used.

2. The interior surface of exterior walls shall be gypsum board at least 1/2 inch thick, or an alternative material of equal surface mass.

3. For wood-framed walls: Fiberglass, mineral fiber, or cellulose batt or blanket insulation shall be installed continuously and completely throughout the stud cavity. Batts or blankets should be held firmly in place between the studs, with fasteners if necessary, to prevent sagging; however, packing the insulation such that it is compressed may slightly reduce its acoustical (and thermal) performance.

4. Insulated concrete form (ICF) walls, where present, shall contain at least 4" thick normal weight concrete throughout the surface of the wall.

B. Windows

1. For rooms with at least one wood-framed wall:

   a. The interior surface of exterior walls shall be gypsum board at least 1/2 inch thick, or an alternative material of equal surface mass.
      i. If the exterior windows and doors together comprise less than 25% of the Total Exterior Wall Area the windows shall have a laboratory sound transmission class rating of at least STC 26.
      ii. If the exterior windows and doors together comprise 25-40% of the Total Exterior Wall Area the windows shall have a laboratory sound transmission class rating of at least STC 28.
      iii. If the exterior windows and doors together comprise more than 40% of the Total Exterior Wall Area the windows shall have a laboratory sound transmission class rating of at least STC 30.

   b. If there are two or more exterior walls:
      i. If the exterior windows and doors together comprise less than 20% of the Total Exterior Wall Area the windows shall have a laboratory sound transmission class rating of at least STC 28.
      ii. If the exterior windows and doors together comprise 20-35% of the Total Exterior Wall Area the windows shall have a laboratory sound transmission class rating of at least STC 30.
      iii. If the exterior windows and doors together comprise more than 35% of the Total Exterior Wall Area the windows shall have a laboratory sound transmission class rating of at least STC 32..

2. For rooms with all ICF walls:

   a. If there is one exterior wall:
      i. If the exterior windows and doors together comprise less than 40% of the Total Exterior Wall Area the windows shall have a laboratory sound transmission class rating of at least STC 26.
      ii. If the exterior windows and doors together comprise 40% or more of the Total Exterior Wall Area the windows shall have a laboratory sound transmission class rating of at least STC 30.

   b. If there are two or more exterior walls:
      i. If the exterior windows and doors together comprise less than 20% of the Total Exterior Wall Area the windows shall have a laboratory sound transmission class rating of at least STC 26.
      ii. If the exterior windows and doors together comprise 20-30% of the Total Exterior Wall Area the windows shall have a laboratory sound transmission class rating of at least STC 28.
      iii. If the exterior windows and doors together comprise 30-75% of the Total Exterior Wall Area the windows shall have a laboratory sound transmission class rating of at least STC 30.
      iv. If the exterior windows and doors together comprise more than 75% of the Total Exterior Wall Area the windows shall have a laboratory sound transmission class rating of at least STC 32.

C. Doors

1. For rooms with all ICF walls:

   a. If there is only one exterior wall: If exterior windows and doors together comprise more than 40% of the Total Exterior Wall Area the doors shall have a laboratory sound transmission class rating of at least STC 29.

b. If there are more than one exterior wall: If exterior windows and doors together comprise 20% or more of the Total Exterior Wall Area the doors shall have a laboratory sound transmission class rating of at least STC 29.

2. For rooms with all ICF walls:

   a. If there is only one exterior wall and the exterior windows and doors together comprise 40% or more of the Total Exterior Wall Area the doors shall have a laboratory sound transmission class rating of at least STC 29.

   b. If there are more than one exterior wall and the exterior windows and doors together comprise 30% or more of the Total Exterior Wall Area the doors shall have a laboratory sound transmission class rating of at least STC 29.

3. Interior doors between occupied spaces and attached garages, unfinished attics, or other non-habitable spaces with an exterior wall or ceiling shall have a laboratory sound transmission class rating of at least STC 23.

D. Roof-Ceiling Assembly

1. Gypsum board ceilings at least 1/2 inch thick shall be provided. Ceilings shall be substantially airtight with a minimum number of penetrations.

2. Fiberglass, mineral fiber, or cellulose insulation shall be installed continuously and completely throughout the ceiling joist cavity to a depth of at least 10 inches.

3. Roof framing members shall be at least 14" deep for their entire span.

4. Attic access panels shall be constructed of 3/4" thick plywood and shall have continuous neoprene perimeter bulb seals. Pull-down attic stairs shall have moveable or operable covers.

5. Skylights shall not be provided.

E. Floors and Foundations

1. For houses elevated on pylons: Use plywood or OSB at least 1/2" thick at the underside of the floor joists with at least 10" thick fiberglass, mineral fiber, or cellulose insulation.

2. If crawl spaces do not have masonry walls, a massive barrier panel must be used as a skirt connecting the bottom of the walls to the ground. 2" thick precast concrete panels are ideal barrier skirts. Alternatively, 2x4 pressure-treated wood studs with ¾" pressure-treated plywood on each side may be used, as long as the joints between the plywood are covered with batten strips.

F. Ventilation and Wall and Roof Penetrations

1. In-window, through-wall, or through-floor air-conditioning, ventilating, or heating units shall not be used.

2. Through-the-wall/door mailboxes or mail slots shall not be used.

3. 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, as specified in the North Carolina state building code, without the need to open any windows, doors, or other openings to the exterior.

4. Gravity vent openings in attics shall not exceed the code minimum in number and size.

5. If an attic 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 at least 5 feet long with at least one 90° bend.

6. All vent ducts, including those for bathroom exhaust fans and dryers, connecting the interior space to the outdoors shall contain at least two 90° bends.

7. Vented domestic range fans shall be not used.

8. Vented fireplaces, wood stoves, or gas-powered prefabricated units shall not be used.

9. Vented fuel-burning appliances (e.g., gas dryers, gas fireplaces, oil or gas furnaces, and gas water heaters) shall not be located in living spaces (e.g, kitchens, living rooms, bedrooms, etc.). Vent ducts for fuel-burning appliances in non-living spaces (e.g., closets and attics) shall have double-wall sheet metal construction.

10. Whole-house fans shall not be provided.

11. Dryer shall be located in closets or other non-habitable spaces. Dryer ducts shall be rigid metal.

SECTION 5: BUILDING REQUIREMENTS FOR A MINIMUM NLR OF 30 dB.

A. Exterior Walls

1. The interior surface of exterior walls shall be gypsum board at least 1/2 inch thick, or an alternative material of equal surface mass.

2. For wood-framed walls:

   a. Fiberglass, mineral fiber, or cellulose batt or blanket insulation shall be installed continuously and completely throughout the stud cavity. Batts or blankets should be held firmly in place between the studs, with fasteners if necessary, to prevent sagging; however, packing the insulation such that it is compressed may slightly reduce its acoustical (and thermal) performance.

   b. If there is one only one exterior wall: If exterior windows and doors together comprise 30% or more of the Total Exterior Wall Area, single-leaf resilient channels shall be used between the studs and gypsum board.

c. If there are two or more exterior walls single-leaf resilient channels shall be used between the studs and gypsum board.

3. Insulated concrete form (ICF) walls, where present, shall contain at least 4" thick normal weight concrete throughout the surface of the wall.

B. Windows

1. For rooms with at least one wood-framed wall:

   a. If there is one exterior wall:
      i. If the exterior windows and doors together comprise less than 20% of the Total Exterior Wall Area the windows shall have a laboratory sound transmission class rating of at least STC 32.
      ii. If the exterior windows and doors together comprise 20-30% of the Total Exterior Wall Area the windows shall have a laboratory sound transmission class rating of at least STC 34.
      iii. if the exterior windows and doors together comprise 30-50% of the Total Exterior Wall Area the windows shall have a laboratory sound transmission class rating of at least STC 32.
      iv. if the exterior windows and doors together comprise more than 50% of the Total Exterior Wall Area the windows shall have a laboratory sound transmission class rating of at least STC 34.

   b. If there are two exterior walls: The windows shall have a laboratory sound transmission class rating of at least STC 34.

   c. If there are three or more exterior walls:
      i. If the exterior windows and doors together comprise 70% or less of the Total Exterior Wall Area the windows shall have a laboratory sound transmission class rating of at least STC 34.
      ii. If the exterior windows and doors together comprise more than 70% of the Total Exterior Wall Area the windows shall have a laboratory sound transmission class rating of at least STC 36.

2. For rooms with all ICF walls:

   a. If there is one exterior wall:
      i. If the exterior windows and doors together comprise less than 20% of the Total Exterior Wall Area the windows shall have a laboratory sound transmission class rating of at least STC 30.
      ii. If the exterior windows and doors together comprise 20 to 50% of the Total Exterior Wall Area the windows shall have a laboratory sound transmission class rating of at least STC 32.
      iii. If the exterior windows and doors together comprise more than 50% of the Total Exterior Wall Area the windows shall have a laboratory sound transmission class rating of at least STC 34.

   b. If there are two exterior walls: The windows shall have a laboratory sound transmission class rating of at least STC 34.

   c. If there are three or more exterior walls:
      i. If the exterior windows and doors together comprise 70% or less of the Total Exterior Wall Area the windows shall have a laboratory sound transmission class rating of at least STC 34.
      ii. If the exterior windows and doors together comprise more than 70% of the Total Exterior Wall Area the windows shall have a laboratory sound transmission class rating of at least STC 36.

C. Doors

1. For rooms with At least one wood-framed wall:

   a. If there is one exterior wall:
      i. If the exterior windows and doors together comprise less than 20% of the Total Exterior Wall Area the doors shall have a laboratory sound transmission class rating of at least STC 31.
      ii. If the exterior windows and doors together comprise 20-30% of the Total Exterior Wall Area the doors shall have a laboratory sound transmission class rating of at least STC 34.
      iii. If the exterior windows and doors together comprise 30-50% of the Total Exterior Wall Area the doors shall have a laboratory sound transmission class rating of at least STC 31.
      iv. If the exterior windows and doors together comprise more than 50% of the Total Exterior Wall Area the doors shall have a laboratory sound transmission class rating of at least STC 34.

   b. If there are two exterior walls:
      i. If the exterior windows and doors together comprise less than 20% of the Total Exterior Wall Area the doors shall have a laboratory sound transmission class rating of at least STC 31.
      ii. If the exterior windows and doors together comprise 20% or more of the Total Exterior Wall Area the doors shall have a laboratory sound transmission class rating of at least STC 34.

   c. If there are three or more exterior walls:
      i. If the exterior windows and doors together comprise less than 20% of the Total Exterior Wall Area the doors shall have a laboratory sound transmission class rating of at least STC 31.
      ii. If the exterior windows and doors together comprise 20% or more of the Total Exterior Wall Area the doors shall have a laboratory sound transmission class rating of at least STC 34.

2. For rooms with all ICF walls:

   a. If there is one exterior wall:
      i. If the exterior windows and doors together comprise less than 20% of the Total Exterior Wall Area the doors shall have a laboratory sound transmission class rating of at least STC 29.
      ii. If the exterior windows and doors together comprise 20 to 50% of the Total Exterior Wall Area the doors shall have a laboratory sound transmission class rating of at least STC 31.
      iii. If the exterior windows and doors together comprise more than 50% of the Total Exterior Wall Area the doors shall have a laboratory sound transmission class rating of at least STC 34.

   b. If there are two exterior walls:
      i. If the exterior windows and doors together comprise less than 20% of the Total Exterior Wall Area the doors shall have a laboratory sound transmission class rating of at least STC 31.
      ii. If the exterior windows and doors together comprise 20% or more of the Total Exterior Wall Area the doors shall have a laboratory sound transmission class rating of at least STC 34.

   c. If there are three or more exterior walls:
      i. If the exterior windows and doors together comprise less than 20% of the Total Exterior Wall Area the doors shall have a laboratory sound transmission class rating of at least STC 31.
      ii. If the exterior windows and doors together comprise 20% or more of the Total Exterior Wall Area the doors shall have a laboratory sound transmission class rating of at least STC 34.

3. Interior doors between occupied spaces and attached garages, unfinished attics , or other non-habitable spaces with an exterior wall or ceiling shall have a laboratory sound transmission class rating of at least STC 29.

D. Roof-Ceiling Assembly

1. Ceilings consisting of at least two layers of at least 1/2-inch thick gypsum board shall be provided. Ceilings shall be substantially airtight with a minimum number of penetrations.

2. Fiberglass, mineral fiber, or cellulose insulation shall be installed continuously and completely throughout the ceiling joist cavity to a depth of at least 10 inches.

3. Roof framing members shall be at least 14" deep for their entire span.

4. Attic access panels shall be constructed of 3/4" thick plywood and shall have continuous neoprene perimeter bulb seals. Pull-down attic stairs shall have moveable or operable covers.

5. Skylights shall not be provided.

E. Floors and Foundations

1. For houses elevated on pylons: Use plywood or OSB at least 1/2" thick at the underside of floor joists that are at least 14" deep with at least 10" thick fiberglass, mineral fiber, or cellulose insulation.

2. If crawl spaces do not have masonry walls, a massive barrier panel must be used as a skirt connecting the bottom of the walls to the ground. 2" thick precast concrete panels are ideal barrier skirts. Alternatively, 2x4 pressure-treated wood studs with ¾" pressure-treated plywood on each side may be used, as long as the joints between the plywood are covered with batten strips.

F. Ventilation and Wall and Roof Penetrations

1. In-window, through-wall, or through-floor air-conditioning, ventilating, or heating units shall not be used.

2. Through-the-wall/door mailboxes or mail slots shall not be used.

3. 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, as specified in the North Carolina state building code, without the need to open any windows, doors, or other openings to the exterior.

4. Gravity vent openings in attics shall not exceed the code minimum in number and size.

5. If an attic 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 at least 5 feet long with at least one 90° bend.

6. All vent ducts, including those for bathroom exhaust fans and dryers, connecting the interior space to the outdoors shall contain at least two 90° bends.

7. Vented domestic range fans shall be not used.

8. Vented fireplaces, wood stoves, or gas-powered prefabricated units shall not be used.

9. Vented fuel-burning appliances (e.g., gas dryers, gas fireplaces, oil or gas furnaces, and gas water heaters) shall not be located in living spaces (e.g, kitchens, living rooms, bedrooms, etc.). Vent ducts for fuel-burning appliances in non-living spaces (e.g., closets and attics) shall have double-wall sheet metal construction.

10. Whole-house fans shall not be provided.

11. Dryer shall be located in closets or other non-habitable spaces. Dryer ducts shall be rigid metal.

SECTION 6: BUILDING REQUIREMENTS FOR A MINIMUM NLR OF 35 dB.

A. Exterior Walls

1. The interior surface of exterior walls shall be gypsum board at least 1/2 inch thick, or an alternative material of equal surface mass.

2. For wood-framed walls:

   a. Fiberglass, mineral fiber, or cellulose batt or blanket insulation shall be installed continuously and completely throughout the stud cavity. Batts or blankets should be held firmly in place between the studs, with fasteners if necessary, to prevent sagging; however, packing the insulation such that it is compressed may slightly reduce its acoustical (and thermal) performance.

   b. If there is one only one exterior wall:
      i. If exterior windows and doors together comprise less than 25% of the Total Exterior Wall Area single-leaf resilient channels shall be used between the studs and gypsum board.
      ii. If exterior windows and doors together comprise 25% or more of the Total Exterior Wall Area the studs shall be 2x4 studs staggered on 2x6 plates (if the studs need to be 2x6 for structural reasons, use 2x6 studs staggered on 2x8 plates).

   c. If there are two or more exterior walls:
      i. If exterior windows and doors together comprise less than 15% of the Total Exterior Wall Area single-leaf resilient channels shall be used between the studs and gypsum board.
      ii. If exterior windows and doors together comprise 15 to 30% of the Total Exterior Wall Area the studs shall be 2x4 studs staggered on 2x6 plates (if the studs need to be 2x6 for structural reasons, use 2x6 studs staggered on 2x8 plates).
      iii. If exterior windows and doors together comprise more than 30% of the Total Exterior Wall Area the studs shall be 2x4 studs staggered on 2x6 plates (if the studs need to be 2x6 for structural reasons, use 2x6 studs staggered on 2x8 plates), and two layers of 1/2" gypsum board shall be provided at the interior surface of the room.

3. Insulated concrete form (ICF) walls, where present, shall contain at least 4" thick normal weight concrete throughout the surface of the wall.

B. Windows

1. For rooms with at least one wood-framed wall:

   a. If there is one exterior wall:
      i. If the exterior windows and doors together comprise less than 25% of the Total Exterior Wall Area the windows shall have a laboratory sound transmission class rating of at least STC 36.
      ii. If the exterior windows and doors together comprise 25% or more of the Total Exterior Wall Area the windows shall have a laboratory sound transmission class rating of at least STC 40.

   b. If there are two or more exterior walls:
      i. If the exterior windows and doors together comprise less than 20% of the Total Exterior Wall Area the windows shall have a laboratory sound transmission class rating of at least STC 38.
      ii. If the exterior windows and doors together comprise 20% or more of the Total Exterior Wall Area the windows shall have a laboratory sound transmission class rating of at least STC 42.

2. For rooms with all ICF walls:

   a. If there is one exterior wall:
      i. If the exterior windows and doors together comprise less than 15% of the Total Exterior Wall Area the windows shall have a laboratory sound transmission class rating of at least STC 34.
      ii. If the exterior windows and doors together comprise 15 to 25% of the Total Exterior Wall Area the windows shall have a laboratory sound transmission class rating of at least STC 36.
      iii. If the exterior windows and doors together comprise 25 to 50% of the Total Exterior Wall Area the windows shall have a laboratory sound transmission class rating of at least STC 38.
      iv. If the exterior windows and doors together comprise more than 50% of the Total Exterior Wall Area the windows shall have a laboratory sound transmission class rating of at least STC 40.

   b. If there are two or more exterior walls:
      i. If the exterior windows and doors together comprise less than 20% of the Total Exterior Wall Area the windows shall have a laboratory sound transmission class rating of at least STC 40.
      ii. If the exterior windows and doors together comprise 20% or more of the Total Exterior Wall Area the windows shall have a laboratory sound transmission class rating of at least STC 44.

C. Doors

1. For rooms with at least one wood-framed wall:

   a. If there is one exterior wall:
      i. If the exterior windows and doors together comprise less than 25% of the Total Exterior Wall Area the doors shall have a laboratory sound transmission class rating of at least STC 34.
      ii. If the exterior windows and doors together comprise 25% or more of the Total Exterior Wall Area the doors shall have a laboratory sound transmission class rating of at least STC 40.

b. If there are two or more exterior walls:
   i. If the exterior windows and doors together comprise 30% or less of the Total Exterior Wall Area the doors shall have a laboratory sound transmission class rating of at least STC 37.
   ii. If the exterior windows and doors together comprise more than 30% of the Total Exterior Wall Area the doors shall have a laboratory sound transmission class rating of at least STC 40.

2. For rooms with all ICF walls:

   a. If there is one exterior wall:
      i. If the exterior windows and doors together comprise less than 25% of the Total Exterior Wall Area the doors shall have a laboratory sound transmission class rating of at least STC 34.
      ii. If the exterior windows and doors together comprise 25 to 50% of the Total Exterior Wall Area the doors shall have a laboratory sound transmission class rating of at least STC 37.
      iii. If the exterior windows and doors together comprise more than 50% of the Total Exterior Wall Area the doors shall have a laboratory sound transmission class rating of at least STC 40.

   b. If there are two or more exterior walls:
      i. If the exterior windows and doors together comprise less than 15% of the Total Exterior Wall Area the doors shall have a laboratory sound transmission class rating of at least STC 37.
      ii. If the exterior windows and doors together comprise 15 to 30% of the Total Exterior Wall Area the doors shall have a laboratory sound transmission class rating of at least STC 40.
      iii. If the exterior windows and doors together comprise more than 30% of the Total Exterior Wall Area the doors shall have a laboratory sound transmission class rating of at least STC 43.

3. Interior doors between occupied spaces and attached garages, unfinished attics, or other non-habitable spaces with an exterior wall or ceiling shall have a laboratory sound transmission class rating of at least STC 29.

D. Roof-Ceiling Assembly

1. Gypsum board ceilings at least 1/2 inch thick shall be provided. Single-leaf resilient channels shall be used to hang the gypsum board. Ceilings shall be substantially airtight with a minimum number of penetrations.

2. Fiberglass, mineral fiber, or cellulose insulation shall be installed continuously and completely throughout the ceiling joist cavity to a depth of at least 10 inches.

3. Roof framing members shall be at least 14" deep for their entire span.

4. Attic access panels shall be constructed of 3/4" thick plywood and shall have continuous neoprene perimeter bulb seals. Pull-down attic stairs shall have moveable or operable covers.

5. Skylights shall not be provided.

E. Floors and Foundations

1. For houses elevated on pylons: Use plywood or OSB at least 1/2" thick at the underside of floor joists that are at least 14" deep with at least 10" thick fiberglass, mineral fiber, or cellulose insulation.

2. If crawl spaces do not have masonry walls, a massive barrier panel must be used as a skirt connecting the bottom of the walls to the ground. 2" thick precast concrete panels are ideal barrier skirts. Alternatively, 2x4 pressure-treated wood studs with ¾" pressure-treated plywood on each side may be used, as long as the joints between the plywood are covered with batten strips.

F. Ventilation and Wall and Roof Penetrations

1. In-window, through-wall, or through-floor air-conditioning, ventilating, or heating units shall not be used.

2. Through-the-wall/door mailboxes or mail slots shall not be used.

3. 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, as specified in the North Carolina state building code, without the need to open any windows, doors, or other openings to the exterior.

4. Gravity vent openings in attics shall not exceed the code minimum in number and size.

5. If an attic 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 at least 5 feet long with at least one 90° bend.

6. All vent ducts, including those for bathroom exhaust fans and dryers, connecting the interior space to the outdoors shall contain at least two 90° bends.

7. Vented domestic range fans shall be not used.

8. Vented fireplaces, wood stoves, or gas-powered prefabricated units shall not be used.

9. Vented fuel-burning appliances (e.g., gas dryers, gas fireplaces, gas furnaces, and gas water heaters) shall not be located in living spaces (e.g, kitchens, living rooms, bedrooms, etc.). Vent ducts for fuel-burning driven appliances in non-living spaces (e.g., closets and attics) shall have double-wall sheet metal construction.

10. Whole-house fans shall not be provided.

11. Dryer shall be located in closets or other non-habitable spaces. Dryer ducts shall be rigid metal.

APPENDIX B

MANUFACTURERS OF ACOUSTICAL MATERIALS

Appendix B
Manufacturers of Acoustical Materials

This list represents a partial list of typical suppliers of specialty acoustical products. Other manufacturers not listed may have comparable products. The list below does not imply a product endorsement or recommendation by Wyle Laboratories.

BATTS AND RIGID FIBERGLASS INSULATION

CertainTeed
Headquarters
P.O. Box 860 or
750E Swedesford Rd.
Valley Forge, PA 19482
Tel: 800-233-8990
www.certainteed.com

Johns Manville
P.O. Box 5108
Denver, CO 80217-5108
Tel: 800-654-3103
www.jm.com

Knauf Fiberglass
One Knaff Drive
Shelbyville, IN 46176
Tel: 800-825-4434
Fax: 317-398-3675

Owens Corning Fiberglass Corp.
One Owens Corning Parkway
Toledo, OH 43659
Tel: 800-438-7465 (800-GET-PINK)
www.owenscorning.com

ACOUSTICALLY TESTED DOORS

Algoma Hardwoods
1001 Perry Street
Algoma, WI 54201
Tel: 800-678-8910
www.algomahardwoods.com

Armaclad, Inc.
P.O. Box 70
Waynesboro, PA 17268
Tel: 800-541-6666
www.armaclad.com

Buell Door Company
5200 East Grand Ave.
Suite 500
Dallas, TX 75223
Tel: 800-556-0155
www.buelldoor.com

Ceco Door Products
9159 Telecom Drive
Milan, TN 38358
Tel: 888-232-6366
www.cecodoor.com

Eggers Industries
P.O. Box 1050
Neenah, WI 54957-1050
Tel: 920-722-6444
www.eggersindustries.com

Frieger Specialty Products
9880 Gregg Road
Pico Rivera, CA 90660
Tel: 866-203-5060
www.kriegerproducts.com

Graham Architectural Products
1551 Mt. Rose Avenue
York, PA 17403-2909
Tel: 800-755-6274
www.grahamarch.com

Harvey Industries, Inc.
1400 Main Street
Waltham, MA 02154
Tel: 800-942-7839
www.harveyind.com

Industrial Acoustics Company
1160 Commerce Avenue
Bronx, NY 10462
Tel: 718-931-8000
www.industrialacoustics.com

Jeld-wen
19618 Wildwood Drive
West Linn, OR 97068
Tel: 877-783-2057
www.jeld-wen.com

ACOUSTICALLY TESTED DOORS - *Concluded*

Jamison Door Company
55 J.V. Jamison Drive
P.O. Box 70
Hagerstown, MD 21741-0070
Tel: 800-532-3667
www.jamison-door.com

Krieger Specialty Products
4880 Gregg Road
Pico Rivera, CA 90660
Tel: 866-203-5060
www.kriegerproducts.com

Larson Doors
Tel: 800-352-3360
www.larsondoors.com

Marshfield Doors Systems, Inc.
1401 East 4th Street
Marshfield, WI 54449-7780
Tel: 800-869-3667
www.marshfielddoors.com

Mohawk Flush Doors, Inc.
980 Point Township Road
P.O. Box 112
Northumberland, PA 17857-0112
Tel: 570-473-3557
www.mohawkdoors.com

Mon-Ray, Inc.
801 Boone Avenue North
Minneapolis, MN 55427-4432
Tel: 800-544-3646
www.monray.com

Overly Door Company
574 West Otterman St.
Greensburg, PA 15601
Tel: 800-979-7300
www.overly.com

P.H. Tech Corp.
144 Ferry Street
Buncher Industrial Park
Leetsdale, PA 15056
www.phtech.ca

Pioneer Industries
171 South Newman Street
Hackensack, NJ 07601
Tel: 201-933-1900
www.pioneerindustries.com

Rehau Incorporated
P.O. Box 1706
Leesburg, VA 20177
Tel: 800-247-9445
www.rehau.com

Republic Windows and Doors
930 West Evergreen Ave.
Chicago, IL 60622
Tel: 800-248-1775
www.republicwindows.com

Torrance Aluminum
22850 Perry St.
Perris, CA 92570
Tel: 909-943-0430
www.torrancealuminum.com

Vancouver Door Company
203 5th St., N.W.
P.O. Box 1418
Puyallup, WA 98371
Tel: 800-999-3667
www.vancouverdoorco.com

Wausau Window and Wall Systems
1415 West Street
Wausau, WI 54401
Tel: 715-845-2161
www.wausauwindows.com

Whisper-Like
P.O. Box 2949
Toledo, OH 43606
Tel: 800-227-8246
whisper-like.com

Windor Supply and Manufacturing
4237 S. 74th E. Ave.
Tulsa, OK 74145
Tel: 800-324-1947
www.windor.com

DUCT AND FAN NOISE CONTROL

Acoustical Surfaces, Inc.
123 Columbia Court North, Suite 201
Chaska, MN 55318
Tel: 800-448-0737

Aeroacoustic Corporation
3300 Corporation Way
Darlington, SC 29532
Tel: 843-398-1006
www.aeroacoustic.com

Industrial Acoustics Company
1160 Commerce Avenue
Bronx, NY 10462
Tel: 718-931-8000
www.industrialacoustics.com

McGill Airflow Corporation
One Mission Park
Groveport, OH 43125
Tel: 614-836-9981
www.mcgillairflow.com

DOOR SEALS AND WEATHERSTRIPPING

National Guard Products, Inc.
4985 East Raines Rd.
Memphis, TN 38118
Tel: 800-647-7874
www.ngpinc.com

Pemko Manufacturing Co.
5535 Distribution Drive
Memphis, TN 38141
Tel: 800-824-3018
www.pemko.com

Zero International, Inc.
415 Concord Avenue
Bronx, NY 10455
Tel: 800-635-5335
www.zerointernational.com

ACOUSTICALLY TESTED WINDOWS

Century Manufacturing, Inc.
4620 Andrews St.
North Las Vegas, NV 89031
Tel: 800-654-7027
www.windowtech.com

Graham Architectural Products
1551 Mt. Rose Avenue
York, PA 17403-2909
Tel: 800-755-6274
www.grahamarch.com

Harvey Industries Inc.
1400 Main Steret
Waltham, MA 02154
Tel: 800-942-7839
www.harveyind.com

Industrial Acoustics Company
1160 Commerce Avenue
Bronx, NY 10462
Tel: 718-931-8000
www.industrialacoustics.com

Jeld-wen
19618 Wildwood Drive
West Linn, OR 97068
Tel: 877-783-2057
www.jeld-wen.com

Loewen, Inc.
6465 East Johns Crossing, Suite 400
Duluth, GA 30097
Tel: 800-563-9367
www.loewen.com

Milgard Windows
965 54th Ave. East
Tacoma, WA 98424
Tel: 800-645-4273 (800-MIL-GARD)
www.milgard.com

Mon-Ray, Inc.
801 Boone Avenue North
Minneapolis, N 55427-4432
Tel: 800-544-3646
www.monray.com

ACOUSTICALLY TESTED WINDOWS - *Concluded*

NRG, Inc.
22520 Ecorse Rd.
Taylor, MI 48180
Tel: 312-295-4100

National Gypsum Company
2001 Rexford Road
Charlotte, NC 28211
Tel: 704-365-7300
www.nationalgypsum.com

Peerless Products, Inc.
2403 S. Main Street
Fort Scott, KS 66701
Tel: 866-420-4000
www.peerlessproducts.com

Rehau Incorporated
P.O. Box 1706
Leesburg, VA 20177
Tel: 800-247-9445
www.rehau.com

Republic Windows and Doors
930 West Evergreen Ave.
Chicago, IL 60622
Tel: 800-248-1775
www.republicwindows.com

St. Cloud Window, Inc.
P.O. Box 1577
St. Cloud, MN 56302
Tel: 800-383-9311
www.stcloudwindow.com

Therm-o-lite
635 S. Lafayette Blvd.
South Bend, IN 46601
Tel: 574-234-4004
www.therm-o-lite-windows.com

Torrance Aluminum
22850 Perry St.
Perris, CA 92570
Tel: 909-943-0430
www.torrancealuminum.com

Wausau Window and Wall Systems
1415 West Street
Wausau, WI 54401
Tel: 715-845-2161
www.wausauwindows.com

WALL TREATMENTS

National Gypsum Company
2001 Rexford Road
Charlotte, NC 28211
Tel: 704-365-7300
www.nationalgypsum.com

PAC International Inc.
10680 S.W. Industrial Way
Tualatin, OR 97062-9502
Tel: 866-774-2100
www.pac-intl.com

Quiet Solution, Inc.
522 Almanor Ave.
Sunnyvale, CA 94085
Tel: 800-797-8438
www.quietsolution.com

USG
125 South Franklin
Chicago, IL 60606
Tel: 312-606-4000
www.usg.com

APPENDIX C

INDEPENDENT CERTIFIED ACOUSTICAL TESTING LABORATORIES

Appendix C
Independent Certified Acoustical Testing Laboratories

This list represents a partial list of Certified Acoustical Testing Laboratories. The list below does not imply an endorsement or recommendation by Wyle Laboratories. The National Voluntary Laboratory Accreditation Program (NVLAP) maintains a Directory of Accredited Laboratories on their website:

http://ts.nist.gov/ts/htdocs/210/214/scopes/acots.htm

Acoustic Systems Acoustical
Research Facility, Inc.
415 East St. Elmo Road
P.O. Box 3610
Austin, TX 78764
512/444-1961

Western Electro-Acoustic Lab., Inc.
25132 Rye Canyon Loop
Santa Clarita, CA 91355
661-775-3741

Architectural Testing Inc.
130 Derry Ct.
York, PA 17402
717-764-7700

Stork-Twin City Testing, Inc.
662 Cromwell Avenue
St. Paul, MN 55114-1776
651-645-3601

Riverbank Acoustical Labs, Inc.
1512 Batavia Avenue
Geneva, Illinois 60134
630-232-0104

Orfield Laboratories, Inc.
2709 E. 25th Street
Minneapolis, MN 55406
612-721-2455

APPENDIX D

GLOSSARY

Appendix D
Glossary

Absorption Coefficient The sound-absorbing ability of a material. Values of absorption coefficient are a function of the frequency of the incident sound. The values of sound absorption coefficients usually range from about 0.01 (for hard smooth surfaces) to about 1.0 (for thick absorptive fiberglass).

Acoustical Treatment Applying design principles in architectural acoustics to reduce noise or vibration and to correct acoustical problems.

Acoustics The science of sound, including the generation, transmission, and effects of sound waves, both audible and inaudible.

Airborne Sound Sound traveling through air rather than through solid materials or the structure of the building.

Ambient Noise Level Sometimes called the "background" noise, the level of noise that is all-encompassing within a given environment. It is usually made up of many different sounds, some originating near to and far from the receiver.

American National Standards Institute (ANSI) A voluntary federation of organizations concerned with developing standards covering a broad spectrum of topics.

American Society of Heating, Refrigerating, and Air-Conditioning Engineers (ASHRAE) A professional organization which identifies and publishes specifications and standard practices relating to all aspects of heating, ventilation, refrigeration, and air conditioning.

American Society for Testing and Materials (ASTM) An organization which develops and publishes recommended practices and standards for a broad range of testing and material properties issues.

Architectural Acoustics The science of sound, including its production, transmission, control, and effects within buildings.

Attenuation The reduction of sound.

A-Weighted Sound Level A sound measure, in decibels, that reflects the heightened sensitivity of the human ear to sound frequencies between 1000 and 6000 Hz, and the relatively reduced sensitivity to sound below 1000 Hz or above 6000 Hz. The A-weighted sound level is used to predict the relative "noisiness" or "annoyance" of many common sounds.

Background Noise Ambient noise from all sources unrelated to a any particular sound. Background noise may include airborne, structureborne, and instrument noise.

Balanced Design A noise control design in which all important noise paths transmit the same amount of acoustic energy into the space, avoiding any "weak links" so that the combined effect ensures an acceptable noise level.

Building Officials and Code Administrators International (BOCA) *See International Building Code.*

Dampen To cause a reduction, usually through dissipation, of the sound energy.

Day-Night Average Sound Level (DNL or Ldn) The day-night average sound level is a measure of the average noise environment over a 24-hour day. It is the 24-hour energy-averaged, A-weighted sound level with a 10 dB penalty applied to the nighttime levels which occur between 10:00 p.m. to 7:00 a.m.

Decibel (dB) The term used to describe sound levels.

Design Criteria Design goals used in acoustical and noise control design of buildings. Design criteria may be stated either as the maximum allowable noise levels inside buildings or as noise reduction values (from outside to inside) required for certain types of buildings or rooms.

DNL See Day-Night Average Sound Level.

Environmental Noise Unwanted sound from various outdoor noise sources. Environmental noise sources include aircraft, cars, trucks, buses, railways, industrial plants, construction activities, lawnmowers, etc.

Frequency The number of oscillations per second of a vibrating object, measured in Hertz (Hz).

Hertz The unit used to designate frequency. Specifically, the number of cycles per second.

International Building Code (IBC) A comprehensive building code published by the International Code Council (ICC) covering the fire, life, and structural safety aspects of all buildings and related structures. As of January 2003, the three largest building code organizations in America merged. Building Officials and Code Administrators International (BOCA), Southern Building Code Congress International (SBCCI), and the International Conference of Building Officials (ICBO) integrated to form the International Code Council (ICC). Municipalities may still reference earlier versions of BOCA, UBC, and SBC (as well as IBC). Also, states typically have their own building codes that may incorporate all or part of these codes.

Loudness The attribute of a sound, on a scale extending from very soft to very loud. Loudness depends most on the sound pressure or energy of the source, but it also depends upon the frequency and wave form of the source (because the human ear is more sensitive to some frequencies and forms than others).

Masking The ability of one sound to block out the perception of another sound. For example, radio static may mask voices in a nearby room. Masking may involve the intentional use of an unobtrusive background noise to cover some other specific intruding sound.

Noise Any sound which is undesirable because it interferes with speech and hearing, or is intense enough to damage hearing, or is otherwise annoying.

Noise Contours Lines or "footprints" of noise level usually drawn around a noise source (such as an airport, industrial plant or highway). The lines are generally drawn in 5-decibel increments so that they resemble elevation contours found in topographic maps.

Noise Exposure The cumulative noise reaching the ear of a person over a specified period of time (e.g., a work shift, a day, a working life, or a lifetime).

Noise Level Reduction (NLR) The difference between A-weighted sound levels indoors and outdoors.

Noise Reduction (NR) The difference, in decibels, of the average sound levels in two adjacent areas or rooms. Noise reduction could be from outside to inside, or from one room to another. Noise reduction combines the effects of the building construction plus the effect of acoustic absorption present in the receiving room. By knowing the noise reduction values and the outdoor noise levels one can determine the Noise Level Reduction (NLR).

Octave The interval between two sound frequencies having a ratio of 2. For example, if the center frequency of one octave is 125 Hz, the next octave up will be centered at 250 Hz. and the octave above that will be at 500 Hz.

Octave Band A frequency range which is one octave wide. Standard octave bands are designed by their center frequency.

Octave Band Center Frequency The average of the upper and lower frequencies of the octave. Standard octave band center frequencies in the audible range are 31.5, 63, 125, 250, 500, 1000, 2000, 4000, 8000, and 16,000 hertz.

One-Third Octave Band A frequency range which is one-third octave wide. Standard one-third octave bands are designed by their center frequency.

One-Third Octave Band Center Frequency The average of the upper and lower frequencies of the one-third octave bands. Standard one-third octave band center frequencies in the audible range are:

25.0	100	400	1600	6300
31.5	125	500	2000	8000
40.0	160	630	2500	10,000
50.0	200	800	3150	12,500
63.0	250	1000	4000	16,000
80.0	315	1250	5000	20,000

Receiver The listener who hears a sound or the measuring microphone which detects the sound transmitted by the source.

Reverberation The persistence of sound in an enclosed space, as a result of multiple reflections, after the sound source has stopped. The more absorptive the room is, the shorter the reverberation time will be. Generally, if the reverberation time is too short, people feel that the room is "dead" while if it is too long, there is confusion among sounds.

Shielding The ability of hills or structures to physically block sound or create shadow zones where sound levels are reduced.

Sound Absorption The ability of sound-absorbing materials to trap sound and convert it to heat or some other form of energy.

Sound Insulation Reducing the sound level inside a building through the use of specific building construction materials, and component assemblies which provide noise reduction.

Sound Transmission Class (STC) A single-number rating derived from measured values of transmission loss, in accordance with ASTM Classification E413, "Determination of Sound Transmission Class". It provides an evaluation of the sound-isolating properties of built construction against sounds of speech, radio, television, etc.

Sound Transmission Loss (TL) A measure of a built construction's ability to reduce sound passing through it, expressed in decibels.

Source The object which generates the sound.

Southern Building Code (SBC) *See International Building Code.*

Spectral Characteristics/Spectrum The frequency content of the noise produced by the source.

Structureborne Sound Sound energy transmitted through a solid medium such as the building structure.

Thermal Insulation A material or assembly of materials used primarily to provide resistance to heat flow.

TL See Sound Transmission Loss.

Uniform Building Code (UBC) *See International Building Code.*