April 2005

Guidelines for Sound Insulation of Residences Exposed to Aircraft Operations

Prepared for

Department of the Navy

Naval Facilities Engineering Command

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1.0 Introduction

This Chapter gives an overview of the purpose for the *Guidelines*, background information on their origin, the development of this revised edition, and a description of the document's organization.

1.1 Purpose and Intent of the Guidelines

Residences located near airports and military air installations experience many economic benefits from the facility, but are unfortunately exposed to aircraft noise, sometimes resulting in significant adverse impacts. However, using proper construction techniques and materials minimizes the impact of aircraft noise and reduces interference with regular indoor activities. The *Guidelines* provide a comprehensive overview of sound insulation techniques for homeowners and builders concerned with modifying an existing home or constructing a new one that incorporates sound insulation principles. They also give guidance to planning, zoning and building code officials who may want to incorporate zoning overlays and model building codes for residences near airports and military air installations.

This publication is concerned with the sound insulation of homes, apartments, and nursing homes, both existing and new. Sound insulation programs may include public buildings such as schools and churches. The techniques described here can be applied to non-residential buildings up to a point, but institutional and commercial structures usually have different building elements (such as window-wall structures), different mechanical systems and different building code requirements that must be met. For those reasons, the *Guidelines* are only recommended for residential buildings.

The *Guidelines* seek to provide clear, unambiguous direction that is practical and can be implemented with minimal additional cost. However, construction quality is especially important for maintaining the acoustical integrity of a design. For example, a good window that has been installed improperly will allow a significant amount of noise into the building. High-quality construction standards are absolutely essential for these techniques to work effectively. Similarly, because all building elements must work together to reduce noise intrusion; if some of the guidance offered here is used but other elements are neglected, the overall benefit may be substantially reduced.

The intent of the *Guidelines* is to address a wide range of common building types, and give practical, cost-effective measures to reduce noise impacts. Sound insulation treatments have been developed to account for: (1) the variety of construction materials and methods used in new and existing houses, and (2) the need to provide a noticeable improvement in indoor noise levels. The techniques described here were tested through simulations on prototypical rooms and have been carefully analyzed to ensure their acoustical effectiveness. The measures have also been field-tested on thousands of homes being renovated through federally funded airport noise mitigation programs. However, because no general text can provide the kind of specific guidance that is required for actual construction, users of the *Guidelines* may wish to seek professional assistance when undertaking sound insulation in their own homes, as a commercial enterprise, or within a community noise mitigation program.

In general, there are no safety factors built into the recommendations in this report, except to the extent that homes are grouped into 5 dB ranges of outdoor noise exposure. The recommendations provided in this guide are based on the predicted average performance of rooms in houses. However, there is inherent variability in the acoustical performance of different buildings, both well above and well below the average. When greater precision is desired or to evaluate conditions not covered in this document, consult with a qualified acoustical consultant, or use the recommendations for the next higher noise zone. To ensure that the recommended measures comply with the building codes consult with a qualified architect.

The recommendations in this document are based on an average of many types of aircraft. Noise levels inside homes due to specific aircraft will differ from those for average aircraft. The amount of low-frequency or high-frequency energy produced by the aircraft plays a significant role in determining overall outdoor and indoor noise levels. For example, noise levels inside homes exposed only to aircraft arrivals, which produce less low-frequency noise, will be slightly lower than those inside homes exposed to both arrivals and departures. Also, the frequency content of military jet aircraft differ from that of civilian jet aircraft, as does the frequency content of jet and propeller aircraft. The recommendations contained in these *Guidelines* are based on calculations using the frequency content of military jet operations. For more recommendations at houses impacted predominantly by propeller aircraft, helicopters, or civilian jet aircraft see Section 3.4.

This report does not address special low-frequency problems such as vibration and rattling, vibration-induced noise, or noise-induced vibration.

1.2 Background

Aircraft noise has been recognized as a community problem since at least the 1960s when jets became common at commercial airports. Acousticians and architects began developing methods to sound insulate homes with the first airport-sponsored program in 1967 at Los Angeles International Airport. Since then, literally tens of thousands of American homes have been modified to reduce interior noise. There was a need to condense this knowledge and practical guidance into a form that is usable by the average homeowner, as well as by building professionals and concerned local and military officials.

In the late 1980s, the US Dept. of the Navy and the Federal Aviation Administration (FAA) jointly commissioned the preparation of *Guidelines for Sound Insulation of Residences Exposed to Aircraft Operations*. That document was completed in 1989 and, after initial release internal to those two agencies, was published more broadly in October 1992 by the Dept. of Transportation as Publication DOT/FAA/PP 92-5.

Over the course of the decade following the initial release, the Navy and FAA received feedback that the *Guidelines*, while very useful, needed revision in some elements. Areas of concern included simplifying the methods used to specify treatments and materials and updating the cost information. To address these weaknesses, the Navy has sponsored a substantial update to the *Guidelines*, preserving the basic functionality but revising both the approach to prescribing treatments and the costs for implementing them.

Major changes from the original version include:

- A revised organization wherein the main text serves as a concise overview of the material and much of the technical material is given in appendices,
- Recommendations are made on a room-by-room basis for existing homes and on a whole house basis for new construction,
- The inclusion of Sound Transmission Class rather than Exterior Wall Rating for specifying building products,
- The costs have been updated to reflect 2004 values, and
- Calculations performed using the specific frequency content of various types of aircraft.

1.3 Document Organization

Chapters two through five take the user through a step-by-step process to learn how to sound insulate a room, a house, or a group of homes. The appendices provide additional information of interest to various users, depending on their role in sound insulation efforts.

Chapter 2 – Noise Reduction Requirements – Information is given on how to determine the noise reduction required for a home, based on the DNL zone. Goals are established for reducing noise to an acceptable level inside the house. Typical sound insulation characteristics of standard construction are discussed as well as the factors that influence sound insulation in general.

Chapter 3 – Sound Insulating Existing Homes – The types of rooms to be insulated are identified and look-up tables are provided for sound insulation treatments in existing homes.

Chapter 4 – Sound Insulating New Homes – Look-up tables give the treatments required to achieve the level of noise reduction needed in new homes.

Chapter 5 – Sound Insulation Costs – Estimates are given for the cost of construction in existing rooms and new homes, as well as cost multipliers for different regions of the country.

Appendix A – New Home Floor Plans – Floor plans for 21 prototype homes are given in Appendix A. These are the homes for which modifications are specified in Chapter 4. Homeowners, builders and program managers may find this information useful.

Appendix B – Basic Concepts – Appendix B contains a discussion of basic acoustics concepts such as how sound travels, how sound insulation works and how aircraft noise impacts residents. This appendix will be of general interest to all users of the *Guidelines*.

Appendix C – Sound Insulation Methods – Information is given on how to design and specify sound insulation treatments and what to look for during construction to see that the designs are implemented correctly to achieve the acoustical goals listed in Chapter 2. This appendix will be of interest to homeowners, architects, engineers, builders/developers, and building inspectors.

Appendix D – Model Building Code – A model building code that has been developed for the communities surrounding an air installation, which predominantly has military jet aircraft, provides sample language to include in a zoning ordinance or building code to incorporate sound insulation requirements. This model building code would have to be adapted considering the predominant aircraft at the specific air installation, the prevalent local building methods, and state and local building code requirements. This appendix will be of interest to planning and zoning officials, building inspectors, and builders/developers.

Appendix E – Manufacturers and Suppliers – A list of sources for acoustically-rated products gives contact information that will be of interest to homeowners, architects, engineers, and builders/developers.

Appendix F – Testing Laboratories – A list of laboratories tells where products can be tested to determine their acoustical performance. This appendix will be of greatest interest to architects and engineers specifying or approving products as well as manufacturers of products.

Appendix G – Glossary – Definitions of a wide variety of acoustical and sound insulation terms are given in this appendix. The glossary will be of general interest to all users of the *Guidelines*.

Appendix H – Bibliography – A list of references is given that indicates where to go for more information. This appendix will be of general interest to all users of the *Guidelines*.

1.4 Supplemental Computer Program

The recommendations and cost estimates contained in Chapters 3, 4, and 5 are for a variety of existing rooms and prototypical new houses. However, it is not feasible to address every possible room or house type. To supplement this document, a computer program was developed that enables the user to input the style of room construction and determine the recommended scope and approximate cost of sound insulation. This program is on the disk in the front of this report. To obtain an additional copy of this program, contact the regional Naval Facilities Engineering Command office near you:

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2.0 Noise Reduction Requirements

This chapter discusses various aspects of determining the noise reduction goals for a residence. Basic goals for mitigating aircraft noise are introduced in Section 2.1. Then, Section 2.2 explains how to determine the level of noise to which a home is exposed. This is followed by a discussion of interior noise guidance in Section 2.3 and information on how well typical dwellings meet this guidance in Section 2.4. Finally, Section 2.5 provides information on how sound insulation treatments will be specified in the *Guidelines*.

2.1 Mitigating Aircraft Noise

Aircraft noise is disturbing to people because of several different factors. First, the sound may include a combination of low frequency rumble and higher-pitched whine from jet engines, the throbbing of helicopters, or the steady, annoying buzz of smaller aircraft. Second, unlike highway noise which is generally constant and may fade into the background, each aircraft overflight is likely to be recognized as a distinct event, calling attention to itself when it interrupts speech or some other activity.

Individuals differ in their response to noise. In an aircraft noise-affected neighborhood, a number of residents may be very annoyed by aircraft overflights, while quite a few others may not. If properly implemented, the recommendations in the *Guidelines* will reduce noise inside the home to levels that most people would find acceptable. Aircraft noise will still be discernible; sound insulation is not sound elimination. People will know that an aircraft is passing overhead but, with implementation of the techniques outlined in this document, the noise in most cases should not interfere with normal daily indoor activities. However, individuals who are most sensitive to noise may continue to be annoyed. Overall, the number of people who perceive unacceptable indoor noise levels can be significantly reduced by the use of proper renovation and construction techniques.

Sound insulation of homes and schools has proven to be very effective at mitigating adverse noise impacts across the country. For this reason, many civilian airports undertake sound insulation programs, often with the assistance of federal funds under the authority of the FAA in the form of matching grants. While most users of the *Guidelines* are anticipated to be homeowners and building professionals, information is also given for local officials considering a residential sound insulation program.

2.2 Aircraft Noise Exposure Zones

Communities near military air installations and joint-use facilities are exposed to varying levels of noise depending on how close they are to the air installation and whether or not they experience direct overflights on a regular basis. Generally, the closer a house is to a flight corridor, the louder the noise will be. Military airfields and civilian airports typically document the levels of noise exposure around their facility using computer-generated noise contours. These contours may be obtained from the airfield or airport, or depending on the community, from other sources such as the local public library or the department of planning and zoning. The contours usually represent the average, annual noise exposure due to all flight operations and take into account the number of flights, the types of aircraft, the flight tracks they use, and whether the flights occur during the day or at night. Nighttime noise, defined as that occurring after 10 PM and before 7 AM, is counted more heavily in the noise calculations because it is more intrusive than daytime noise.

In most parts of the US, noise contours are depicted in terms of the Day Night Average Sound Level, or DNL[1]. In California, a similar metric is used, the Community Noise Equivalent Level, or CNEL. Regardless of whether DNL or CNEL is used, the noise contours are generally shown as "noise footprints" on the ground in levels such as 60 dB, 65 dB, 70 dB, 75 dB and so on. The higher the number, the greater the noise level.

2.3 Interior Noise Reduction Goals

The DoD and other Federal agencies have determined that noise exposure below 65 dB DNL (or 65 dB CNEL) is generally compatible with residential development. At 65 dB and higher, however, homes may need varying levels of sound insulation treatment to ensure that noise levels inside the house are sufficiently reduced, should local governments approve residential development in these areas at and above 65 dB. To determine the correct level of acoustical treatment, it is necessary to determine in which noise exposure zone the house is located. This is simply a matter of finding the house location on a noise contour map, such as the one shown in Figure 2-1, and noting whether the house is outside the 60 dB contour line, between the 60 and 65 dB lines, between the 65 and 70 dB lines, between the 70 and 75 dB lines, between the 75 and 80 dB lines or inside the 80 dB line. Once the noise exposure zone is determined, the interior noise reduction goals can be established and the treatments specified. The tables in the *Guidelines* that prescribe treatments have columns for each of these noise zones.

[1] See Appendix B for a more complete explanation of DNL and CNEL.

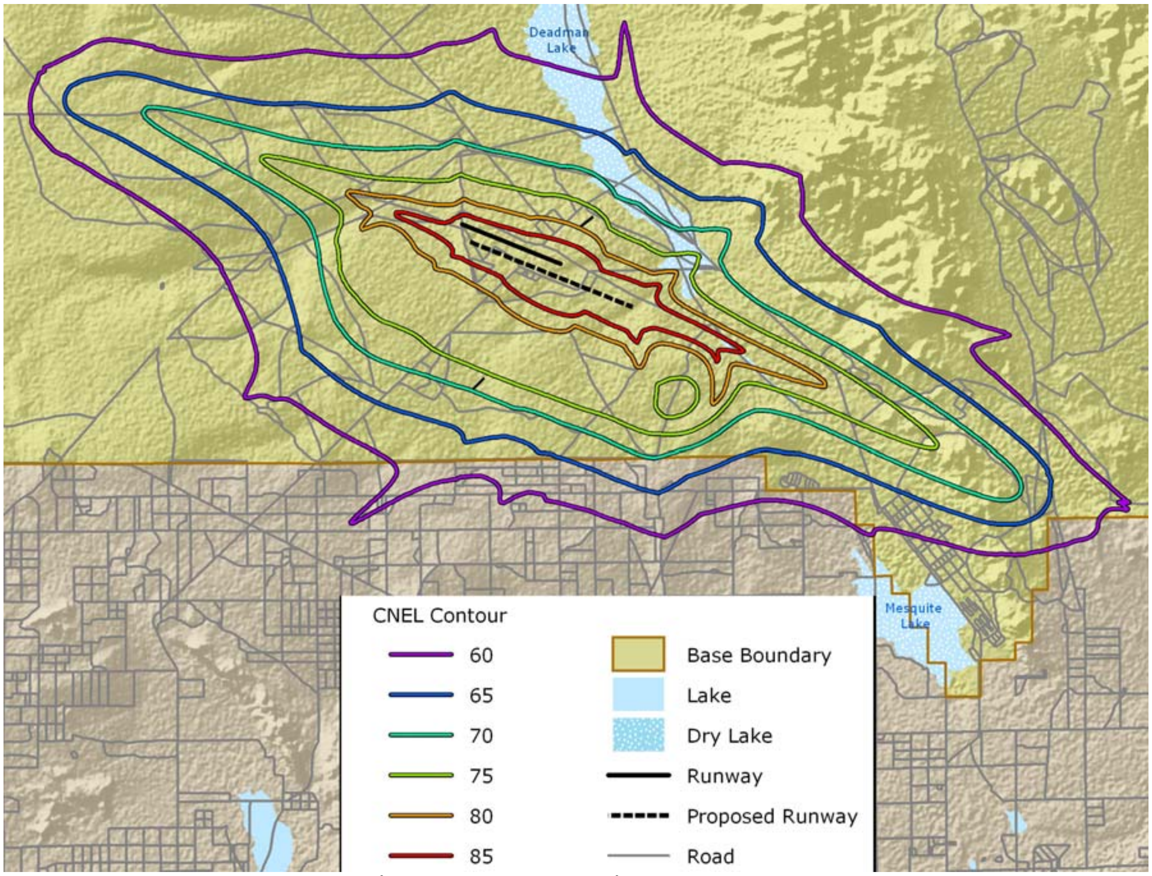


Figure 2-1. Sample Noise Contour Map

The Environmental Protection Agency (EPA) and the Federal Aviation Administration (FAA) have established an interior DNL goal of 45 dB. This is based on the assumption that when the exterior DNL is 65 dB, and a building provides 20 dB of outdoor-to-indoor noise level reduction (NLR), activity interference for most people is minimal[2]. While the Department of Defense (DoD) does not specify an interior noise goal, they do provide guidance that the NLR be at least 25 dB for homes located between the 65 and 70 dB DNL noise contours, and 30 dB for homes located between the 70 and 75 dB DNL noise contours. This is equivalent to providing guidance that the DNL not exceed 45 dB indoors. Reducing the DNL to this level through sound insulation will reduce the interior noise levels to a level where aircraft noise no longer interferes with daily activities such as watching TV, talking on the phone, or sleeping.

The land-use compatibility table shown in Table 2-1 was issued by the Chief of Naval Operations (OPNAVINST 11010.36B, Dec. 2002). The Air Force and FAA use similar tables. This table specifies the outside-to-inside NLR to be provided for various land uses such as residences, hospitals and others, by noise impact zone. The table refers to DNL but the guidance applies to

[2] See Appendix B for an explanation of NLR.

CNEL as well without adjustments. For example, Table 2-1 recommends that a home exposed to a DNL of 65 to 70 dB should provide at least 25 dB of NLR and a home exposed to a DNL of 70 to 75 dB should provide at least 30 dB of NLR. These are the NLRs that would result in an interior DNL of 45 dB. The use of other NLR goals may be appropriate in some cases, especially if a noise metric other than DNL or CNEL is used for a particular area or if there are special concerns.

For sound insulating existing homes there should be two acoustical goals: the target NLR, and the reduction in noise level. The target NLR can be found in Table 2-1, possibly in local zoning ordinances, or from an acoustical consultant. Typically, homes are only sound insulated if the interior noise level could be reduced significantly; a 5 dB reduction in noise level is generally considered significant. The recommended modifications in Section 3 include the NLR goal corresponding to the noise zone, as well as this 5 dB reduction. For example a room exposed to an outdoor DNL of 70 dB would have a target NLR of 25 dB. But if the existing NLR is 22 dB, the room should be designed to achieve an NLR of 27 dB. For this reason two similar rooms could have dramatically different recommended modifications in the lower noise zones.

The outdoor DNL, the NLR, and the 5 dB reduction goal discussed above are all based on A-weighted sound levels (see Appendix B). By definition A-weighted sound levels are more based on middle- and high-frequency sound than on low-frequency sound. Therefore, the recommended measures in this report are not focused on low-frequency noise mitigation. If the home is exposed only to strong low frequency noise, as would be the case when aircraft primarily depart away from a home located near the end of a runway, additional noise control measures would be appropriate. Some types of aircraft produce more low-frequency noise than others. For recommendations relating to aircraft type see Section 3.4.

Table 2-1. Air Installations Compatible Use Zones Suggested Land Use Compatibility In Noise Zones

Land Use		Suggested Land Use Compatibility						
		Noise Zone 1 *(DNL or CNEL)*		Noise Zone 2 *(DNL or CNEL)*		Noise Zone 3 *(DNL or CNEL)*		
SLUCM NO	**LAND USE NAME**	**<55**	**55- 64**	**65 - 69**	**70 -74**	**75- 79**	**80 -84**	**85+**
	Residential							
11	Household Units	Y	Y 1	N 1	N 1	N	N	N
11.11	Single units: detached	Y	Y 1	N 1	N 1	N	N	N
11.12	Single units: semidetached	Y	Y 1	N 1	N 1	N	N	N
11.13	Single units: attached row	Y	Y 1	N 1	N 1	N	N	N
11.21	Two units: side-by-side	Y	Y 1	N 1	N 1	N	N	N
11.22	Two units: one above the other	Y	Y 1	N 1	N 1	N	N	N
11.31	Apartments: walk-up	Y	Y 1	N 1	N 1	N	N	N
11.32	Apartment: elevator	Y	Y 1	N 1	N 1	N	N	N
12	Group quarters	Y	Y 1	N 1	N 1	N	N	N
13	Residential Hotels	Y	Y 1	N 1	N 1	N	N	N
14	Mobile home parks or Courts	Y	Y 1	N	N	N	N	N
15	Transient lodgings	Y	Y 1	N 1	N 1	N 1	N	N
16	Other residential	Y	Y 1	N 1	N 1	N	N	N
20	***Manufacturing***							
21	Food & kindred products; Manufacturing	Y	Y	Y	Y2	Y3	Y4	N
22	Textile mill products; Manufacturing	Y	Y	Y	Y2	Y3	Y4	N
23	Apparel and other finished products; products made from fabrics, leather and similar materials; manufacturing	Y	Y	Y	Y2	Y3	Y4	N
24	Lumber and wood products (except furniture); manufacturing	Y	Y	Y	Y2	Y3	Y4	N
25	Furniture and fixtures; manufacturing	Y	Y	Y	Y2	Y3	Y4	N
26	Paper and allied products; manufacturing	Y	Y	Y	Y2	Y3	Y4	N
27	Printing, publishing, and allied industries	Y	Y	Y	Y2	Y3	Y4	N
28	Chemicals and allied products; manufacturing	Y	Y	Y	Y2	Y3	Y4	N
29	Petroleum refining and related industries	Y	Y	Y	Y2	Y3	Y4	N

Table 2-1. Air Installations Compatible Use Zones Suggested Land Use Compatibility In Noise Zones - *continued*

Land Use		Suggested Land Use Compatibility						
		Noise Zone 1 *(DNL or CNEL)*		Noise Zone 2 *(DNL or CNEL)*		Noise Zone 3 *(DNL or CNEL)*		
SLUCM NO.	**LAND USE NAME**	**<55**	**55- 64**	**65 - 69**	**70 -74**	**75- 79**	**80 -84**	**85+**
30	***Manufacturing (continued)***							
31	Rubber and misc. plastic products; manufacturing	Y	Y	Y	Y 2	Y 3	Y 4	N
32	Stone, clay and glass products; manufacturing	Y	Y	Y	Y 2	Y 3	Y 4	N
33	Primary metal products; manufacturing	Y	Y	Y	Y 2	Y 3	Y 4	N
34	Fabricated metal products; manufacturing	Y	Y	Y	Y 2	Y 3	Y 4	N
35	Professional scientific, and controlling instruments; photographic and optical goods; watches and clocks	Y	Y	Y	25	30	N	N
39	Miscellaneous manufacturing	Y	Y	Y	Y 2	Y 3	Y 4	N
40	***Transportation, communication and utilities***							
41	Railroad, rapid rail transit, and street railway transportation	Y	Y	Y	Y 2	Y 3	Y 4	N
42	Motor vehicle transportation	Y	Y	Y	Y 2	Y 3	Y 4	N
43	Aircraft transportation	Y	Y	Y	Y 2	Y 3	Y 4	N
44	Marine craft transportation	Y	Y	Y	Y 2	Y 3	Y 4	N
45	Highway and street right-of-way	Y	Y	Y	Y 2	Y 3	Y 4	N
46	Automobile parking	Y	Y	Y	Y 2	Y 3	Y 4	N
47	Communication	Y	Y	Y	25 5	30 5	N	N
48	Utilities	Y	Y	Y	Y 2	Y 3	Y 4	N
49	Other transportation, communication and utilities	Y	Y	Y	25 5	30 5	N	N
50	***Trade***							
51	Wholesale trade	Y	Y	Y	Y 2	Y 3	Y 4	N
52	Retail trade – building materials, hardware and farm equipment	Y	Y	Y	Y 2	Y 3	Y 4	N
53	Retail trade – shopping centers	Y	Y	Y	25	30	N	N
54	Retail trade - food	Y	Y	Y	25	30	N	N

Table 2-1. Air Installations Compatible Use Zones Suggested Land Use Compatibility In Noise Zones *- continued*

Land Use		Suggested Land Use Compatibility						
		Noise Zone 1 (DNL or CNEL)		Noise Zone 2 (DNL or CNEL)		Noise Zone 3 (DNL or CNEL)		
SLUCM NO	LAND USE NAME	< 55	55- 64	65 -69	70 -74	75-79	80 -84	85+
50	***Trade (Continued)***							
55	Retail trade – automotive, marine craft, aircraft and accessories	Y	Y	Y	25	30	N	N
56	Retail trade – apparel and accessories	Y	Y	Y	25	30	N	N
57	Retail trade – furniture, home, furnishings and equipment	Y	Y	Y	25	30	N	N
58	Retail trade – eating and drinking establishments	Y	Y	Y	25	30	N	N
59	Other retail trade	Y	Y	Y	25	30	N	N
60	***Services***							
61	Finance, insurance and real estate services	Y	Y	Y	25	30	N	N
62	Personal services	Y	Y	Y	25	30	N	N
62.4	Cemeteries	Y	Y	Y	Y 2	Y 3	Y 4,11	Y 6,11
63	Business services	Y	Y	Y	25	30	N	N
63.7	Warehousing and storage	Y	Y	Y	Y 2	Y 3	Y 4	N
64	Repair Services	Y	Y	Y	Y 2	Y 3	Y 4	N
65	Professional services	Y	Y	Y	25	30	N	N
65.1	Hospitals, other medical fac.	Y	Y 1	25	30	N	N	N
65.16	Nursing Homes	Y	Y	N 1	N 1	N	N	N
66	Contract construction services	Y	Y	Y	25	30	N	N
67	Government Services	Y	Y 1	Y 1	25	30	N	N
68	Educational services	Y	Y 1	25	30	N	N	N
69	Miscellaneous	Y	Y	Y	25	30	N	N
70	***Cultural, entertainment and recreational***							
71	Cultural activities (& churches)	Y	Y1	25	30	N	N	N
71.2	Nature exhibits	Y	Y1	Y1	N	N	N	N
72	Public assembly	Y	Y1	Y	N	N	N	N
72.1	Auditoriums, concert halls	Y	Y	25	30	N	N	N
72.11	Outdoor music shells, amphitheaters	Y	Y 1	N	N	N	N	N
72.2	Outdoor sports arenas, spectator sports	Y	Y	Y 7	Y 7	N	N	N
73	Amusements	Y	Y	Y	Y	N	N	N
74	Recreational activities (include golf courses, riding stables, water rec.)	Y	Y1	Y1	25	30	N	N
75	Resorts and group camps	Y	Y 1	Y 1	Y 1	N	N	N
76	Parks	Y	Y 1	Y 1	Y 1	N	N	N
79	Other cultural, entertainment and recreation	Y	Y 1	Y 1	Y 1	N	N	N

Table 2-1. Air Installations Compatible Use Zones Suggested Land Use Compatibility In Noise Zones - *concluded*

Land Use		Suggested Land Use Compatibility						
		Noise Zone 1 *(DNL or CNEL)*		Noise Zone 2 *(DNL or CNEL)*		Noise Zone 3 *(DNL or CNEL)*		
SLUCM NO.	**LAND USE NAME**	**<55**	**55- 64**	**65 -69**	**70 -74**	**75-79**	**80 -84**	**85+**
80	***Resource Production and Extraction***							
81	Agriculture (except live stock)	Y	Y	Y 8	Y 9	Y 10	Y 10,11	Y 10,11
81.5,	Livestock farming	Y	Y	Y 8	Y 9	N	N	N
81.7	Animal breeding	Y	Y	Y 8	Y 9	N	N	N
82	Agriculture related activities	Y	Y	Y 8	Y 9	Y 10	Y 10,11	Y 10,11
83	Forestry Activities	Y	Y	Y 8	Y 9	Y 10	Y 10,11	Y 10,11
84	Fishing Activities	Y	Y	Y	Y	Y	Y	Y
85	Mining Activities	Y	Y	Y	Y	Y	Y	Y
89	Other resource production or extraction	Y	Y	Y	Y	Y	Y	Y

SLUCM	Standard Land Use Coding Manual, U.S. Department of Transportation
Y (Yes)	Land Use and related structures compatible without restrictions.
N (No)	Land Use and related structures are not compatible and should be prohibited.
Y^x (Yes with Restrictions)	The land use and related structures are generally compatible. However, see note(s) indicated by the superscript.
N^x (No with exceptions)	The land use and related structures are generally incompatible. However, see notes indicated by the superscript.
NLR (Noise Level Reduction)	Noise Level Reduction (outdoor to indoor) to be achieved through incorporation of noise attenuation into the design and construction of the structure.
25, 30, 04 35	The numbers refer to Noise Level Reduction levels. Land Use and related structures generally compatible however, measures to achieve NLR of 25, 30 or 35 must be incorporated into design and construction of structures. However, measures to achieve an overall noise reduction do not necessarily solve noise difficulties outside the structure and additional evaluation is warranted. Also, see notes indicated by superscripts where they appear with one of these numbers.
DNL	Day-Night Average Sound Level.
CNEL	Community Noise Equivalent Level (Normally within a very small decibel difference of DNL)
L_{dn}	Mathematical symbol for DNL.

Notes For Table 2-1. Suggested Land Use Compatibility In Noise Zones

1.

a) Although local conditions regarding the need for housing may require residential use in these Zones, residential use is discouraged in DNL 65-69 and strongly discouraged in DNL 70-74. The absence of viable alternative development options should be determined and an evaluation should be conducted locally prior to local approvals indicating that a demonstrated community need for the residential use would not be met if development were prohibited in these Zones.

b) Where the community determines that these uses must be allowed, measures to achieve and outdoor to indoor Noise Level Reduction (NLR) of at least 25 dB in DNL 65-69 and NLR of 30 dB in DNL 70-74 should be incorporated into building codes and be in individual approvals; for transient housing a NLR of at least 35 dB should be incorporated in DNL 75-79.

c) Normal permanent construction can be expected to provide a NLR of 20 dB, thus the reduction requirements are often stated as 5, 10 or 15 dB over standard construction and normally assume mechanical ventilation, upgraded Sound Transmission Class (STC) ratings in windows and doors and closed windows year round. Additional consideration should be given to modifying NLR levels based on peak noise levels or vibrations.

d) NLR criteria will not eliminate outdoor noise problems. However, building location and site planning, design and use of berms and barriers can help mitigate outdoor noise exposure NLR particularly from ground level sources. Measures that reduce noise at a site should be used wherever practical in preference to measures that only protect interior spaces.

2. Measures to achieve NLR of 25 must be incorporated into the design and construction of portions of these buildings where the public is received, office areas, noise sensitive areas or where the normal noise level is low.

3. Measures to achieve NLR of 30 must be incorporated into the design and construction of portions of these buildings where the public is received, office areas, noise sensitive areas or where the normal noise level is low.

4. Measures to achieve NLR of 35 must be incorporated into the design and construction of portions of these buildings where the public is received, office areas, noise sensitive areas or where the normal noise level is low.

5. If project or proposed development is noise sensitive, use indicated NLR; if not, land use is compatible without NLR.

Notes For Table 2-1. Suggested Land Use Compatibility In Noise Zones - *concluded*

6. No buildings.

7. Land use compatible provided special sound reinforcement systems are installed.

8. Residential buildings require a NLR of 25.

9. Residential buildings require a NLR of 30.

10. Residential buildings not permitted.

11. Land use not recommended, but if community decides use is necessary, hearing protection devices should be worn.

The *Guidelines* are targeted at rooms where people spend extended periods of time engaged in activities such as speaking, watching TV or sleeping. These noise-sensitive rooms, referred to as the “habitable rooms” or “living spaces”, include living rooms, kitchens, family rooms, dining rooms, and bedrooms. Typical residential building design and construction methods, even those that are thermally efficient, are normally inadequate to protect occupants from external noise that may interfere with their activities, especially in the higher noise zones. In non-habitable rooms such as bathrooms, garages, mudrooms, and breezeways, higher noise levels may be tolerated and standard design and construction methods can typically be used. However, if the non-habitable room opens directly to a habitable room without interior doors in between, it may be necessary to apply sound insulation techniques to the non-habitable room in order to protect adjacent spaces.

2.4 Typical Dwelling Noise Reduction

A typical home exposed predominantly to military jet operations incorporating standard designs and built with standard materials might provide 20 to 30 dB of NLR when the windows and doors are kept closed if the home is in good condition. In contrast, an acoustically well insulated home can provide 30 to 35 dB of NLR. (In either case, a house with the windows open will be much noisier). Providing more than 35 to 40 dB of NLR is not usually practical for a residence.

As discussed in Chapters 3 and 4, the NLR of any given room or house depends significantly on the characteristics of the room and on the construction of the house. The more windows and doors there are in a room, and the larger these openings are, the more noise will enter. In general, brick is a better sound insulator than siding; small windows allow less noise transmission than large ones of the same construction; solid core or heavy doors protect better than hollow, light-weight doors; and there is a benefit from reducing the number of openings such as through-wall ventilators, mail slots, and chimneys. Cathedral or vaulted ceilings allow more noise in than do ceilings with attic spaces above; basements and crawlspaces allow noise to pass through where a slab foundation would have blocked it. All of these factors, and many more, have been taken into account in the analyses and recommendations of Chapters 3 and 4.

2.5 Specifying Building Materials for Sound Insulation

The following chapters recommend modifications to existing homes or design changes to new homes in order to meet the noise reduction goals outlined above. In order to articulate the requirements for the windows, doors, and other building materials to be used, it is necessary to understand how acoustical performance is specified. The *Guidelines* use the most common descriptor of acoustical performance, Sound Transmission Class, or STC. The STC rating of a window, door or other building assembly indicates how well the product or assembly blocks sound. The higher the STC value, the better it protects against sound transmission.

Manufacturers send their products to independent acoustical testing laboratories to document the STC rating of their windows and doors. Appendix E lists some manufacturers of acoustically-rated products, and Appendix F lists several testing laboratories.

STC ratings have been determined for a large number of building elements, as well as for assemblies of elements. The tables prescribing acoustical treatments in Chapters 3 and 4 give STC ratings for recommended windows and doors. Generally, windows and doors specified in the *Guidelines* have STC ratings of 24 to 46, with the higher ratings required in higher noise zones.

One characteristic that is central to effective sound insulation must be stressed: all building elements must work together in a balanced manner to reduce noise intrusion. Combining strong windows with an acoustically-weak door will allow significant noise into the home. Therefore, it is important to apply all of the modifications recommended in the packages of Chapters 4 and 5 to meet the noise reduction goals. Leaving out one part may compromise the effectiveness of all the others.

3.0 Sound Insulating Existing Homes

This chapter approaches an existing home as a collection of rooms in order to specify the set of recommended modifications, or treatments, that will meet the interior noise goals discussed in Chapter 2. Recommended treatments are given on a room-by-room basis. All the information needed to develop a balanced combination ("package") of sound insulation treatments for an existing home is given here (new homes are discussed in Chapter 4). Estimated costs for these treatments are given in Chapter 5.

Section 3.1 explains how rooms differ from one another. Section 3.2 includes a table defining 75 types of rooms covering a wide range of room configurations encountered. Specific guidance for each room type, organized by noise impact zone, is given in Section 3.3. Instructions for dealing with special conditions are given in Section 3.4.

Since the construction of houses varies so much throughout the country a computer program was developed to complement this document. This program, included on the disk in the front of this report, can be used to determine the approximate scope and cost to sound insulate a room. To obtain an additional copy of this program contact the regional Naval Facilities Engineering Command office near you (see Section 1.4 for contact information).

3.1 Room Variations

The noise level of different rooms in a house depends on two factors, the noise entering from the outside and the sound absorption within the room itself. The exterior sound is transmitted through the perimeter building elements (depending on their construction) and is further modified by the absorption inside the room to determine the interior noise level. For example, upholstered furniture, drapes, and carpeting absorb sound and reduce the noise level. For this reason, a bedroom or living room with carpeting and soft furniture is likely to be quieter than a kitchen having all hard surfaces. The recommendations that follow are based on the assumption that rooms would be normally furnished and that noise levels would be evaluated approximately six feet from the exterior walls.

As might be anticipated, only perimeter walls – those facing the outside – allow noise from the exterior to enter. A room with two perimeter walls will have more noise intrusion than a room with only one perimeter wall. Similarly, for a room of a given size, the number and type of windows and doors will greatly affect the noise transmission from the outside. Generally, more noise passes through windows and doors than enters through walls and ceiling/roof assemblies. Also, rooms protected by an upper story will generally be quieter than rooms that have a roof or attic above them. All these factors influence the noise level in the room, the type of sound insulation treatments that would be recommended to improve the noise reduction, and the cost of sound insulation.

3.2 Room Types

A large number of typical rooms are defined and modifications given room-by-room so that a composite set of recommendations can be developed for almost any existing house. Rooms are described and differentiated based on the following factors:

- Exterior wall construction (masonry, siding on wood frame, stucco on wood frame),
- Openings and penetrations (through-wall or in-window fans or air conditioners, Jalousie windows)
- Number of exterior walls,
- Type of room (e.g., bedroom, kitchen, living),
- Number and type of doors,
- Roof and ceiling construction, and
- Number of windows.

Each room has a specific identification (ID) code that is keyed to the treatments. Different rooms are described in Table 3-1 and are given ID codes. Once this ID code is known, the user can turn to Section 3.3 which gives modifications for each of these room types by ID code and noise impact zone. Section 3.2 may be used in sequence with the tables of Section 3.3 for each room in the house, first identifying the type of room to be analyzed and then finding the modifications that are recommended for that room.

To use Table 3-1, first choose the construction of the outside wall(s) of the particular room. If a room has more than one wall type, use the acoustically weaker category (appearing first in Table 3-1). "Siding" includes wood, vinyl, aluminum, asbestos, cement board, asphalt shingles, or any other type of siding, shakes, or shingles on wood frame construction. The data used in this report is an average for insulated and uninsulated wood frame walls. If your walls are uninsulated, modifications might be appropriate in lower noise zones even if none are indicated in Table 3-2. Conversely, if your walls are insulated some of the modifications in low noise zones may be unnecessary. "Siding/Paneling" indicates sided walls as above, except that the interior side of the walls have light (wooden or synthetic) paneling on studs with no drywall or plaster behind them. "Brick/Block/ICF" indicates that there are bricks, concrete blocks, or Insulating Concrete Forms (ICF) in the wall, regardless of the type of exterior or interior finish. ICF consists of approximately two-inch thick foam forms with approximately four inches of normal weight concrete poured between them. "Stucco/Studs" indicates Stucco or Exterior Insulation and Finish Systems (EIFS) that is applied onto a wood frame, not onto masonry. EIFS consists of a thin (approximately 1/8") stucco application on approximately one- to two-inch thick foam panels. The calculations used to develop this report used an average of acoustical data for thin and thick stucco. For rooms with thin stucco it would be appropriate to use slightly more stringent modifications than indicated in Table 3-2. "Block/Siding" is used for Basement Dens or Recreation rooms to indicate that while most of the room is concrete block or buried concrete walls, sometimes a half buried basement will have some wood frame sided walls above ground level. Note that room identifier numbers (ID codes) are given at the left side of the table.

Table 3-1. Existing Room Types and ID Codes

Step 1	Step 2	Step 3	Step 4	Step 5			
Wall Type and ID Code	Misc. Wall Openings[1]	Exterior Walls	Room Type	Doors[2] Sliding Glass Door	Doors[2] Hinged Doors	Roof/Ceiling Notes	Number of Windows[2,3]
Siding with Thin Paneling on Studs (with no masonry)							
1	A/C, VRF	1	Bed/Den	No	No	Attic above with a drywall or plaster ceiling	1
2	A/C, VRF	2	Living/Family	No	1+	Full story above	3
3	None	2	Bed/Den	No	No	Attic above acoustic tile ceiling	2
4	None	3	Sun Room	No	1	Vaulted ceiling	4
5	None	3	Sun Room	1	No	Attic above with a drywall or plaster ceiling	6
Siding with Gypsum Board or Plaster on Studs (with no masonry)							
6	A/C, VRF	1	Living/Family	No	No	Full story above	2
7	A/C, VRF	1	Living/Family	1	No	Full story above	2
8	A/C, VRF	1	Kit/Din/Break	No	No	Full story above	1
9	A/C, VRF	2	Bed/Den	No	No	Attic above with a drywall or plaster ceiling	2
10	A/C, VRF	2	Bed/Den	No	No	Acoustic tile ceiling, crawl space above.	3+
11	A/C, VRF	2	Living/Family	No	No	Attic above with a drywall or plaster ceiling	2
12	A/C, VRF	2	Living/Family	No	1+	Vaulted ceiling with some acoustic tiles	2+
13	A/C, VRF	2	Living/Family	1	No	Vaulted ceiling	4
14	A/C, VRF	2	Kit/Din/Break	1	No	Full story above	2
15	A/C, VRF	2	Kit/Din/Break	No	1	Attic above with a drywall or plaster ceiling	1
16	A/C, VRF	3	Bed/Den	No	No	Vaulted ceiling	4
17	Jalousie	1	Bed/Den	No	No	Open beam roof, no ceiling	2
18	Jalousie	1	Kit/Din/Break	No	1	Open beam roof, no ceiling	2
19	Jalousie	2	Bed/Den	1	No	Full story above	3
20	Jalousie	2	Living/Family	No	1	Attic above with a drywall or plaster ceiling	4
21	Jalousie	3	Sun Room	No	No	Open beam roof, no ceiling	5
22	None	1	Bed/Den	No	No	Attic above with a drywall or plaster ceiling	1+
23	None	1	Bed/Den	No	No	Full story above	2
24	None	1	Living/Family	1	No	Attic above with a drywall or plaster ceiling	1
25	None	1	Living/Family	No	1	Full story above	2
26	None	1	Kit/Din/Break	1	No	Attic above with a drywall or plaster ceiling	1
27	None	2	Bed/Den	1	No	Attic above with a drywall or plaster ceiling	1
28	None	2	Bed/Den	No	No	Attic above with a drywall or plaster ceiling	1
29	None	2	Bed/Den	No	1+	Full story above	2
30	None	2	Bed/Den	No	No	Attic above acoustic tile	4
31	None	2	Living/Family	1	No	Full story above	2
32	None	2	Living/Family	No	No	Vaulted ceiling	3
33	None	2	Living/Family	No	1+	Full story above	4+
34	None	2	Living/Family	No	No	Open beam roof, no ceiling	4
35	None	2	Kit/Din/Break	No	No	Attic above acoustic tile	2
36	None	2	Kit/Din/Break	No	1+	Full story above	2
37	None	2	Kit/Din/Break	1	No	Attic above with a drywall or plaster ceiling	3
38	None	3	Bed/Den	No	No	Vaulted ceiling	2
39	None	3	Bed/Den	1	No	Attic above with a drywall or plaster ceiling	6
40	None	3	Living/Family	1	1	Full story above	6
41	None	3	Sun Room	1	No	Attic above with a drywall or plaster ceiling	7+

Notes:
1. "A/C, VRF" = Openings in the wall including through-wall or in-window air-conditioners, vented range fans, and evaporative coolers ("swamp coolers")
2. "+" = with a storm door or storm windows
3. Consider one large window as two windows in this table

Table 3-1. Existing Room Types and ID Codes - *concluded*

Step 1	Step 2	Step 3	Step 4	Step 5			
Wall Type and ID Code	Misc. Wall Openings[1]	Exterior Walls	Room Type	Doors[2] Sliding Glass Door	Doors[2] Hinged Doors	Roof/Ceiling Notes	Number of Windows[2,3]
Half Concrete Block, Half Siding on Studs							
42	Jalousie	3	Sun Room	No	1	Open beam roof, no ceiling	10
43	None	1	Bsmt Den/Rec	No	No	1/2 height buried walls. Full story above	2
44	None	3	Bsmt Den/Rec	No	No	1/2 height buried walls. Full story above	6
45	None	3	Bsmt Den/Rec	No	1	1/2 height buried walls. Full story above	4
Stucco or Exterior Insulation and Finish Systems (EIFS) on Studs (with no masonry)							
46	A/C, VRF	1	Bed/Den	No	No	Attic above acoustic tile	2
47	A/C, VRF	1	Living/Family	No	1	Full story above	3
48	A/C, VRF	1	Kit/Din/Break	1	No	Attic above with a drywall or plaster ceiling	2
49	A/C, VRF	2	Bed/Den	1	No	Vaulted Ceiling	3
50	A/C, VRF	2	Living/Family	1	1	Open beam roof, no ceiling	3
51	A/C, VRF	2	Sun Room	No	1	Full story above	8
52	None	1	Bed/Den	No	No	Full story above	1
53	None	1	Living/Family	1	No	Attic above with acoustic tile ceiling	2+
54	None	1	Kit/Din/Break	No	No	Full story above	1+
55	None	2	Bed/Den	No	No	Attic above with a drywall or plaster ceiling	4
56	None	2	Living/Family	No	1	Vaulted ceiling with some acoustic tiles	5
57	None	2	Kit/Din/Break	No	1	Attic above with a drywall or plaster ceiling	2
Brick, Concrete Block, or Insulating Concrete Forms (ICF); may have siding or stucco over block							
58	A/C, VRF	1	Bed/Den	No	No	Attic above with a drywall or plaster ceiling	1
59	A/C, VRF	1	Living/Family	1	No	Vaulted ceiling with some acoustic tiles	2
60	A/C, VRF	1	Kit/Din/Break	No	1	Open beam roof, no ceiling	2
61	A/C, VRF	2	Bed/Den	1	No	Full story above	3
62	A/C, VRF	2	Living/Family	1	1	Full story above	4
63	A/C, VRF	2	Kit/Din/Break	No	No	Attic above with a drywall or plaster ceiling	1
64	None	1	Bed/Den	No	No	Attic above with a drywall or plaster ceiling	1
65	None	1	Living/Family	No	No	Attic above with a drywall or plaster ceiling	2
66	None	1	Kit/Din/Break	No	No	Full story above	1
67	None	2	Bed/Den	No	No	Full story above	2
68	None	2	Bed/Den	No	No	Attic above acoustic tile	4
69	None	2	Living/Family	1	1	Full story above	0
70	None	2	Kit/Din/Break	1	No	Vaulted ceiling with some acoustic tiles	1
71	None	2	Bsmt Den/Rec	No	No	Fully buried, Full story above	0
72	None	2	Bsmt Den/Rec	No	1	1/2 buried. Full story above	3
73	None	3	Living/Family	No	2	Vaulted ceiling	4
74	None	3	Bsmt Den/Rec	No	No	3/4 height buried walls. Full story above	5
75	None	3	Bsmt Den/Rec	No	1	3/4 height buried walls. Full story above	3

Notes:
1. "A/C, VRF" = Openings in the wall including through-wall or in-window air-conditioners, vented range fans, and evaporative coolers ("swamp coolers")
2. "+" = with a storm door or storm windows
3. Consider one large window as two windows in this table

In the column labeled "Step 2" note whether the room has a through-wall or in-window air conditioner (A/C), vented range fan (VRF), or evaporative cooler ("swamp cooler"). The calculations used to develop this report were based on leaky in-window air conditioners. If these are present in your room, choose a room with "A/C, VRF" in the Step 2 column. The calculations used to develop this report were based on leaky in-window air-conditioners. If more tight-fitting equipment such as a through-wall unit are present, the required modifications would be slightly different. If these are not present, but there are louvered "Jalousie" windows, choose a row labeled "Jalousie". "Jalousie" windows consist of many narrow horizontal glass pieces operated with a crank. "Jalousie" windows have significantly poorer acoustical performance than other windows. If none of these options are present, select a room with "None" in the step 2 column. If the room has central air conditioning instead of through-wall or in-window air conditioners select "None."

Under the "Step 3" column find a room with the same number of exterior walls as the room you are planning to sound insulate. Count partial walls as full walls.

The next important parameter for sound insulation in "Step 4" is what the room is used for. The table gives five types of habitable rooms[3]: bedroom or den; living room or family room; kitchen, dining or breakfast room; basement den or recreation room; and sun room. A "walkout" basement room (that is, a room with at least one exterior wall that is completely above ground) would be considered a "bedroom or den" or a "living room or family room", but not a basement den or recreation room." Herein a sun room is considered a room that has a relatively large area of exterior exposure given its size, usually by having 2 or 3 exterior walls, and has a large area of windows or doors. The size of the room affects noise levels due to aircraft. For the calculations used to develop this report the following room areas were assumed: 10 by 12 feet in bedrooms or dens, 12 by 16 feet in living or family rooms, 10 by 14 feet in kitchens, dining, or breakfast rooms, and 10 by 12 feet in sunrooms. Basement dens or recreation rooms were assumed to be 10 by 12 feet if they had one exterior wall, 12 by 14 feet if they had two, and 12 by 24 feet if they had three. Select the room with the generally most similar use even if the dimensions are somewhat different. These calculations assume that bedrooms would be carpeted; living rooms, sun rooms, and recreation rooms would have 50% rug coverage; and kitchens would have a hard floor. Do not substitute a kitchen for a bedroom or living room, because the interior furnishings (and, as a result, the room absorption) are very different.

Finally, select the room that most closely approximates your room (step 5). If your room is very similar to a room described in the table, note the ID code to use in Section 3.3. Review the choices given in the table along that row (in the Doors, Roof/Ceiling and Windows columns) and note any ways that your room may differ from the room described in the table. The calculations used to develop this report were based on all six-foot wide doors being sliding glass doors. If you have a six-foot wide hinged patio door, additional modifications may be required in the lower noise zones, since hinged doors tend to perform more poorly than sliding doors. The roof/ceiling column lists most of the rooms as having an attic above a drywall or plaster ceiling, a vaulted ceiling (i.e., a sloped ceiling with no attic above), an acoustic tile ceiling with an attic above, a full story above, an open beam roof without a ceiling, or a 2-story tall (e.g., a 16-foot high) flat ceiling. A room with an acoustical tile ceiling suspended below or attached to a drywall or plaster ceiling, is considered to have a "drywall or plaster ceiling." It was assumed that all existing ceilings have insulation above them. For the basement rooms, walls are described in this column as either three-quarters below grade or one-half below grade.

For most rooms a window size of three feet wide and five feet tall was assumed in the calculations used for this report. For three-quarter buried basements the windows were assumed to be 2′-3″ wide and 1′-3″ tall. If the windows in your room are not these sizes, try to choose a room in the table that has approximately the same total area of windows.

In general, if your room has characteristics that tend to make it perform more poorly than the selected room in the table, two things happen. First, it may require <u>less</u> stringent modifications to provide a noticeable <u>reduction</u> in noise level. Second, it may require <u>more</u> stringent modifications to provide an appropriate interior noise level. The result is that the room may need additional

[3] For a discussion of habitable rooms, see Section 2.3.

modifications if the house were located in some DNL zones but not in others. For example, if the existing walls of room 22 do not currently have insulation, the room may need modifications in the 65-70 dB DNL zone.

In Section 3.3, the packages of modifications are recommended for your room, given the noise level to which your house is exposed.

3.3 Sound Insulation Treatments for Existing Rooms

This section provides recommendations for sound insulating rooms in existing dwellings. ID codes from Table 3-1 are used in Table 3-2. Table 3-2 gives the recommended modifications for each room type in Section 3-2, depending on your home's noise exposure zone. For recommendations of houses exposed predominantly to noise from propeller aircraft, helicopters, or civilian aircraft see Section 3.4.

In Table 3-2 modifications are recommended separately for each perimeter building element of the room such as the walls, windows, doors and ceilings. To ensure adequate reduction in noise level, keeping in mind that costs to provide these modifications are higher, it is always acceptable to use the package of recommendations for higher noise zones. The following information will be helpful in interpreting the recommendations.

Walls

For walls the recommendations use the following options, depending on what is needed to meet the interior noise goals. The options are listed in order of increasing ability to reduce noise. For example, option 4 reduces noise more effectively than option 3. Note that it is always acceptable to use a higher number option, since those nearer the bottom of the list have the best acoustical performance.

(1) "1 gyp" which is to add insulation to the wall if none exists and add one layer of 5/8" gypsum board to the wall (fire-rated gypsum board is recommended because it is heavier than regular gypsum board and is therefore a better sound insulator),

(2) "2 gyp" which is to add insulation to the wall if none exists and add two layers of fire-rated 5/8" gypsum board to the wall,

(3) "Furr" which is to remove the existing wall board, add 2x2 wood plates beside the existing plates, add 2x2 wood studs spaced 16" on center but staggered relative to the existing studs, add 5" thick batt insulation, and add a new layer of fire-rated 5/8" gypsum board,

(4) "Furr, 2 gyp" which is the same as (3) but with two layers of gypsum board instead of one, and

(5) "Furr, RC, 2 gyp" which is the same as (4) but with single-leaf resilient channels installed between the studs and first layer of gypsum board. This option is not listed in Table 3-2 but is used in the supplemental computer program.

Infill of In-Wall Air Conditioners and Vented Range Fans

For in-wall air conditioners ("A/C"), vented range fans ("VRF"), or evaporative coolers ("Swamp Coolers") the recommendations are either to do nothing or to "remove" the unit. For through-wall air conditioners and evaporative coolers, this means to remove the unit, patch the sheathing and siding to match the rest of the wall, add insulation, and patch the interior finish to match the rest of the wall. For vented range fans, this means to replace the unit with a ductless model and block the duct with batt insulation. If it is desired to keep the vented range fan, it may be acceptable to add at least two 90-degree elbows in the duct if none are present. Consult the fan manufacturer and local code requirements pertaining to air quality and moisture within the home. However, installing a ductless model will provide greater acoustical benefits.

Windows

Replace the windows with new windows that have a specified STC rating. In many cases it is also acceptable to add storm windows over the existing windows, although this is not possible with jalousie windows. If the existing windows are double pane windows in good condition a new storm window could be added. Adding an acoustical storm window with a rating of STC 29 could be used whenever the table calls for an STC 36 or lower.

Likewise, a new prime-and-storm window assembly could be used. If an STC rating is only available for the prime window, it can be assumed that adding a storm window would increase the STC rating of the prime windows. Adding an acoustical storm window with a rating of STC 29 would yield an STC rating for the prime-and-storm assembly at least approximately 8 points higher than for the prime window alone.

If the room in Table 3-1 does not have storm windows yet the existing room does, it is appropriate to use new windows with higher ratings than are specified in Table 3-2. Use an STC rating 2 points or more higher if you currently have single pane windows with storm windows, and use an STC rating 4 points or more higher if you currently have double pane windows with storm windows.

Table 3-2. Modifications for Existing Rooms

Room ID	Room Elements	Noise Zone (dB, DNL) 60 - 65	65 - 70	70 - 75	75 - 80
1	Walls	None	None	None	1 gyp
	Windows	None	None	STC 32	STC 32
	Ceiling	None	None	None	None
	A/C, VRF	None	None	Remove	Remove
2	Walls	None	1 gyp	1 gyp	1 gyp
	Windows	None	STC 30	STC 30	STC 38
	Door	None	None	None	New + storm
	A/C, VRF	None	Remove	Remove	Remove
3	Walls	None	None	1 gyp	2 gyp
	Windows	None	None	STC 32	STC 34
	Ceiling	None	None	1 gyp	1 gyp
4	Walls	None	1 gyp	1 gyp	2 gyp
	Windows	None	STC 32	STC 34	STC 42
	Door	None	STC 31	STC 31	STC 40
	Ceiling	None	None	None	1 gyp
5	Walls	None	1 gyp	1 gyp	Furr
	Windows	None	STC 38	STC 34	STC 42
	Door	None	None	STC 32	STC 37
	Ceiling	None	None	None	None
6	Walls	None	None	None	None
	Windows	None	None	STC 30	STC 38
	A/C, VRF	None	None	Remove	Remove
7	Walls	None	None	None	None
	Windows	None	STC 32	STC 36	STC 40
	Door	None	None	None	STC 37
	A/C, VRF	None	Remove	Remove	Remove
8	Walls	None	None	None	2 gyp
	Windows	None	None	STC 30	STC 36
	A/C, VRF	None	Remove	Remove	Remove
9	Walls	None	None	None	1 gyp
	Windows	None	None	STC 30	STC 42
	Ceiling	None	None	None	None
	A/C, VRF	None	None	Remove	Remove
10	Walls	None	None	None	1 gyp
	Windows	None	None	STC 34	STC 36
	Ceiling	None	None	None	1 gyp
	A/C, VRF	None	None	Remove	Remove
11	Walls	None	None	None	2 gyp
	Windows	None	None	STC 30	STC 36
	Ceiling	None	None	None	None
	A/C, VRF	None	None	Remove	Remove
12	Walls	None	None	None	2 gyp
	Windows	None	None	STC 34	STC 36
	Door	None	None	STC 31	New + storm
	Ceiling	None	None	None	RC
	A/C, VRF	None	None	Remove	Remove
13	Walls	None	None	None	2 gyp
	Windows	None	STC 36	STC 34	STC 40
	Door	None	None	STC 32	STC 37
	Ceiling	None	None	None	RC
	A/C, VRF	None	Remove	Remove	Remove
14	Walls	None	None	1 gyp	Furr
	Windows	None	STC 34	STC 34	STC 38
	Door	None	None	STC 34	New + storm
	A/C, VRF	None	Remove	Remove	Remove
15	Walls	None	None	None	Furr
	Windows	None	STC 32	STC 36	STC 38
	Door	None	None	STC 37	New + storm
	Ceiling	None	None	None	None
	A/C, VRF	None	Remove	Remove	Remove

Note: These modifications apply only to military jet aircraft. For modifications at houses impacted predominantly by propeller aircraft, helicopters, or civilian jet aircraft, see section 3.4.

Table 3-2. Modifications for Existing Rooms - *continued*

Room ID	Room Elements	Noise Zone (dB, DNL)			
		60 - 65	65 - 70	70 - 75	75 - 80
16	Walls	None	None	None	2 gyp
	Windows	None	STC 34	STC 34	STC 42
	Ceiling	None	None	None	RC
	A/C, VRF	None	Remove	Remove	Remove
17	Walls	None	None	None	1 gyp
	Windows	STC 24	STC 24	STC 28	STC 38
	Ceiling	1 gyp	1 gyp	1 gyp	1 gyp
18	Walls	None	None	None	2 gyp
	Windows	STC 26	STC 28	STC 34	STC 40
	Door	None	None	STC 34	New + storm
	Ceiling	1 gyp	1 gyp	1 gyp	RC
19	Walls	None	None	None	2 gyp
	Windows	None	STC 28	STC 32	STC 40
	Door	None	None	STC 32	STC 37
20	Walls	None	None	None	2 gyp
	Windows	None	STC 28	STC 32	STC 40
	Door	None	None	STC 31	STC 34
	Ceiling	None	None	None	None
21	Walls	None	None	None	2 gyp
	Windows	STC 26	STC 28	STC 36	STC 44
	Ceiling	1 gyp	1 gyp	1 gyp	RC
22	Walls	None	None	None	2 gyp
	Windows	None	None	None	STC 40
	Ceiling	None	None	None	None
23	Walls	None	None	None	1 gyp
	Windows	None	None	None	STC 34
24	Walls	None	None	None	None
	Windows	None	None	STC 38	STC 38
	Door	None	None	STC 34	STC 37
	Ceiling	None	None	None	None
25	Walls	None	None	None	None
	Windows	None	None	STC 34	STC 40
	Door	None	None	STC 34	STC 34
26	Walls	None	None	None	Furr, 2 gyp
	Windows	None	None	STC 32	STC 42
	Door	None	None	STC 34	STC 37
	Ceiling	None	None	None	RC, 2 gyp
27	Walls	None	None	1 gyp	2 gyp
	Windows	None	None	STC 38	STC 40
	Door	None	None	STC 34	STC 37
	Ceiling	None	None	None	None
28	Walls	None	None	None	2 gyp
	Windows	None	None	None	STC 40
	Ceiling	None	None	None	None
29	Walls	None	None	1 gyp	1 gyp
	Windows	None	None	STC 36	STC 38
	Door	None	None	New + storm	New + storm
30	Walls	None	None	None	1 gyp
	Windows	None	None	STC 36	STC 38
	Ceiling	None	None	1 gyp	1 gyp
31	Walls	None	None	None	2 gyp
	Windows	None	None	STC 40	STC 40
	Door	None	None	STC 37	STC 37
32	Walls	None	None	2 gyp	2 gyp
	Windows	None	None	STC 36	STC 36
	Ceiling	None	None	None	RC
33	Walls	None	None	1 gyp	1 gyp
	Windows	None	None	STC 38	STC 40
	Door	None	None	New + storm	New + storm

Note: These modifications apply only to military jet aircraft. For modifications at houses impacted predominantly by propeller aircraft, helicopters, or civilian jet aircraft, see section 3.4.

Table 3-2. Modifications for Existing Rooms - *continued*

Room ID	Room Elements	Noise Zone (dB, DNL)			
		60 - 65	65 - 70	70 - 75	75 - 80
34	Walls	None	None	None	2 gyp
	Windows	None	None	STC 32	STC 38
	Ceiling	1 gyp	1 gyp	1 gyp	RC
35	Walls	None	None	1 gyp	2 gyp
	Windows	None	None	STC 36	STC 36
	Ceiling	None	None	1 gyp	1 gyp
36	Walls	None	None	1 gyp	Furr
	Windows	None	None	STC 34	STC 38
	Door	None	None	New + storm	New + storm
37	Walls	None	None	None	Furr
	Windows	None	STC 34	STC 38	STC 42
	Door	None	STC 34	STC 34	New + storm
	Ceiling	None	None	None	None
38	Walls	None	None	2 gyp	2 gyp
	Windows	None.	None	STC 40	STC 42
	Ceiling	None	None	None	RC, 2 gyp
39	Walls	None	None	None	2 gyp
	Windows	None	None	STC 38	STC 44
	Door	None	None	STC 32	STC 37
	Ceiling	None	None	None	RC, 2 gyp
40	Walls	None	None	None	Furr
	Windows	None	None	STC 40	STC 40
	Swing door	None	None	STC 31	New + storm
	Sliding glass door	None	None	STC 32	STC 37
41	Walls	None	None	None	Furr, 2 gyp
	Windows	None	None	STC 38	STC 42
	Door	None	None	STC 34	STC 37
	Ceiling	None	None	None	None
42	Walls	None	None	None	None
	Windows	STC 26	STC 30	STC 34	STC 42
	Door	None	None	STC 34	STC 37
	Ceiling	1 gyp	1 gyp	1 gyp	1 gyp
43	Walls	None	None	None	None
	Windows	None	None	STC 34	STC 36
44	Walls	None	None	None	1 gyp
	Windows	None	None	STC 36	STC 38
45	Walls	None	None	None	1 gyp
	Windows	None	None	STC 38	STC 38
	Door	None	None	STC 31	STC 34
46	Walls	None	None	None	None
	Windows	None	None	STC 30	STC 36
	Ceiling	None	None	None	None
	A/C, VRF	None	None	Remove	Remove
47	Walls	None	None	None	None
	Windows	None	STC 32	STC 32	STC 36
	Door	None	None	None	STC 34
	A/C, VRF	None	Remove	Remove	Remove
48	Walls	None	None	None	2 gyp
	Windows	None	STC 32	STC 34	STC 44
	Door	None	None	STC 32	STC 37
	Ceiling	None	None	None	RC, 2 gyp
	A/C, VRF	None	Remove	Remove	Remove
49	Walls	None	None	None	None
	Windows	None	STC 34	STC 34	STC 40
	Door	None	None	None	STC 37
	Ceiling	None	None	None	None
	A/C, VRF	None	Remove	Remove	Remove

Note: These modifications apply only to military jet aircraft. For modifications at houses impacted predominantly by propeller aircraft, helicopters, or civilian jet aircraft, see section 3.4.

Table 3-2. Modifications for Existing Rooms - *continued*

Room ID	Room Elements	Noise Zone (dB, DNL)			
		60 - 65	65 - 70	70 - 75	75 - 80
50	Walls	None	None	None	None
	Windows	None	None	STC 34	STC 40
	Swing door	None	None	STC 34	STC 37
	Sliding glass door	None	None	None	STC 34
	Ceiling	1 gyp	1 gyp	1 gyp	RC
	A/C, VRF	None	Remove	Remove	Remove
51	Walls	None	None	None	None
	Windows	None	STC 32	STC 34	STC 40
	Door	None	STC 29	STC 31	STC 37
	A/C, VRF	None	Remove	Remove	Remove
52	Walls	None	None	None	None
	Windows	None	None	None	STC 34
53	Walls	None	None	None	None
	Windows	None	None	None	STC 36
	Door	None	None	None	STC 32
	Ceiling	None	None	None	1 gyp
54	Walls	None	None	None	None
	Windows	None	None	None	STC 38
55	Walls	None	None	None	None
	Windows	None	None	STC 34	STC 36
	Ceiling	None	None	None	None
56	Walls	None	None	None	None
	Windows	None	None	STC 34	STC 40
	Door	None	None	STC 31	STC 37
	Ceiling	None	None	None	None
57	Walls	None	None	None	None
	Windows	None	None	STC 34	STC 40
	Door	None	None	STC 31	STC 40
	Ceiling	None	None	None	None
58	Walls	None	None	None	None
	Windows	None	None	None	STC 30
	Ceiling	None	None	None	None
	A/C, VRF	None	None	Remove	Remove
59	Walls	None	None	None	None
	Windows	None	None	STC 32	STC 38
	Door	None	None	None	STC 34
	Ceiling	None	None	None	None
	A/C, VRF	None	None	Remove	Remove
60	Walls	None	None	None	None
	Windows	None	None	STC 34	STC 40
	Door	None	None	STC 31	STC 34
	Ceiling	1 gyp	1 gyp	1 gyp	RC
	A/C, VRF	None	Remove	Remove	Remove
61	Walls	None	None	None	None
	Windows	None	STC 32	STC 34	STC 38
	Ceiling	None	None	None	STC 34
	A/C, VRF	None	Remove	Remove	Remove
62	Walls	None	None	None	None
	Windows	None	STC 32	STC 36	STC 40
	Swing door	None	STC 31	STC 31	STC 34
	Sliding glass door	None	None	None	STC 34
	A/C, VRF	None	Remove	Remove	Remove
63	Walls	None	None	None	None
	Windows	None	None	None	STC 34
	Ceiling	None	None	None	None
	A/C, VRF	None	Remove	Remove	Remove
64	Walls	None	None	None	None
	Windows	None	None	None	STC 34
	Ceiling	None	None	None	None

Note: These modifications apply only to military jet aircraft. For modifications at houses impacted predominantly by propeller aircraft, helicopters, or civilian jet aircraft, see section 3.4.

Table 3-2. Modifications for Existing Rooms - *concluded*

Room ID	Room Elements	Noise Zone (dB, DNL)			
		60 - 65	65 - 70	70 - 75	75 - 80
	Windows	None	None	None	STC 34
	Ceiling	None	None	None	None
66	Walls	None	None	None	None
	Windows	None	None	None	STC 34
67	Walls	None	None	None	None
	Windows	None	None	None	STC 34
68	Walls	None	None	None	None
	Windows	None	None	STC 36	STC 38
	Ceiling	None	None	None	None
69	Walls	None	None	None	None
	Swing door	None	None	STC 34	STC 34
	Sliding glass door	None	None	STC 32	STC 34
70	Walls	None	None	None	None
	Windows	None	None	STC 32	STC 42
	Door	None	None	STC 34	STC 37
	Ceiling	None	None	None	RC
71	Walls	None	None	None	None
	Windows	None	None	None	None
72	Walls	None	None	None	None
	Windows	None	None	STC 34	STC 36
	Door	None	None	STC 31	STC 34
73	Walls	None	None	None	None
	Windows	None	None	STC 34	STC 40
	Door	None	None	STC 31	STC 37
	Ceiling	None	None	None	None
74	Walls	None	None	None	None
	Windows	None	None	None	None
75	Walls	None	None	None	None
	Windows	None	None	None	STC 34
	Door	None	None	None	STC 31

Note: These modifications apply only to military jet aircraft. For modifications at houses impacted predominantly by propeller aircraft, helicopters, or civilian jet aircraft, see section 3.4.

Doors

One of the following recommendations will be given:

(1) "STC xx". A new prime door should be installed that meets the stated STC requirement. If there is difficulty obtaining a prime door that has a sufficiently high STC rating without the use of a storm door, or if a storm door is desired, it may be acceptable to use a prime-and-storm door combination that meets the STC requirement given in the table. If an existing swinging door is in good condition a new acoustical storm door which has a rating of at least STC 29 could be added whenever the table calls for STC 36 or lower. If an existing sliding glass door is in good condition a new acoustical secondary sliding door which has a rating of at least STC 29 and 3/16" (minimum) tempered or laminated glass could be added whenever the table calls for STC 37 or lower.

(2) "+ storm". Add an acoustical storm door with a rating of at least STC 29. The storm is installed over the existing door without modifying the existing door (except for upgrading the weather-stripping of swinging doors, which is always advised). Although it is not normal to see a sliding glass door with a secondary "storm" door, this modification is recommended in many cases. See Appendix E for a list of door and acoustical weather-stripping manufacturers.

(3) "New + storm". Replace the door with a new prime door having an STC 29 rating or higher, in combination with a new storm door having an STC 29 or higher. Typically, it is necessary to use solid-core wood doors with acoustical gaskets in order to achieve STC 29 for a prime door.

(4) "Remove". In some extreme cases there is no feasible sound insulation modification for the highest noise zone. This option is not listed in Table 3-2 but may be needed under certain circumstances when using the supplemental computer program. If removing the door and infilling the hole in the wall (in combination with other modifications) would sufficiently reduce the noise level, this is noted in the table. Replacing the prime door with a new prime door that has an STC 29 rating, providing a three-foot vestibule, and using an STC 32 storm door would be an acceptable substitute to removing the door.

Ceilings

For ceilings one of the following recommendations will be given:

(1) "1 gyp" which is add 6" insulation (if none is present) and add one layer of fire-rated 5/8" gypsum board to the ceiling,

(2) "RC" which is to remove the existing ceiling (if present), add 6" batt insulation, install single-leaf resilient channels, and install a new layer of fire-rated 5/8" gypsum board, and

(3) "RC, 2 gyp" which is to remove the existing ceiling (if present), add 6" batt insulation, install single-leaf resilient channels, and install two new layers of fire-rated 5/8" gypsum board below the resilient channels.

(4) "Flat, RC, 2 gyp" which is the same as (3) but with a flat ceiling where there currently is a vaulted ceiling. This option is not listed in Table 3-2 but is used in the supplemental computer program.

Note that in some cases the rafters or ceiling joists may not be strong enough to carry the added weight. Consult a structural engineer or architect before using options 1, 3, or 4.

For all accessible attics that have less than six inches of insulation, it is recommended to add batt or blown-in insulation. The total depth of insulation should be selected to comply with the local building and energy codes.

These modifications were selected to meet the interior noise reduction goals listed in Section 3.2. These goals were affected both by the desired interior noise level and the need to provide a noticeable reduction in noise level. In many cases, especially in the lower noise zones, this latter goal controlled the recommendations. For example, trying to meet the noise goals in Section 3.2 might require treatments that provide a two to three dB improvement. However, since it generally takes a 5 dB improvement in order to be noticeable, the recommendations given here always aim to achieve that for existing homes. This is why rooms that have in-wall air-conditioners typically require fewer modifications to walls, windows, doors, and ceilings. Simply removing the in-wall unit provides a substantial change in noise level.

3.4 Special Conditions

Table 3-3 gives a list of special circumstances that often occur in existing homes, and for which recommendations have been developed. All of these recommendations are based on experience of what works with actual renovated homes. For non-habitable rooms, no modifications are required. For example, if a duct from a gas-fired water heater is in an unfinished basement area no modification is necessary.

Table 3-3. Special Modifications by DNL Noise Zone

Element	60 - 65	65 – 70	70 – 75	75 - 80
Skylights	Add secondary interior glass	Add secondary interior 1/4" laminated glass	Add secondary interior ¼″ laminated glass or replace with STC 38 units	Remove
Fireplaces, vented prefab units	Add damper or doors	Add chimney damper	Add chimney damper and doors	Add chimney damper and doors
Wood stoves	Double-wall duct	Remove	Remove	Remove
Combusting exhaust, dryer duct	Double-wall rigid duct; use combustion air enforcer	Enclose in chase; use combustion air enforcer	Enclose in chase; use combustion air enforcer	Enclose in chase; use combustion air enforcer
Gravity heating systems	Remove	Remove	Remove	Remove
Pet doors, mail slots	Remove	Remove	Remove	Remove
Attic Insulation[4]	Ok	Provide 5.25-8″	Provide 9-13″	Provide 9-13″
Attic access panels	Ok	Replace with 3/4″ plywood and seals	Replace with 3/4″ plywood and seals	Replace with 3/4″ plywood and seals
Pull-down attic stairs	Ok	Add cover	Add cover	Add cover
Whole-house attic fan	Add interior cover	Add interior cover	Add interior cover	Remove
Elevated floors	Ok	5.25-8″ insulation, ½″ OSB	14″ trusses, 9-13″ insulation, ½″ OSB	14″ trusses, 9-13″ insulation, ½″ OSB

Note: These modifications apply only to military jet aircraft. For modifications at houses impacted predominantly by propeller aircraft, helicopters, or civilian jet aircraft, see section 3.4.

Most of the special modifications listed in Table 3-3 are very important for achieving the noise reduction goal. However, in some cases, minor exceptions can be made to these recommendations if the performance of other room elements is significantly greater than would have been required to meet the noise reduction goal. Such exceptions would have to be evaluated on a case-by-case basis. In these cases, an acoustical engineer could evaluate the alternative design.

When interpreting Table 3-3, the following notes apply:

Skylights – For skylights the recommended modifications are to add secondary interior glass panels, to replace the units with special acoustical skylights, or to remove the skylights.

[4] For attic insulation requirements consult the local building and energy codes.

Fireplaces – The recommended modifications for fireplaces and vented prefabricated units are to either provide a special acoustical chimney-top damper, or to provide tight-fitting glass doors over the fireplace.

Attic Insulation – If there is currently little insulation between ceiling joists in attics, add blown-in or batt insulation to provide the total depth listed in Table 3-3. The higher end of the range is for blown-in insulation. Do not use blown-in insulation at sloped joists. Protect attic vents or recessed lights and fans in the ceiling from the additional insulation by appropriate means.

Attic Access and Attic Fans – Attic access panels can be significant sound leaks if they are located in habitable rooms; in closets or corridors they are usually not a significant sound leak. The recommended modification is to replace the panels with thicker wood and add acoustical seals (gaskets) around the perimeter. For pull-down attic stairs and whole-house fans it is often necessary to add a cover panel; for attic stairs the cover could be above or below the stairs, but for whole-house fans the cover would have to be below the fan. The cover would consist of a 3/4" thick plywood panel that either slides or swings out of the way of the stairs or fan.

Elevated Floors – Beach houses are often elevated using tall pylons. In these cases aircraft noise can enter the house through the floor. The recommended modification is to use floor trusses that are at least 14" deep with blown-in or batt insulation, and ½" (nominal) OSB or plywood at the bottom chords. The high end of the insulation thickness range is for blown-in insulation and the low end is for batt.

Rooms that face away from the predominant aircraft flight path will be exposed to lower sound levels due to shielding provided by the house. The amount of shielding can vary greatly but can be as high as 10 dB when all aircraft fly only on the opposite side of the house.

Sound Insulation of Manufactured 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. Department 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 mobile home or trailer) 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 home and a modular home (see 24 CFR 3282.12).

Only the HUD Code can be used to limit the construction of manufactured homes, with certain exceptions related to wind and snow loads, and foundation design. States and localities cannot preempt the 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 add layers of gypsum board to walls or ceilings, there is a question as to whether the structure can carry the extra weight. This may make it impossible or cost prohibitive to modify existing manufactured homes for sound insulation. Some manufacturers may be able to supply homes that meet sound insulation requirements in the lower noise exposure zones (60-65 and possibly 65-70 dB DNL).

Aircraft Type

The recommendations presented in Tables 3-2, 3-3, 4-2, and 4-3 are based on calculations using the frequency content of military jet aircraft operations. As noted earlier different aircraft types produce different frequency content. Generally, military jet aircraft produce the highest sound levels at frequencies between 200 and 1000 Hz. Civilian aircraft typically produce high sound levels at 50 to 400 Hz, propeller aircraft produce high sound levels at 60 to 250 Hz, and helicopters produce high sound levels at 10 to 80 Hz. Due to the strong low-frequency content of noise from propeller aircraft, helicopters, and civilian aircraft, noise from these types of aircraft can more easily penetrate into a house than can noise from military jet aircraft. The noise generated by these aircraft is more difficult to attenuate than the higher frequency military aircraft noise. Therefore, for a given outdoor noise exposure, expressed in terms of DNL, the indoor noise exposure will be higher if these other types of aircraft are the predominant noise sources than if military jet aircraft are predominant.

To account for the strong low-frequency noise produced by these aircraft, it is necessary to use more stringent modifications to the house in order to realize the NLR goals outlined in this report. In Tables 3-2, 3-3, 4-2, and 4-3 use the recommended modifications for the next higher DNL noise zone. For example, if an existing house is located in the 70-75 dB DNL zone and is exposed predominantly to civilian aircraft, the recommended modifications are those presented in Tables 3-2 and 3-3 in the column labeled 75-80 dB. If the house to be sound insulated is in the 75-80 dB DNL zone Tables 3-2, 3-3, 4-2, and 4-3 will not be applicable. In this case, or whenever the room to be sound insulated is not included in these tables, use the supplemental computer program (see Section 1.4).

Figure 3-1 shows the frequency spectra shapes used in the calculations. Note that the absolute sound levels (dB) are irrelevant in this figure; the intent is just to show the shape of the spectra. It can be seen from the figure that propeller aircraft, helicopters, and civilian aircraft have spectra with strong low-frequency content. It can also be seen from this figure that the shape of the helicopter spectrum is a steep slope at the lowest evaluated frequency bands of 50 and 63 Hz. This indicates that helicopters produce as high or higher sound levels below 50 Hz than above 50 Hz. Since the analysis did not consider sound below 50Hz, sound levels inside houses exposed predominantly to helicopter operations will be higher than predicted using these guidelines, and additional modifications to homes may be necessary.

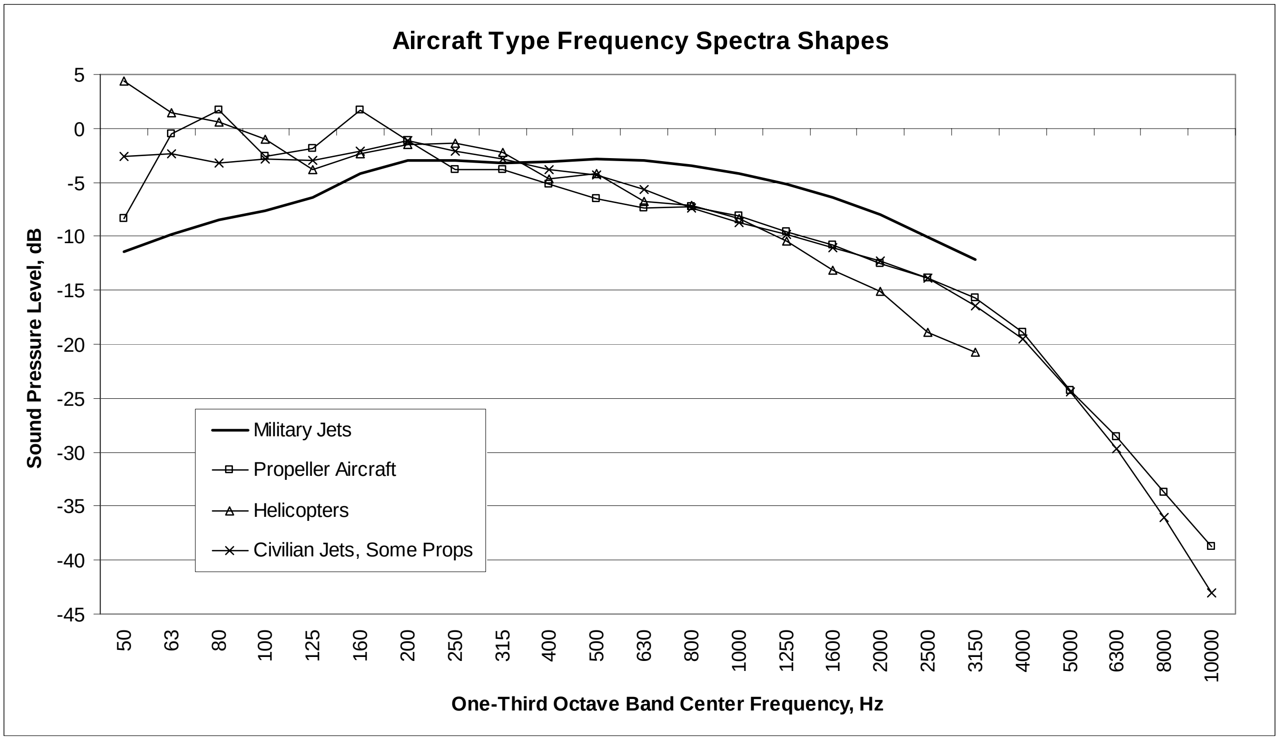


Figure 3-1. Spectra Summary

The DNL at most houses is determined in 5 dB ranges by identifying the two DNL contours between which the house is located. In some cases it is possible to determine the DNL to the nearest dB. In these cases use the adjustments to the DNL shown in Table 3-4. To use this table first determine the DNL at the house and select the appropriate column. Next, select the appropriate row based on the predominant type of aircraft. Finally, read the value in the table and add it to the outdoor DNL at the house. Use this new DNL value to select modifications in Tables 3-2, 3-3, 4-2, and 4-3.

Table 3-4. Additions to DNL

	Outdoor DNL Noise Zone (dB)				
Type of Aircraft	**60 - 65**	**65 – 68**	**68 – 72**	**72 -75**	**75 - 80**
Propeller Aircraft or Helicopters	3	3	4	5	6
Mostly Civilian Jets with some Propeller Aircraft	2	3	3	3	4

4.0 Sound Insulating New Homes

This chapter addresses new home construction by specifying what is required to sound insulate a wide variety of new house types. Section 4.1 explains why houses differ from one another in their ability to block noise. Section 4.2 identifies 21 typical homes found around the country for which treatments are specified. Sound insulation modifications are given for these prototype homes in Section 4.3. For special conditions, such as attic fans and fireplaces, refer to Section 4.4. Section 4.5 addresses additional design considerations, such as where to locate bedrooms and patios, using vestibules to reduce noise, and other suggestions.

Since the construction of houses varies so much throughout the country a computer program was developed to complement this document. This program, included on the disk in the front of this report, can be used to determine the approximate scope and cost to sound insulate a room. To obtain an additional copy of this program contact the regional Naval Facilities Engineering Command office near you (see Section 1.4 for contact information).

New houses require different sound insulation treatments than existing houses for three reasons. First, they allow the flexibility of selecting more appropriate materials instead of having to remove existing materials. Second, many older construction methods are not encountered with new construction. Third, since there is no existing room there is no requirement to provide a significant reduction in the existing interior noise level.

As with the existing rooms it was assumed that the rooms would be normally furnished, bedrooms would be carpeted, living rooms would have 50% rug coverage, kitchens would have hard floors, and noise levels would be evaluated approximately six feet from exterior walls.

4.1 House Variations

In preparing the *Guidelines*, researchers identified typical homes that are found throughout the country. Construction techniques described herein are targeted at the most common types of homes. These house types include a wide variety of houses, and the rooms within each house may be used individually for an even wider application.

The principle features that differentiate homes for sound insulation purposes are:

- Exterior wall material (brick, concrete block, insulating concrete forms, siding, stucco, EIFS, or combination),
- Type of roof structure (flat built-up roof, attic, cathedral ceiling),
- Type of foundation (basement, crawlspace, pylons, or slab),
- Number of stories,
- Size and number of windows and doors, and
- Dwelling type (single-family, duplex, townhouse, apartment, or manufactured home).

In addition to the features noted above, other characteristics influence the final noise reduction of the house, including the following:

- Attached garages and large wrap-around porches may provide shielding from noise for those sides of the house.
- The use of cathedral ceilings or flat built-up roofs without an attic above are strongly discouraged because an attic provides a more effective noise buffer.
- Openings or penetrations such as chimneys, whole house attic fans, pet doors, and through-wall heating and air conditioning units are strongly discouraged because they allow noise infiltration.

4.2 Prototype Homes

This section defines the prototype homes for which modifications are presented in Table 4-2. These prototypes represent the majority of designs currently being built.

To use the *Guidelines* for new homes, first identify the type of house to be sound insulated from among the 21 prototype models given in Table 4-1. Select the prototype that most closely resembles the home being designed. For the appropriate dwelling type, choose the house that has the correct exterior wall construction and the correct number of stories rather than the exact house size or number of rooms.

Table 4-1. Prototype Homes[1]

House ID No.	House Category and Description[2]
	Single-Family Houses
1	1-Story with Sided 2x4 Walls (vaulted ceilings)
2	1-Story with Brick, Concrete Block, or ICF Walls
3	1-Story with Stucco on 2x6 Walls
4	1-Story with Brick, Concrete Block, or ICF Walls
5	2-Story with Sided 2x6 Walls
6	2-Story with Stucco or EIFS on 2x6 Walls
7	2-Story with Brick , Concrete Block or ICF Walls (master bedroom with vaulted ceiling)
8	Beach House with Sided 2x4 Walls, on Pylons
	Duplexes
9	2-Story Duplex with Sided 2x4 Walls

1 Thumbnail floor plans for these homes are given in Appendix A.

2 All homes have flat gypsum board ceilings with sloped roofs unless otherwise indicated.

Table 4-1. Prototype Homes[1] - *concluded*

House ID No.	House Category and Description[2]
	Townhouses
10	18'-Wide 3½ Story with Brick, Concrete Block, or ICF Walls
11	24'-Wide End-unit 2-Story with Brick, Concrete Block, or ICF Front Walls, and Sided 2x4 End and Rear Walls
12	20'-Wide with Sided 2x4 Walls
13	24'-Wide End-unit with Sided 2x4 Walls
	Apartments and Nursing Homes
14	Apartment with Brick Walls and Through-Wall A/C Unit
15	Top Floor Apartment with Brick Walls (flat built-up roof)
16	Corner Top-Floor Apartment with Sided 2x4 Walls (flat built-up roof)
17	End Apartment with Sided 2x4 Walls
18	Top-Floor Apartment with Sided 2x4 Walls
	Modular and Manufactured Homes
19	1-Story Modular Home with Sided 2x4 Walls (bedrooms with vaulted ceilings)
20	Small Manufactured Home with Sided 2x6 Walls (vaulted ceilings)
21	Large Manufactured Home with Sided 2x4 Walls (vaulted ceilings)

1 Thumbnail floor plans for these homes are given in Appendix A.

2 All homes have flat gypsum board ceilings with sloped roofs unless otherwise indicated.

See Section 4.4 for special features that may apply. Homes with unique room shapes, materials, or dimensions that differ significantly from the average may require the services of an acoustical consultant in order to ensure adequate noise reduction.

4.3 Sound Insulation Treatments for New Construction

Once the house ID code has been located in Section 4.2, the plans and treatments given on the following pages may be used to determine the recommended package of design modifications and material specifications necessary to meet the noise goals discussed in Chapter 2. Each prototype home is described as a schedule of wall, window, door, ceiling and other modifications to standard construction. If the actual home to be modified has rooms similar to those from several different prototype homes, model rooms may be combined for a different overall house. To do this, make sure the model rooms have the same exterior material, number of exterior walls, and the same ceiling/roof characteristics as the actual rooms.

Table 4-2 lists modifications for each new home prototype. The prototypes are identified in Table 4-1 and floor plans for each are given in Appendix A. For recommendations of houses exposed predominantly to noise from propeller aircraft, helicopters, or civilian aircraft see Section 3.4. To ensure adequate reduction in noise level, keeping in mind that costs to provide the modifications are higher, it is always acceptable to use the package of modifications for higher noise zones. Modifications are generally given for habitable rooms that have exterior walls. The following abbreviations are used; some of these modifications may not be listed in Table 4-2 but are used by the supplemental computer program.

- "2 gyp" = use two layers of ½" minimum gypsum board for exterior walls or ceilings,
- "2 OSB" = use two layers of 7/16" oriented strand board or plywood sheathing,
- "RC" = use single-leaf resilient channels mounted horizontally across the wall studs, or ceiling joists (or roof rafters for vaulted ceilings),
- "Stag" = use 2x4 studs staggered on a 2x6 base plate (see drawing in Appendix C). If 2x6 studs must be used for structural reasons, use 2x6 studs staggered on a 2x8 base,
- "ICF" = insulating concrete forms consisting of approximately two-inch foam forms with at least four-inch normal weight concrete poured between,
- "EIFS" = exterior insulation and finish system consisting of a thin stucco application (approximately 1/8") on 1" to 2" thick foam panels,
- "Cement" = use 10 mm thick cement stucco finish,
- "STC xx" = sound transmission class rating required for the window or door, and
- "Trusses" = use floor trusses that are at least 14" deep with at least 9" thick batt insulation between the trusses, and ½" thick (nominal) plywood or OSB at the bottom chords of the trusses. This recommendation only applies to elevated houses such as house 8.

Wherever the "Room Elements" column lists a door with a storm door, all of the modifications in that row also use a storm door. A typical new prime door with a full-view storm door has a rating of approximate STC 33. To achieve STC 37 with a storm door, use a typical new prime door with an STC 28 storm door, which has 3/16" minimum tempered or laminated glass. To achieve STC 40 with a storm door use a typical new prime door with an STC 30 storm door, which has 3/16" minimum tempered or laminated glass. To achieve STC43 with a storm door use a typical prime door with an STC 32 storm door, which has ¼" laminated glass.

For sliding doors an STC 42 can be achieved with a typical new double pane sliding door plus an STC 29 secondary sliding door.

Table 4-2. Modifications for New Construction

House No.	Room Type	Room Elements	Noise Zone (dB, DNL) 60 - 65	65 - 70	70 - 75	75 - 80
1	Master Bed	14x14				
		Siding	None	None	None	RC
		2 Windows	None	None	STC 30	STC 34
		Vaulted clg.	None	None	None	None
1	Bed 2	12x11				
		Siding	None	None	None	RC
		2 Windows	None	None	STC 32	STC 36
		Vaulted clg.	None	None	None	None
1	Bed 3	10x11				
		Siding	None	None	None	RC
		1 Window	None	None	STC 32	STC 34
		Vaulted clg.	None	None	None	None
1	Living/ Dining/ Kitchen/ Foyer	14x40				
		Siding	None	None	None	RC
		5 Windows	None	None	STC 32	STC 32
		2 drs w/storms	None	None	STC 33	STC 37
		Vaulted clg.	None	None	None	RC
2	Master Bed	16x12				
		Brick	None	None	None	None
		3 Windows	None	None	STC 28	STC 32
		Attic	None	None	None	None
2	Bed 2	10x12				
		Brick	None	None	None	None
		1 Window	None	None	STC 28	STC 34
		Attic	None	None	None	None
2	Bed 3	10x12				
		Brick	None	None	None	None
		1 Window	None	None	STC 28	STC 34
		Attic	None	None	None	None
2	Living/ Dining	27x13				
		Brick	None	None	None	None
		3 Windows	None	None	STC 30	STC 34
		1 door	None	None	STC 29	STC 34
		Attic	None	None	None	None
2	Kitchen	10x12				
		Attic	None	None	None	None
2	Family	18x15				
		Brick	None	None	None	None
		1 Window	None	STC 26	STC 32	STC 38
		Sliding gl. dr.	None	None	STC 32	STC 34
		Vaulted clg.	None	None	None	RC

Note: These modifications apply only to military jet aircraft. For modifications at houses impacted predominantly by propeller aircraft, helicopters, or civilian jet aircraft, see section 3.4.

Table 4-2. Modifications for New Construction - *continued*

House No.	Room Type	Room Elements	Noise Zone (dB, DNL)			
			60 - 65	65 - 70	70 - 75	75 - 80
3	Master Bed	15x18				
		Stucco	None	None	None	RC, 2 gyp
		2 Windows	None	None	STC 26	STC 30
		Attic	None	None	None	2 gyp
3	Bed 2	11x11				
		Stucco	None	None	None	None
		1 Window	None	None	STC 26	STC 34
		Attic	None	None	None	None
3	Bed 3	13x11				
		Stucco	None	None	None	None
		1 Window	None	None	STC 26	STC 34
		Attic	None	None	None	None
3	Study	13x11				
		Stucco	None	None	None	None
		1 Window	None	None	STC 26	STC 34
		Attic	None	None	None	None
3	Dining	13x11				
		Stucco	None	None	None	None
		1 Window	None	None	STC 28	STC 36
		Attic	None	None	None	None
3	Living/ Foyer	14x14				
		Stucco	None	None	None	RC, 2 gyp
		3 Windows	None	STC 28	STC 34	STC 38
		2 Doors		None	STC 31	STC 37
		Attic	None	None	None	2 gyp
3	Family/ Kitchen/ Nook	15x17, 10x21				
		Stucco	None	None	None	RC, 2 gyp
		5 Windows	None	None	STC 32	STC 36
		Hinged patio dr.	None	None	STC 31	STC 34
		Attic	None	None	None	2 gyp
4	Master Bed	13x13				
		Brick	None	None	None	None
		2 Windows	None	None	STC 26	STC 32
		Attic	None	None	None	None
4	Bed 2	10x10				
		Brick	None	None	None	None
		2 Windows	None	None	STC 28	STC 34
		Attic	None	None	None	None
4	Bed 3	8x14				
		Brick	None	None	None	None
		1 Window	None	None	STC 26	STC 32
		Attic	None	None	None	None
4	Living/ Dining/ Kitchen/ Foyer	26x26				
		Brick	None	None	None	None
		10 Windows	None	STC 28	STC 32	STC 38
		1 Door w/storm	None	None	None	STC 37
		Attic	None	None	None	None
5	Master Bed	14x21				
		Siding	None	None	None	RC
		2 Windows	None	None	STC 30	STC 32
		Attic	None	None	None	None
5	Bed 2	12x12				
		Siding	None	None	None	RC
		2 Windows	None	None	STC 30	STC 34
		Attic	None	None	None	None
5	Bed 3	10x12				
		Siding	None	None	None	RC
		1 Window	None	None	STC 28	STC 32
		Attic	None	None	None	None
5	Dining/ Foyer	13x12				
		Siding	None	None	RC	Stag, 2 gyp
		2 Windows	None	STC 26	STC 32	STC 36
		1 Door w/ storm	None	None	None	STC 40

Note: These modifications apply only to military jet aircraft. For modifications at houses impacted predominantly by propeller aircraft, helicopters, or civilian jet aircraft, see section 3.4.

Table 4-2. Modifications for New Construction *- continued*

House No.	Room Type	Room Elements	Noise Zone (dB, DNL)			
			60 - 65	65 - 70	70 - 75	75 - 80
5	Living	12x22				
		Siding	None	None	None	RC
		3 Windows	None	None	STC 32	STC 34
5	Family/ Kitchen/ Nook	13x22				
		Siding	None	None	None	RC
		5 Windows	None	STC 28	STC 32	STC 36
		1 door	None	None	STC 29	STC 29
6	Master Bed	16x17				
		Stucco	None	None	None	RC, 2 gyp
		2 Windows	None	STC 26	STC 32	STC 34
		Attic	None	None	None	2 gyp
6	Bed 2	11x12				
		Stucco	None	None	None	RC, 2 gyp
		1 Window	None	None	STC 26	STC 30
		Attic	None	None	None	None
6	Bed 3	10x12				
		Stucco	None	None	None	RC, 2 gyp
		2 Windows	None	None	STC 30	STC 34
		Attic	None	None	None	None
6	Study	11x13				
		Stucco	None	None	None	RC, 2 gyp
		3 Windows	None	None	STC 30	STC 34
6	Dining	11x13				
		Stucco	None	None	None	RC, 2 gyp
		3 Windows	None	STC 28	STC 34	STC 40
		Sliding gl. dr.	None	None	STC 32	STC 37
6	Living/ Foyer	17x20				
		Stucco	None	None	None	RC, 2 gyp
		3 Windows	None	None	STC 32	STC 36
		1 Door	None	None	STC 29	STC 34
6	Kitchen	12x12				
		Stucco	None	None	None	RC, 2 gyp
		4 Windows	None	STC 28	STC 34	STC 38
7	Master Bed	15x19				
		Brick	None	None	None	None
		5 Windows	None	None	STC 28	STC 34
		Vaulted clg.	None	None	None	None
7	Bed 2	12x13				
		Brick	None	None	None	None
		1 Window	None	None	STC 26	STC 32
		1 Door	None	None	None	STC 31
		Attic	None	None	None	None
7	Bed 3	11x13				
		1 Window	None	None	None	STC 30
		Vaulted clg.	None	None	None	None
7	Bed 4	11x13				
		Brick	None	None	None	None
		2 Windows	None	None	STC 28	STC 32
		Attic	None	None	None	None
7	Game	14x18				
		Brick	None	None	None	None
		1 Window	None	None	None	STC 28
		Attic	None	None	None	None
7	Alcove	10x8				
		Brick	None	None	None	None
		2 Windows	None	None	STC 30	STC 34
		Attic	None	None	None	None
7	Play	12x10				
		Brick	None	None	None	None
		1 Window	None	None	None	STC 30
		Attic	None	None	None	None
7	Study/ Foyer	11x16				
		Brick	None	None	None	None
		2 Windows	None	None	STC 26	STC 34
		1 Door	None	None	None	STC 29
		Attic	None	None	None	None

Note: These modifications apply only to military jet aircraft. For modifications at houses impacted predominantly by propeller aircraft, helicopters, or civilian jet aircraft, see section 3.4.

Table 4-2. Modifications for New Construction – *continued*

House No.	Room Type	Room Elements	Noise Zone (dB, DNL) 60 - 65	65 - 70	70 - 75	75 - 80
7	Dining	12x16 Brick 3 Windows	 None None	 None STC 26	 None STC 32	 None STC 36
7	Living	17x13 Brick 6 Windows Attic	 None None None	 None STC 26 None	 None STC 30 None	 None STC 36 None
7	Kitchen/ Nook	15x26 Brick 3 Windows 1 Door w/storm	 None None None	 None None None	 None STC 28 None	 None STC 34 None
7	Family	14x20 Brick 3 Windows Attic	 None None None	 None None None	 None STC 28 None	 None STC 32 None
8	Master Bed	12x16 Siding 3 Windows Attic	 None None None	 None None None	 None STC 32 None	 RC STC 34 None
8	Bed 2	14x15 Siding 3 Windows Attic	 None None None	 None None None	 None STC 32 None	 RC STC 34 None
8	Living/ Dining	14x32 Siding 5 Windows Sliding gl. dr. Floor	 None None None None	 None STC 26 None None	 RC STC 32 STC 32 None	 RC STC 40 STC 34 Trusses
8	Kitchen/ Foyer	10x12 Siding 1 Window 1 door Floor	 None None None None	 None None None None	 RC STC 32 STC 31 None	 RC STC 34 STC 37 Trusses
9	Living	12x14 Siding 1 Window 1 Door	 None None None	 None None None	 RC STC 28 STC 29	 RC STC 36 STC 34
9	Family/ Kitchen	23x15 Siding 3 Windows	 None None	 None None	 None STC 34	 RC STC 34
9	Master Bed	14x14 Siding 2 Windows Attic	 None None None	 None None None	 None STC 28 None	 RC STC 32 None
9	Bed 2	11x11 Siding 1 Window Attic	 None None None	 None None None	 None STC 32 None	 RC STC 34 None
9	Bed 3	10x12 Siding 1 Window Attic	 None None None	 None None None	 None STC 28 None	 RC STC 32 None
10	Living	12x18 Brick 2 Windows 1 Door w/ storm	 None None None	 None None None	 None STC 30 None	 None STC 34 STC 37
10	Kitchen	17x13 Brick 2 Windows Sliding gl. dr.	 None None None	 None None None	 None STC 30 STC 32	 None STC 38 STC 34
10	Dining	14x9 Attic	 None	 None	 None	 None

Note: These modifications apply only to military jet aircraft. For modifications at houses impacted predominantly by propeller aircraft, helicopters, or civilian jet aircraft, see section 3.4.

Table 4-2. Modifications for New Construction *- continued*

House No.	Room Type	Room Elements	Noise Zone (dB, DNL)			
			60 - 65	65 - 70	70 - 75	75 - 80
10	Master Bed	12x13				
		Brick	None	None	None	None
		2 Windows	None	None	STC 28	STC 32
		Attic	None	None	None	None
10	Bed 2	9x11				
		Brick	None	None	None	None
		2 Windows	None	None	STC 28	STC 34
		Attic	None	None	None	None
10	Bed 3	8x11				
		Brick	None	None	None	None
		1 Window	None	None	STC 26	STC 32
		Attic	None	None	None	None
10	Family	18x20				
		Brick	None	None	None	None
		2 Windows	None	None	STC 26	STC 32
11	Living/ Foyer	13x19				
		Siding	None	None	RC	RC
		Brick	None	None	None	None
		3 Windows	None	STC 26	STC 30	STC 38
		1 Door	None	None	STC 29	STC 34
11	Family	13x11				
		Siding	None	None	RC	RC
		2 Windows	None	None	STC 28	STC 34
11	Dining/ Kitchen	10x21				
		Siding	None	None	None	RC
		1 Window	None	None	STC 30	STC 32
11	Master Bed	12x15				
		Siding	None	None	None	RC
		2 Windows	None	None	STC 30	STC 32
		Attic	None	None	None	None
11	Bed 2	11x12				
		Siding	None	None	None	RC
		1 Window	None	None	STC 26	STC 30
		Attic	None	None	None	None
11	Bed 3	10x12				
		Brick	None	None	None	None
		1 Window	None	None	None	STC 30
		Attic	None	None	None	None
12	Living/ Dining/ Kitchen	16x20				
		Siding	None	None	RC	RC
		1 Window	None	None	STC 30	STC 38
		1 Sliding gl. dr.	None	None	None	STC 34
12	Master Bed	11x16				
		Siding	None	None	None	RC
		2 Windows	None	None	STC 28	STC 32
		Attic	None	None	None	None
12	Bed 2	9x12				
		Siding	None	None	None	RC
		1 Window	None	None	STC 30	STC 34
		Attic	None	None	None	None
12	Bed 3	9x12				
		Siding	None	None	None	RC
		1 Window	None	None	STC 30	STC 34
		Attic	None	None	None	None
13	Living/ Kitchen/ Nook	21x23				
		Siding	None	None	None	RC
		7 Windows	None	STC 26	STC 36	STC 38
		1 door	None	None	STC 34	STC 34
13	Dining	10x12				
		Siding	None	None	None	RC
		2 Windows	None	STC 26	STC 34	STC 36
		Attic	None	None	None	None

Note: These modifications apply only to military jet aircraft. For modifications at houses impacted predominantly by propeller aircraft, helicopters, or civilian jet aircraft, see section 3.4.

Table 4-2. Modifications for New Construction *- continued*

House No.	Room Type	Room Elements	Noise Zone (dB, DNL)			
			60 - 65	65 - 70	70 - 75	75 - 80
13	Master Bed	13x15				
		Siding	None	None	None	RC
		3 Windows	None	None	STC 34	STC 36
		1 Sliding gl. dr.	None	None	STC 32	STC 34
		Attic	None	None	None	None
13	Bed 2	11x13				
		Siding	None	None	None	RC
		2 Windows	None	None	STC 32	STC 34
		Attic	None	None	None	None
13	Bed 3	11x13				
		Siding	None	None	None	RC
		2 Windows	None	None	STC 30	STC 34
		Attic	None	None	None	None
13	Family	23x19				
		Siding	None	None	None	RC
		4 Windows	None	None	STC 34	STC 38
		Sliding gl. dr.	None	None	STC 32	STC 34
		Attic	None	None	None	None
14	Living	15x14				
		Brick	None	None	None	None
		3 Windows	None	None	STC 32	STC 34
		A/C	None	None	None	Remove
15	Living/ Bed	16x17				
		Siding	None	None	None	None
		2 Windows	None	None	STC 28	STC 34
		Built-up roof	None	None	None	None
16	Living/ Dining	18x13				
		Siding	None	None	None	Stag
		Sliding gl. dr.	None	None	STC 32	STC 34
		Built-up roof	None	None	None	None
16	Kitchen	10x9				
		Attic	None	None	None	None
16	Bed	14x13				
		Siding	None	None	None	Stag
		2 Windows	None	None	STC 32	STC 32
		Built-up roof	None	None	None	None
16	Sun Room	10x8				
		Siding	None	None	RC	Stag, 2 gyp
		3 Windows	None	STC 30	STC 34	STC 38
		Built-up roof	None	None	None	2 gyp
17	Living/ Dining/ Kitchen	31x15				
		Siding	None	None	RC	Stag, 2 gyp
		2 Windows	None	STC 32	STC 34	STC 40
		Sliding gl. dr.	None	None	STC 32	STC 34
		1 Door	None	STC 31	STC 34	STC 40
17	Master Bed	10x10				
		Siding	None	None	None	Stag
		2 Windows	None	None	STC 32	STC 34
17	Bed 2	10x10				
		Siding	None	None	None	Stag
		1 Window	None	None	STC 28	STC 32
18	Living/ Dining/ Kitchen	15x18				
		Siding	None	None	None	RC
		3 Windows	None	None	STC 32	STC 34
		1 Door	None	None	STC 31	STC 34
		Attic	None	None	None	None
18	Master Bed	10x15				
		Siding	None	None	None	RC
		Sliding gl. dr.	None	None	STC 32	STC 34
		Attic	None	None	None	None
18	Bed 2	10x11				
		Siding	None	None	None	RC
		2 Windows	None	None	STC 28	STC 32
		Attic	None	None	None	None

Note: These modifications apply only to military jet aircraft. For modifications at houses impacted predominantly by propeller aircraft, helicopters, or civilian jet aircraft, see section 3.4.

Table 4-2. Modifications for New Construction - *continued*

House No.	Room Type	Room Elements	Noise Zone (dB, DNL)			
			60 - 65	65 - 70	70 - 75	75 - 80
19	Living	16x13				
		Siding	None	None	None	Stag
		2 Windows	None	None	STC 34	STC 36
		1 Door	None	None	STC 31	STC 31
		Attic	None	None	None	None
19	Dining/ Kitchen	17x13				
		Siding	None	None	RC	Stag
		2 Windows	None	None	STC 30	STC 36
		1 Door w/storm	None	None	None	STC 37
		Attic	None	None	None	None
19 +	Master Bed	12x11				
		Siding	None	None	None	Stag
		2 Windows	None	None	STC 32	STC 34
		Vaulted clg.	None	None	None	None
19	Bed 2	11x10				
		Siding	None	None	None	Stag
		2 Windows	None	None	STC 32	STC 34
		Vaulted clg.	None	None	None	None
19	Bed 3	9x11				
		Siding	None	None	None	Stag
		1 Window	None	None	STC 28	STC 32
		Vaulted clg.	None	None	None	None
20	Living/ Dining/ Kitchen	14x29				Noise Reduction Goals Are Not Achievable For This Noise Zone
		Siding	None	None	2 gyp	
		5 Windows	None	STC 26	STC 38	
		2 Doors	None	None	STC 34	
		Vaulted clg.	None	None	2 gyp	
20	Master Bed	12x14				Noise Reduction Goals Are Not Achievable For This Noise Zone
		Siding	None	None	None	
		2 Windows	None	None	STC 32	
		Vaulted clg.	None	None	None	
20	Bed 2	10x14				
		Siding	None	None	None	2 gyp
		1 Window	None	None	STC 26	STC 38
		Vaulted clg.	None	None	None	2 gyp
21	Living/ Dining	23x26				Noise Reduction Goals Are Not Achievable For This Noise Zone
		Siding	None	None	None	
		4 Windows	None	None	STC 30	
		2 Doors	None	None	STC 34	
		Sliding gl. dr.	None	None	STC 32	
		Vaulted clg.	None	None	None	
21	Master Bed	18x13				Noise Reduction Goals Are Not Achievable For This Noise Zone
		Siding	None	None	None	
		2 Windows	None	None	STC 32	
		Vaulted clg.	None	None	None	
21	Bed 2	11x13				
		Siding	None	None	None	2 gyp
		1 Window	None	None	STC 26	STC 36
		Vaulted clg.	None	None	None	None
21	Bed 3	11x13				Noise Reduction Goals Are Not Achievable For This Noise Zone
		Siding	None	None	None	
		1 Window	None	None	STC 30	
		Vaulted clg.	None	None	None	

Note: These modifications apply only to military jet aircraft. For modifications at houses impacted predominantly by propeller aircraft, helicopters, or civilian jet aircraft, see section 3.4.

4.4 Special Conditions

Table 4-3 gives a list of special considerations for new homes for which recommendations have been developed. For non-habitable rooms, no modifications are required. See Section 3.4 for additional notes.

Table 4-3. Special Modifications by DNL Noise Zone

	DNL Noise Zone			
Building Element	**60 - 65**	**65 – 70**	**70 – 75**	**75 - 80**
Skylights	STC 28	STC 38	STC 38	Not allowed
Fireplaces, vented prefab units	Add damper or doors	Add chimney damper	Not allowed	Not allowed
Wood stove	Double wall duct	Not allowed	Not allowed	Not allowed
Combustion exhaust, dryer duct	Double wall rigid duct	Enclose in chase; use combustion air enforcer	Enclose in chase; use combustion air enforcer	Enclose in Chase; use combustion air enforcer
A/C in window or in wall	Not allowed	Not allowed	Not allowed	Not allowed
Gravity heating systems	Not allowed	Not allowed	Not allowed	Not allowed
Pet doors, mail slots	Not allowed	Not allowed	Not allowed	Not allowed
Vented kitchen range or in-wall fan	At least 2 90-degree turns in duct	At least 2 90-degree turns in duct	Use ductless	Use ductless
Attic Insulation[5]	–	R19, 5.25-8″	R30, 9-13″	R30, 9-13″
Attic access panels	–	Use 3/4″ plywood and seals	Use 3/4″ plywood and seals	Use 3/4″ plywood and seals
Pull-down attic stairs	–	Add cover	Add cover	Add cover
Whole-house attic fan	Allowed with cover	Allowed with cover	Allowed with cover	Not allowed

Note: These modifications apply only to military jet aircraft. For modifications at houses impacted predominantly by propeller aircraft, helicopters, or civilian jet aircraft, see section 3.4.

Recommendations for manufactured homes and for homes exposed predominantly to noise from propeller aircraft, helicopters, or civilian aircraft are presented in Section 3.4.

4.5 Additional Design Considerations

Building a new house offers important opportunities to design noise reduction in the planning stage. Many of these factors, such as avoiding cathedral ceilings or overly large windows, have

[5] Thermal transmittance is measured in terms of the R-value. For attic insulation requirements consult the local building and energy codes. Thermal resistance is expressed in terms of the R-value. If the building or energy code requires a higher R-value, meet the code requirement.

already been noted. However, there are several additional design considerations that may be very beneficial when planning a new home:

Room Location – Locate bedrooms and other noise sensitive rooms on the side of the house away from the aircraft flight tracks. Using the house structure itself to shield habitable rooms can provide as much as 5 to 10 dB of additional noise reduction.

Outside Spaces – Locate decks and patios or other outdoor gathering places on the side of the house away from the aircraft flight tracks. One of the most common complaints from residents is the difficulty of enjoying their decks and yards when aircraft are flying nearby. Careful location of entertainment areas can reduce adverse impacts. However, locating such areas on the side of the house away from the flight tracks may not be feasible, especially if the bedrooms are also located on that side of the house, recognizing that something has to be on the other side.

Multiple Stories – Build "up" with multiple-story structures instead of using single-story homes. Upper floors protect the rooms below from noise and, consequently, the first floor of a two-story house is noticeably quieter than a single-story home.

Vegetation – Do not rely on trees or shrubs to reduce noise. They are only useful for slightly reducing the noise of aircraft that are at a very low elevation (i.e., when they are departing away from the house). It takes several hundred feet of solid forest to make a significant difference in noise exposure, even for low elevation noise and this does not protect from overflight noise. However, many residents report that they experience some benefit from a visual screen between them and the aircraft, whether the noise is reduced or not.

Vestibules & Mudrooms – Include vestibules and enclosed mudrooms in home designs where possible. Vestibules and mudrooms are non-habitable spaces that buffer the more noise-sensitive rooms from exterior doors, eliminating the need to upgrade the doors. Doors are a significant noise leak and providing acoustical doors can be costly.

Porches & Patios – Enclose patios or porches with some form of walls and windows instead of using only screens. Walls and/or windows can significantly reduce noise in these somewhat habitable indoor spaces. However, be sure to separate the patio or porch from other interior spaces with walls and a door. See the modifications recommended for existing sunrooms in Table 3-2 for ideas if the patio is intended to be habitable.

Ventilation and Air Conditioning – Install a central air-conditioning system instead of relying on open windows, window A/C units, or in-wall units for cooling. This is very important for reducing noise leaks.

5.0 Sound Insulation Costs

This chapter provides cost estimates for renovating existing homes and building new homes using sound insulation methods. Section 5.1 discusses cost considerations for renovating existing houses to achieve the NLR goals, and Section 5.2 addresses the cost of sound insulating new homes. Section 5.3 discusses cost multipliers to be used for various regions.

The cost to sound insulate a new or existing house can vary greatly from one house to the next. To address this variability, a computer program was developed to complement this document. This program, included on the disk in the front of this report, can be used to determine the required scope and cost to sound insulate a room. To obtain an additional copy of this program contact the regional Naval Facilities Engineering Command office near you (see Section 1.4 for contact information).

Sound insulation costs are affected by a variety of factors including:

- Home size
- Home design (number and size of windows, type of roof, etc.)
- Exterior noise exposure zone
- Local and state building codes and local code interpretation
- Community location
- Selected product manufacturers

For projects that sound insulate multiple dwellings, such as Federally-funded sound insulation programs at commercial airports, other factors also influence costs, including:

- Program management, contract structure, and oversight
- Number of homes in contract

Sound insulation designs for existing and new homes have many common elements. For example, both require specially designed and tested windows and doors, extra wall and ceiling treatments (in higher noise zones), and mechanical system upgrades. For new construction, upgrading acoustically-rated products is less costly than replacing elements, which is necessary for sound insulation renovations.

Sound insulation renovation costs for existing homes around airports generally range from $10,000 to more than $50,000 per home, depending on the factors discussed above. Sound insulation impacts on new construction costs are expected to be much lower. Sections 5.1 and 5.2 give estimates for sound insulation costs associated with the measures described in Chapters 3 and 4 of the *Guidelines*. Note that cost estimates for some products are based on data from a small number of manufacturers; costs may vary based on which manufacturers serve your area, which types of products are offered in your area, and the competitiveness of the market.

The costs to provide energy recovery ventilators in this section include a system that has a heat and moisture recovery feature. This feature is useful to reduce heating costs in the winter, and to balance humidity. Systems that do not have this feature, such as heat recovery ventilators, ventilators with re-heat coils, or simple ventilators, will be less expensive.

5.1 Existing Homes

Renovation typically entails replacing many doors and windows. The costs included in this section are for the full replacement cost. In contrast, the costs in the following section for new construction only include the increased costs associated with using special products. The cost to sound insulate an existing structure also includes a variety of elements that are unique to renovation, such as contractor mobilization costs, inefficiencies if the homeowner continues to live in the house during renovation, and additional labor and materials to work around existing conditions. These costs do not include any associated asbestos or lead abatement efforts. Such abatement might be appropriate when disturbing asbestos-containing ceiling tiles, siding, floor tiles, stucco, caulk, or insulation, or when disturbing lead-based paint or stain. Renovation, like new construction, can be performed on single homes or on a group of homes at a time; however, the costs will vary depending on how many are renovated at a time. Large groups cost less on a per-home basis but require more effort to organize and schedule. These factors combine to raise the per-home cost of renovation above what the same building materials and techniques would have cost in a new home.

Table 5-1 gives unit costs for a variety of sound insulation elements for renovation of an existing home, assuming it is part of a larger sound insulation program. These costs were based on sound-insulating 20 to 50 homes at a time. Costs to sound insulate a single home will be somewhat higher. The costs are given on a per-unit basis including labor, materials, overhead, profit, licenses, bonding, and all related contractor costs. These costs do not include design fees, administrative costs of the funding organization, or construction contingencies. The specific treatments are explained in more detail in Section 3.3. For windows and doors, costs are only listed for the selected commonly available STC ratings.

The costs to provide air-conditioning in Table 5-1 do not include new ducts. The cost for ducts can vary widely depending on the size and configuration of the house. There are also ductless cooling systems that can be used.

The costs in Table 5-1 associated with removing existing wall and ceiling finishes do not include any upgrades to the electrical system that may be required by the building code. Nor do the costs include any necessary upgrades to knob-and-tube wiring in attics that needs to be replaced when attic insulation is added. Finally, the costs do not include relocation of electrical meters, which may be required by the building inspector.

Table 5-1. Estimated Unit Costs for Renovation Insulation Elements

Item	Unit	Average Unit Cost
30″x48″ STC 32 window	Each	$ 420.00
36″x72″ STC 32 window	Each	$ 581.00
30″x48″ STC 36 window	Each	$ 442.00
36″x72″ STC 36 window	Each	$ 613.00
30″x48″ STC 40 window	Each	$ 553.00
36″x72″ STC 40 window	Each	$ 766.00
30″x48″ STC 44 window	Each	$ 851.00
36″x72″ STC 44 window	Each	$ 1,179.00
2′x3′-6″ skylight interior glass panel	Each	$ 360.00
Replace 2′x3′-6″ skylight with new STC 38 unit	Each	$ 634.50
3'-0"X6'-8" STC 29 swinging wood prime door	Each	$ 1,223.00
3'-0"X6'-8" STC 40 swinging wood prime door	Each	$ 1,748.00
Swinging acoustical storm door	Each	$ 524.00
6′-0″x6′-8″ STC 34 sliding glass door	Each	$ 1,847.00
6′-0″x6′-8″ STC 37 sliding glass door	Each	$ 2,037.00
6′-0″x6′-8″ secondary sliding glass door	Each	$ 1,157.00
Addition of one layer of gypsum board with insulation	Square-foot	$ 4.37
Addition of two layers of gypsum board with insulation	Square-foot	$ 6.29
Removing gyp board, adding staggered 2x2 studs, adding insulation, then adding new 5/8″ gypsum board (“Furr” in Table 3-2)	Square-foot	$ 9.72
Same, with 2 layers (“Furr, 2 gyp” in Table 3-2)	Square-foot	$ 11.64
Same, with 2 layers and resilient channels between studs and 1st layer	Square foot	$ 13.10
Acoustical fireplace doors	Pair	$ 695.00
Chimney-top acoustical damper	Each	$ 365.00
Upgrade attic access panel or build cover for pull-down stair or whole-house ceiling fan	Each	$ 400.00
Addition of 6″ of attic insulation	Square-foot	$ 1.38
Addition of one layer of ceiling 5/8″ gypsum board	Square-foot	$ 5.24
Removing existing ceiling, then adding resilient channels and 5/8″ gypsum board	Square-foot	$ 9.97
Same, with 2 layers	Square-foot	$ 12.70
Infilling a through-wall air-conditioner	Each	$ 461.00
New central air-conditioning and heating system (does not include ERV or new ducts)	System	$ 7,702.00
Addition of cooling system to existing forced-air heating system (includes cooling coil and condenser; does not include new ducts)	System	$ 3,169.00
Energy recovery ventilator (ERV)	System	$ 1,957.00
Combustion air enforcer	System	$ 472.00
Upgraded electrical panel (keeping existing meter)	Each	$ 2,140.00

Table 5-2 presents a sample worksheet for the costs of sound insulating a single home that is part of a sound insulation program consisting of 20 to 50 homes. Note that insulating only one home at a time may be more expensive.

Table 5-2. Sample Worksheet for Per Home Renovation Cost

Element	Unit	No. of units	Unit Cost	Total
30″x48″ STC 40 Window	Each	15	$553.00	$8,295.00
36″x72″ STC 40 Window	Each	4	$766.00	$3,064.00
2′x3′-6″ skylight interior glass panel	Each	2	$360.00	$720.00
STC 29 swinging wood prime door	Each	2	$1,223.00	$2,446.00
Swinging acoustical storm door	Each	2	$524.00	$1,048.00
Addition of one layer of gypsum board to walls	Square feet	500	$4.37	$2,185.00
New A/C system	System	1	$7,702.00	$7,702.00
Upgraded electrical panel	Each	1	$2,140.00	$2,140.00
Infilling a through-wall air-conditioner	Each	2	$461.00	$461.00
Total				$28,061.00

5.2 New Homes

The cost to build a sound insulated home is only slightly higher than the cost to build a standard home. Some design considerations may have no cost associated with them, such as locating bedrooms away from the flight pattern. Table 5-3 gives the estimated additional costs, beyond standard construction, associated with each of the building elements on a per-unit basis. The unit costs are based on the assumption that the typical wall construction consists of 2x4 wood studs spaced 16” on-center with one layer of 7/16” wood sheathing and vinyl siding on the exterior and one layer of 1/2” gypsum board on the interior. It is assumed that central air-conditioning will be included in typical house construction in warm climate regions.

Table 5-3. Additional Costs for Sound Insulating New Construction

Item	Unit	Average Additional Unit Cost
30″x48″ STC 32 window	Each	$ 16.00
36″x72″ STC 32 window	Each	$ 23.00
30″x48″ STC 36 window	Each	$ 66.00
36″x72″ STC 36 window	Each	$ 91.00
30″x48″ STC 40 window	Each	$ 147.00
36″x72″ STC 40 window	Each	$ 203.00
30″x48″ STC 44 window	Each	$ 195.00
36″x72″ STC 44 window	Each	$ 270.00
2′x3′-6″ STC 38 skylight	Each	$ 150.00
STC 29 swinging acoustical storm door (added cost assumes no storm door would have been used otherwise)	Each	$ 300.00
STC 29 swinging acoustical prime door	Each	$ 162.00
STC 34 swinging acoustical prime door	Each	$ 486.00
STC 40 swinging acoustical prime door	Each	$ 873.00
6′-0″x6′-8″ STC 34 sliding glass door	Each	$ 437.00
6′-0″x6′-8″ STC 37 sliding glass door	Each	$ 1,312.00
6′-0″x6′-8″ secondary sliding glass door	Each	$ 500.00
Adding a second layer of gypsum board to walls	Square-foot	$ 0.70
Adding resilient channels to walls	Square foot	$ 1.10
Adding second layer of gypsum board to sloped ceilings	Square foot	$ 1.41
Adding resilient channels to sloped ceilings	Square-foot	$ 2.31
Using staggered 2x4 wood studs	Square-foot	$ 1.68
Using ½″ thick cement in lieu of 1/8″ exterior finish	Square foot	$ 4.00
Using 14″ deep floor trusses in lieu of 2x10 joists	Square-foot	Varies
Adding a second layer of 7/16″ wood sheathing	Square-foot	$ 1.10
Acoustical fireplace doors	Pair	$ 670.00
Chimney-top acoustical damper	Each	$ 365.00
Provide ¾″ gasketed cover for pull-down attic stairs or whole house fan	Each	$ 400.00
Providing an energy recovery ventilator	System	$ 1,957.00
Providing a combustion air enforcer	System	$ 472.00

5.3 Location Cost Factors

The U.S. Department of Housing and Urban Development (HUD) studies housing and construction costs in the United States. HUD research shows that one of the determinants of home construction cost is whether the home is located in a rural or urban area. Costs are consistently higher in cities than in rural communities, and also differ between geographic regions. Baseline costs given in Tables 5-1 and 5-3 reflect the national average in 2004. To determine the cost of a particular project, multiply those costs by the factors given in Table 5-4.

Table 5-4. Regional Cost Multipliers

Area	Multiplier (based on percent of national median)
National Median	1.00
Inside Metropolitan Statistical Area (MSA)	1.00
Outside MSA	0.98
Northeast (CT, ME, MA, NH, NJ, NY, PA, RI, VT)	1.20
Midwest (IL, IN, IA, KS, MI, MN, MO, NE, ND, OH, SD, WI)	1.09
South (AL, AR, DE, DC, FL, GA, KY, LA, MD, MS, NC, OK, SC, TN, TX, VA, WV)	0.90
West (AK, AZ, CA, CO, HI, ID, MT, NV, NM, OR, UT, WA, WY)	1.17

Appendix A
New Home Floor Plans

Plans used are based on the room types and sizes of actual homes on the market as of September 2003.

Appendix A:
New Home Floor Plans

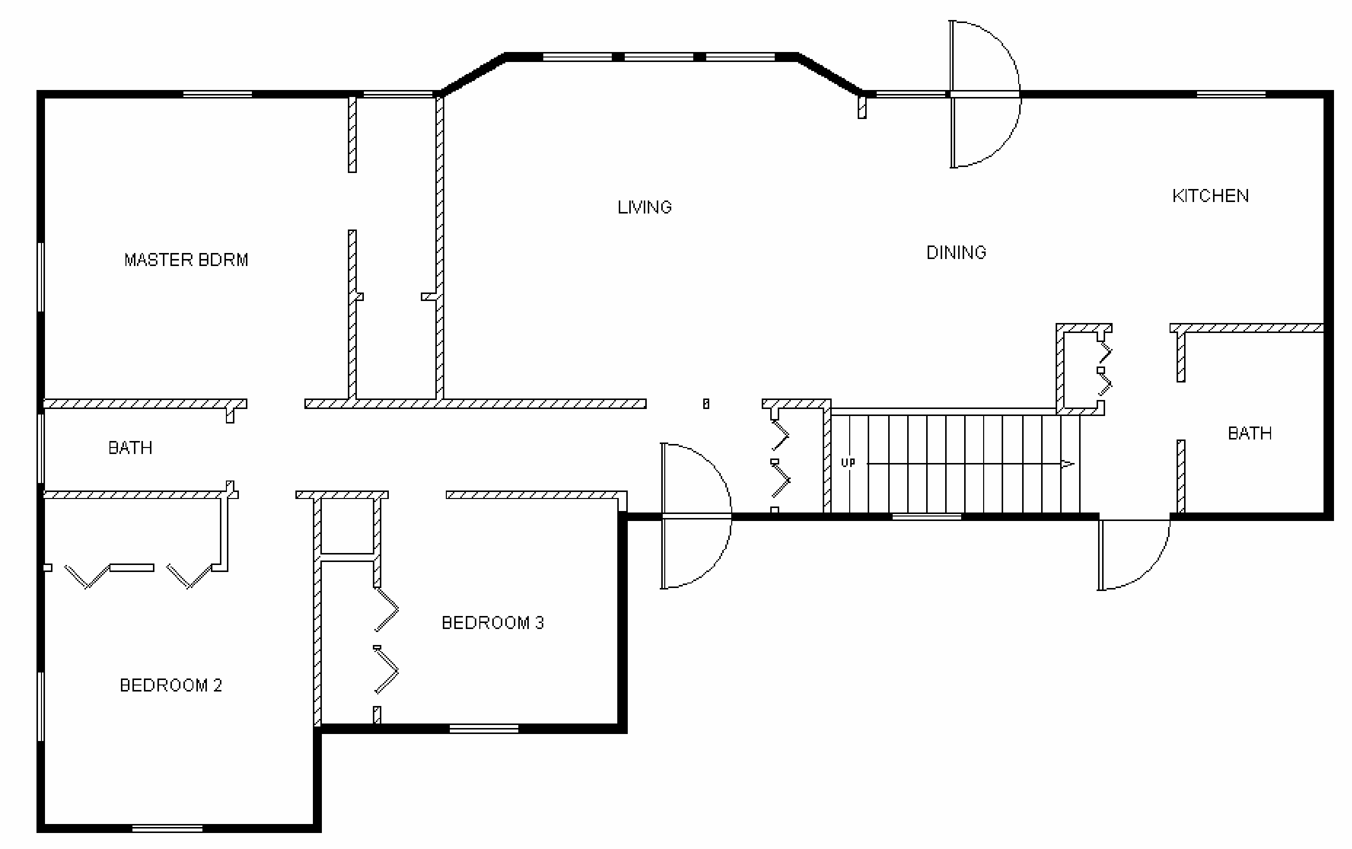
TYPICAL NEW HOUSES: PLAN THUMBNAILS AND DESCRIPTIONS

House ID No.	House Category and Description[2]
	Single-Family Houses
1	1-Story with Sided 2x4 Walls
2	1-Story with Brick, Concrete Block, or ICF Walls
3	1-Story with Stucco on 2x6 Walls
4	1-Story with Brick, Concrete Block, or ICF Walls
5	2-Story with Sided 2x6 Walls
6	2-Story with Stucco or EIFS on 2x6 Walls
7	2-Story with Brick , Concrete Block or ICF Walls
8	Beach House with Sided 2x4 Walls, on Pylons
	Duplexes
9	2-Story Duplex with Sided 2x4 Walls
	Townhouses
10	18'-Wide 3½ Story with Brick, Concrete Block, or ICF Walls
11	24'-Wide End-unit 2-Story with Brick, Concrete Block, or ICF Front Walls, and Sided 2x4 End and Rear Walls
12	20'-Wide with Sided 2x4 Walls
13	24'-Wide End-unit with Sided 2x4 Walls
	Apartments and Nursing Homes
14	Apartment with Brick Walls and Through-Wall A/C Unit
15	Top Floor Apartment with Brick Walls
16	Corner Top-Floor Apartment with Sided 2x4 Walls
17	End Apartment with Sided 2x4 Walls
18	Top-Floor Apartment with Sided 2x4 Walls
	Modular and Manufactured Homes
19	1-Story Modular Home with Sided 2x4 Walls
20	Small Manufactured Home with Sided 2x6 Walls
21	Large Manufactured Home with Sided 2x4 Walls

[1] Thumbnail floor plans for these homes are given in Appendix A.

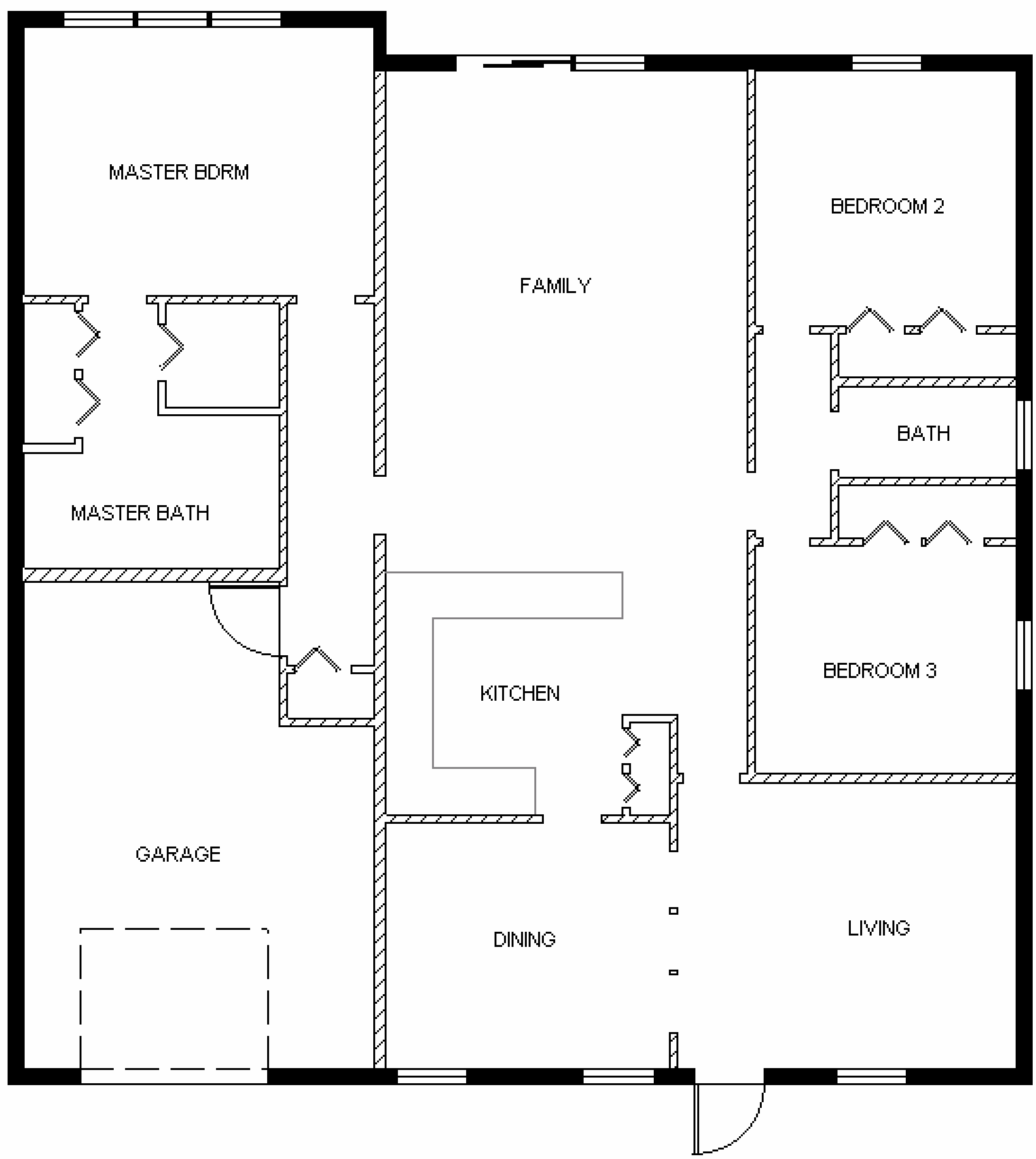
[2] All homes have flat gypsum board ceilings with sloped roofs unless otherwise indicated.

House 1: One-Story with Sided Walls



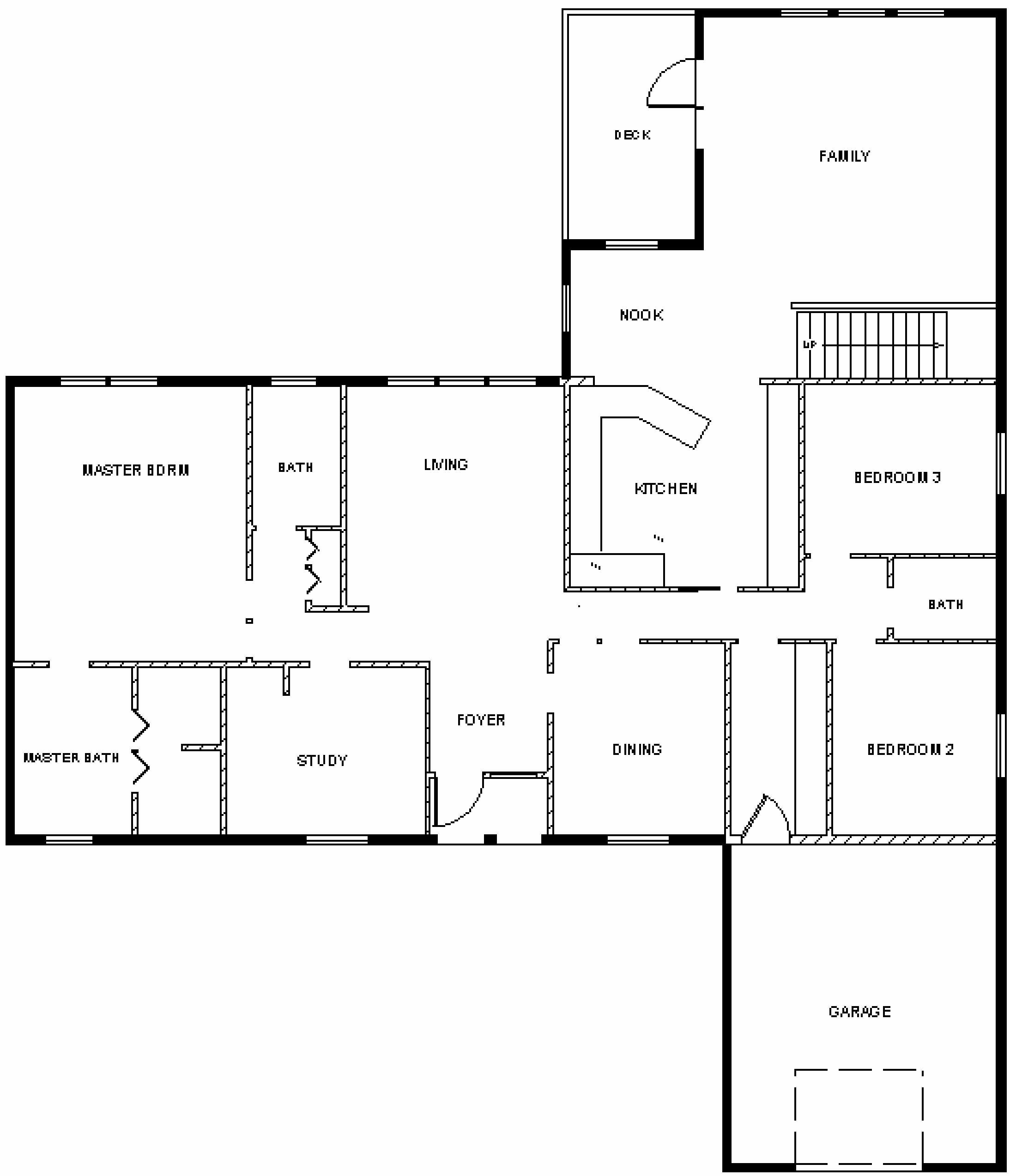
Walls:	Siding on 2x4 wood studs
Windows:	Double pane glass
Ceilings:	9′ high
Roof:	Vaulted ceiling

House 2: One-Story with Masonry Walls



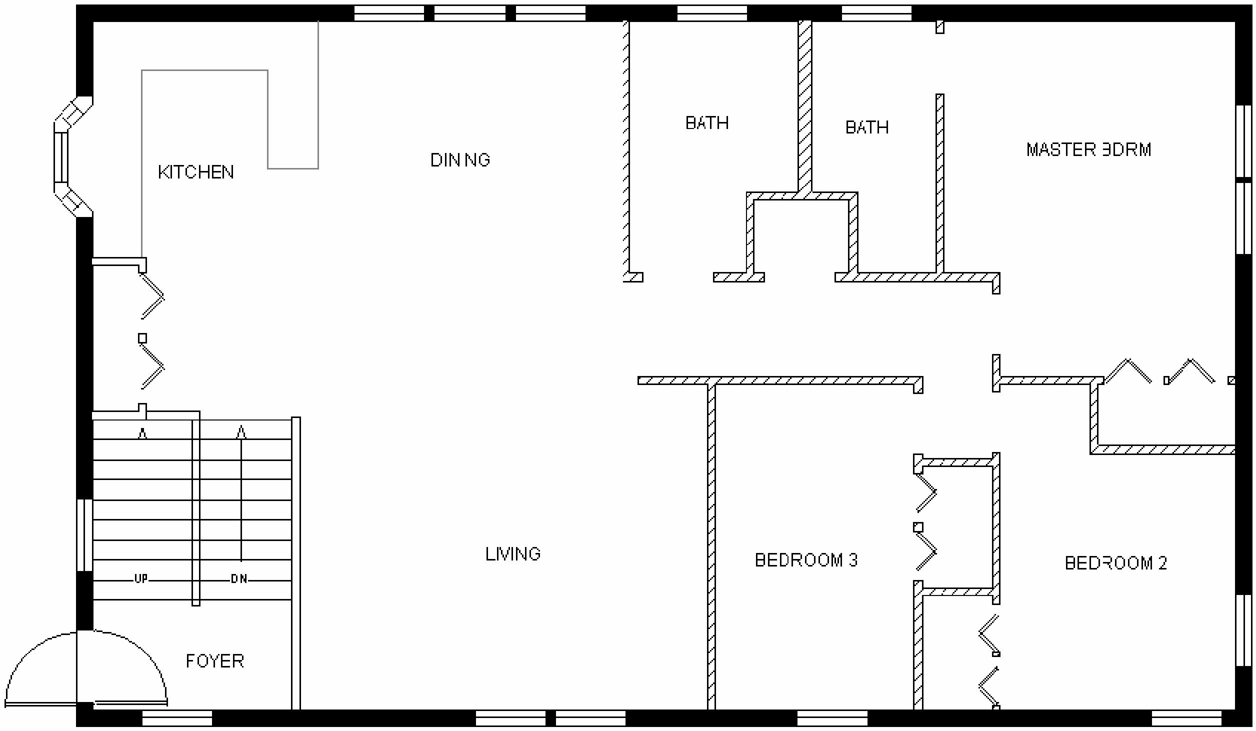
Walls:	Brick, painted concrete masonry units, or insulating concrete forms
Windows:	Double pane glass
Ceilings:	9′ high
Roof:	Vented attic with sloped roof

House 3: One Story with Stucco Walls



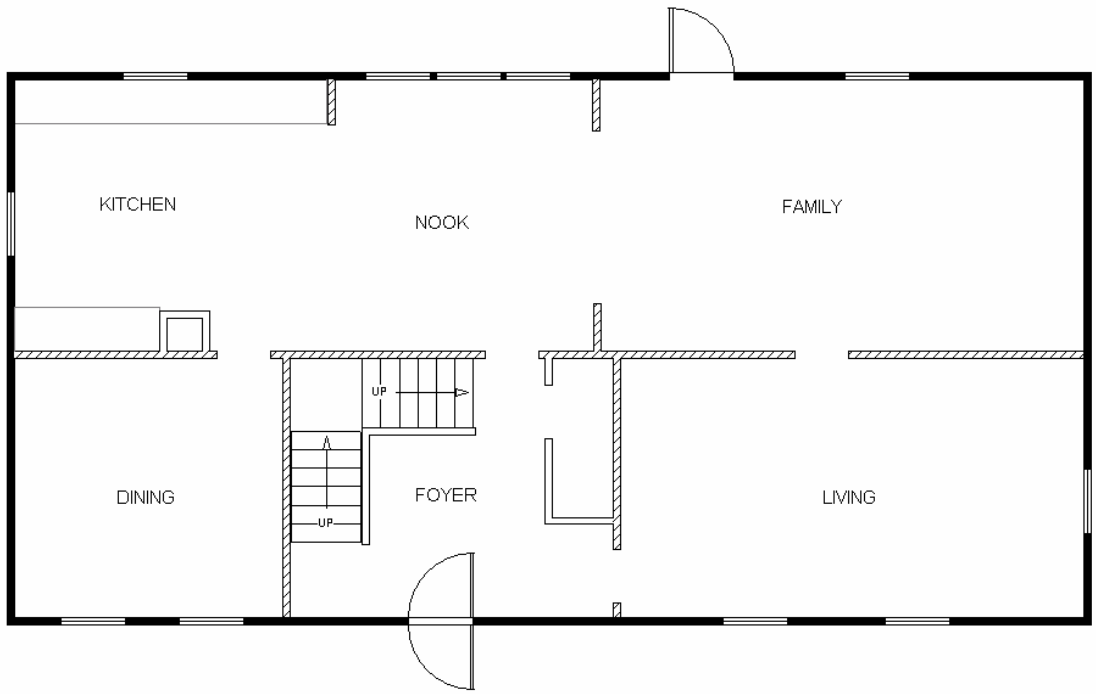
Walls:	Stucco or EIFS on 2x6 wood studs
Windows:	Double pane glass
Ceilings:	8′ high
Roof:	Vented attic with sloped roof

House 4: One-Story with Masonry Walls



Walls:	Brick, concrete masonry units, or insulating concrete forms
Windows:	Double pane glass
Ceilings:	9′ high
Roof:	Vented attic with sloped roof

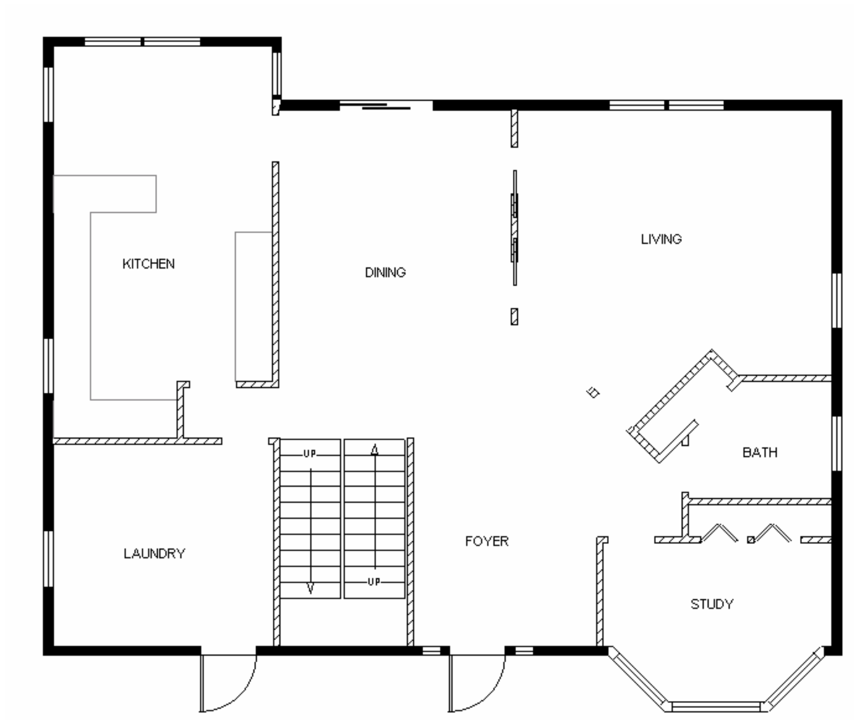
House 5: Two-Story with Sided Walls



Walls:	Siding on 2x6 wood studs
Windows:	Double pane glass with removable storm windows
Ceilings:	8′ high
Roof:	Vented attic with sloped roof

House 6: Two-Story with Stucco Walls

1st Floor

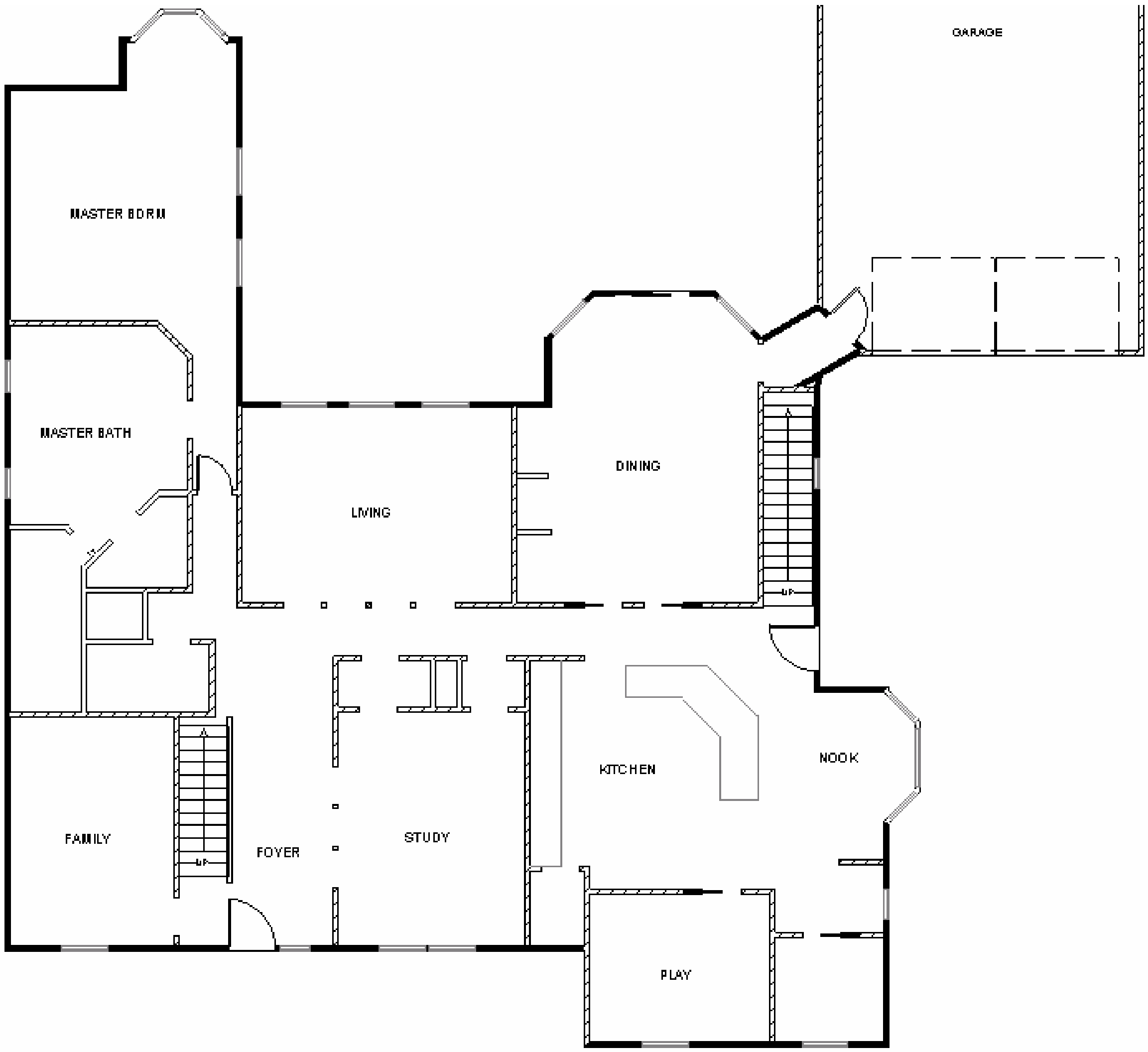


2nd Floor

Walls:
Stucco or EIFS on 2x6 wood studs
Windows: Double pane glass
Ceilings: 8′ high
Roof: Vented attic with sloped roof

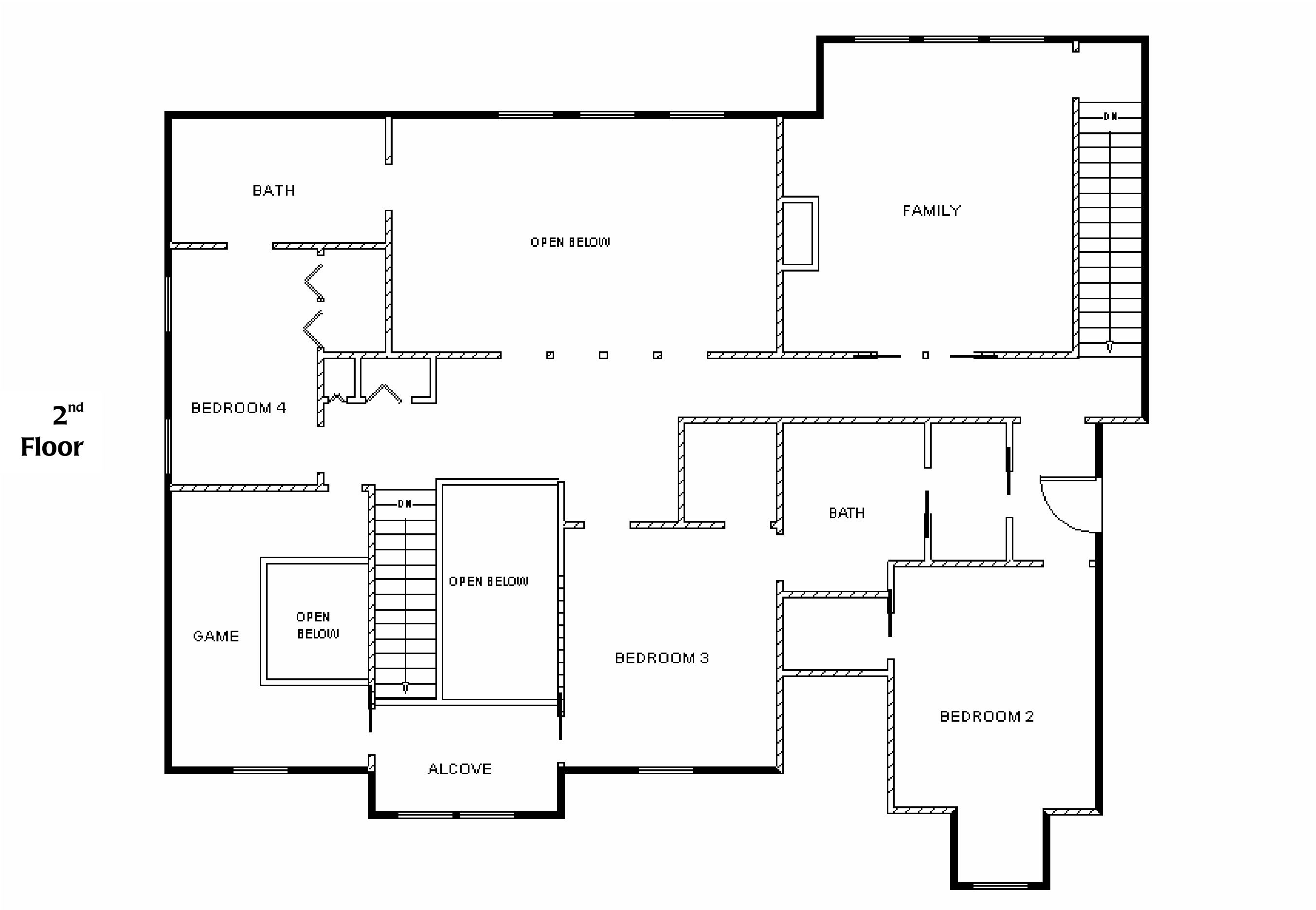
House 7: Two-Story with Masonry Walls

1st Floor



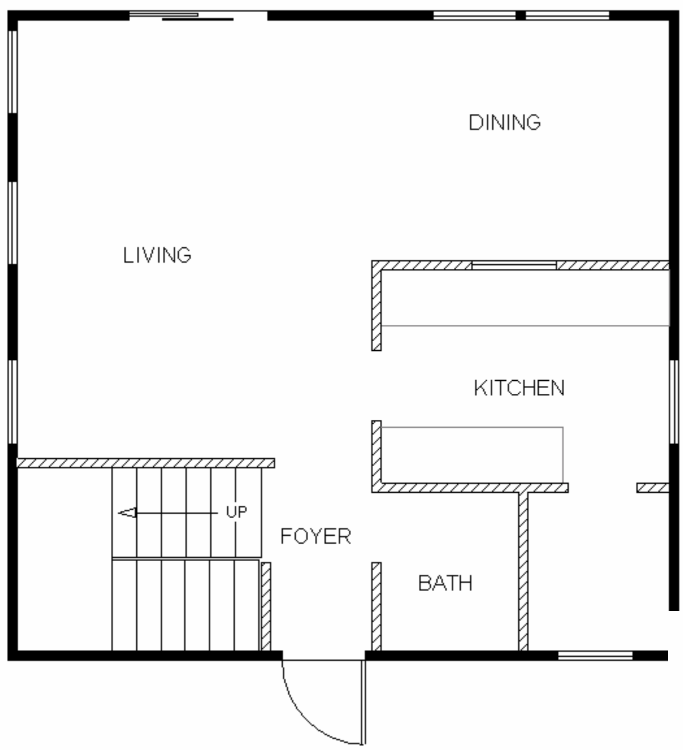
Walls:	Brick, concrete block, or insulating concrete forms
Windows:	Double pane glass
Ceilings:	8′ high
Roof:	Vented attic with sloped roof (Vaulted ceiling in Master Bedroom)

House 7: Two-Story with Masonry Walls - *concluded*



Walls:	Brick, concrete blocks, or insulating concrete forms
Windows:	Double pane glass
Ceilings:	8′ high
Roof:	Vented attic with sloped roof

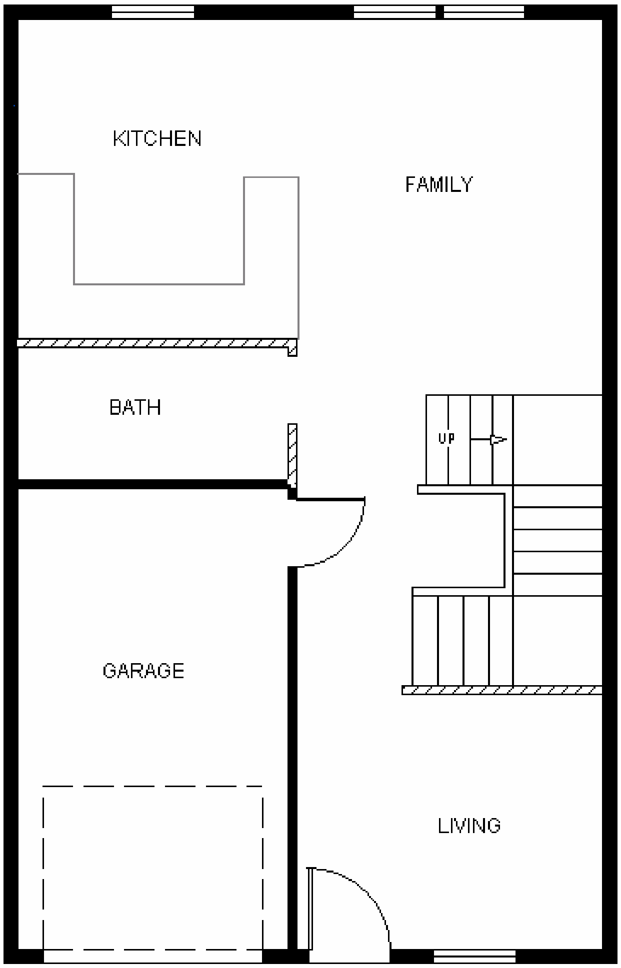
House 8: Beach House with Sided Walls on Pylons



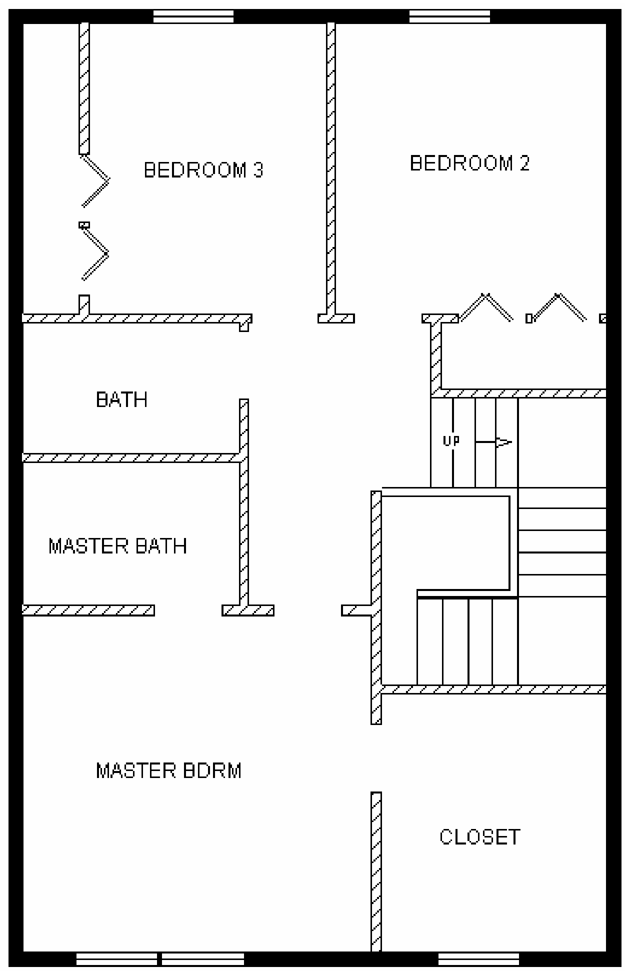
2nd
Floor

Walls:	Siding on 2x4 wood studs
Windows:	Single pane glass
Ceilings:	9′ high
Roof:	Vented attic with sloped roof

House 9: Two-Story Duplex with Sided Walls



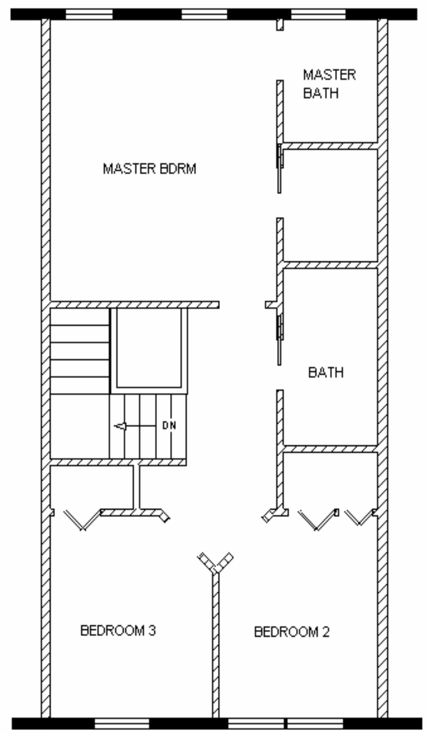
1st Floor



2snd Floor

Walls:	Siding on 2x4 wood studs
Windows:	Double pane glass
Ceilings:	9′ high
Roof:	Vented attic with sloped roof

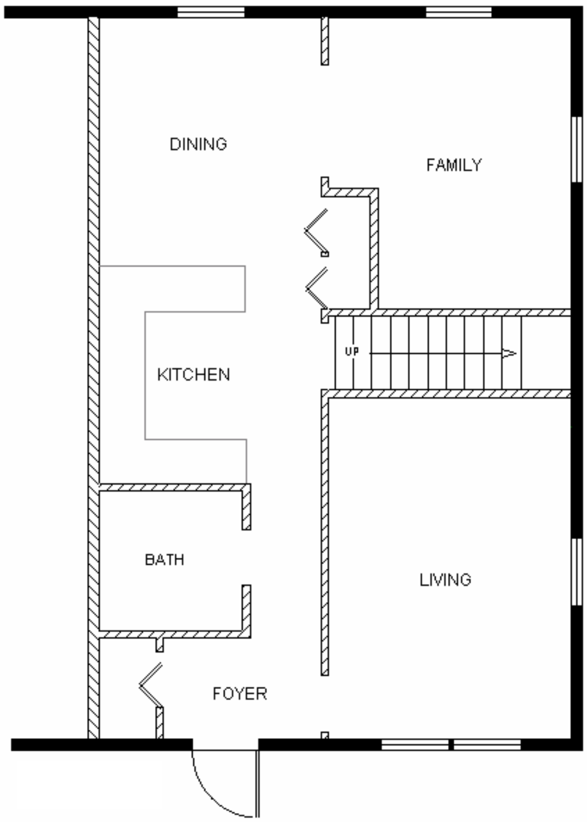
House 10: 18′- Wide Middle-of-Row Townhouse with Brick Walls



1st Floor 2nd Floor 3rd Floor

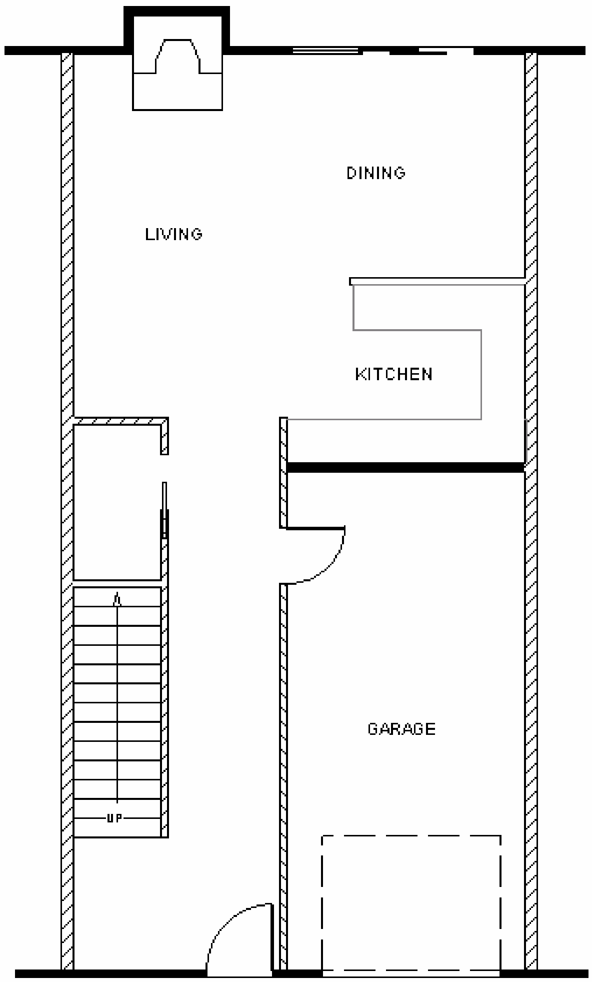
Walls:	Brick, painted concrete masonry units, or insulating concrete forms
Windows:	Double pane glass
Ceilings:	9′ high
Roof:	Vented attic with sloped roof

House 11: 24′-Wide End-of-Row Townhouse with Brick Walls



Walls:	Brick front walls; sided 2x4 stud end and rear walls
Windows:	Double pane glass
Ceilings:	9′ high
Roof:	Vented attic with sloped roof

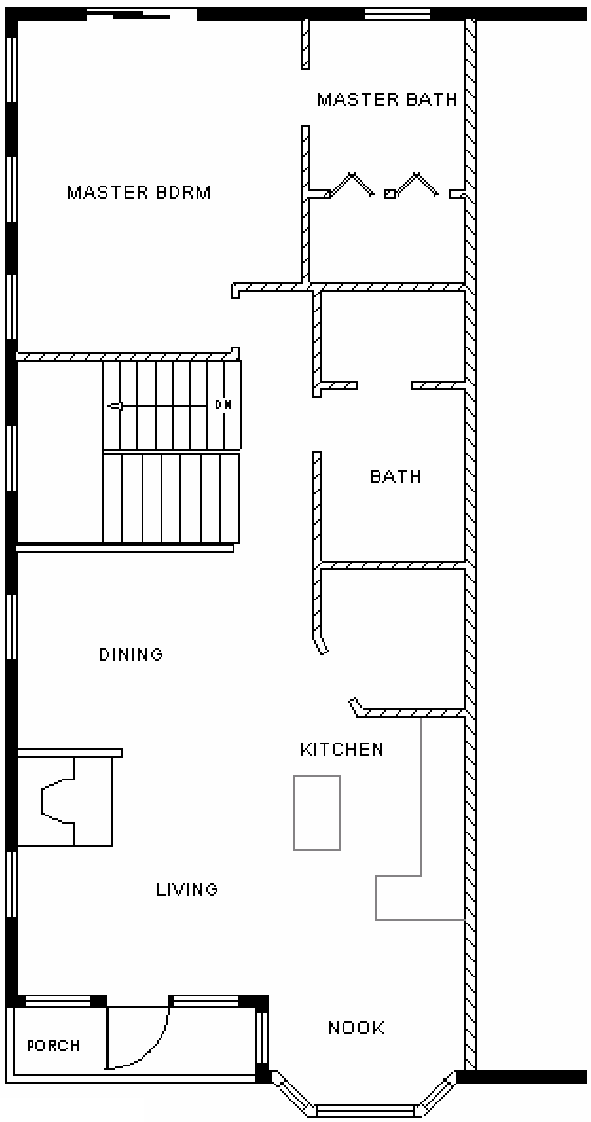
House 12: 20′-Wide Middle-of-Row Townhouse with Sided Walls



2nd Floor

Walls:	Siding on 2x4 wood studs
Windows:	Double pane glass
Ceilings:	9′ high
Roof:	Vented attic with sloped roof

House 13: 24′-Wide End-of-Row Townhouse with Sided Walls



2nd Floor

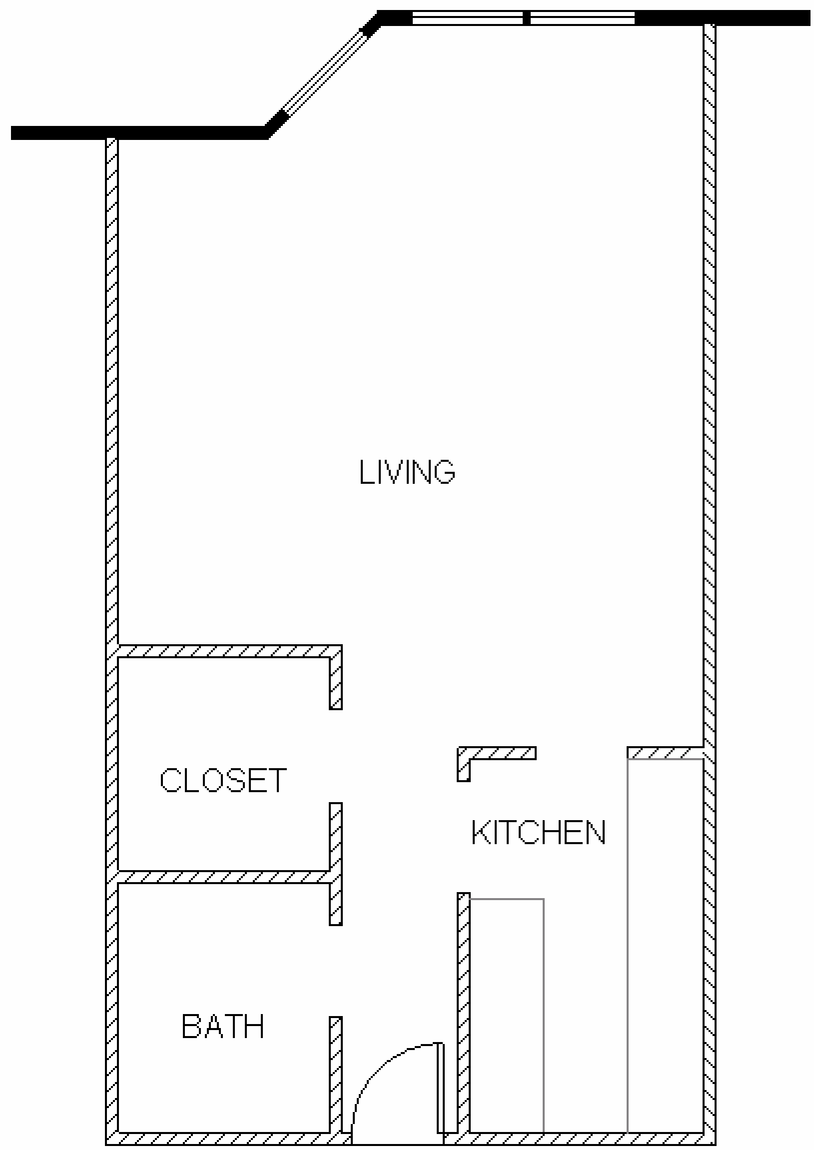
Walls: Siding on 2x4 wood studs

Windows: Double pane glass with removable storm windows

Ceilings: 8′ high

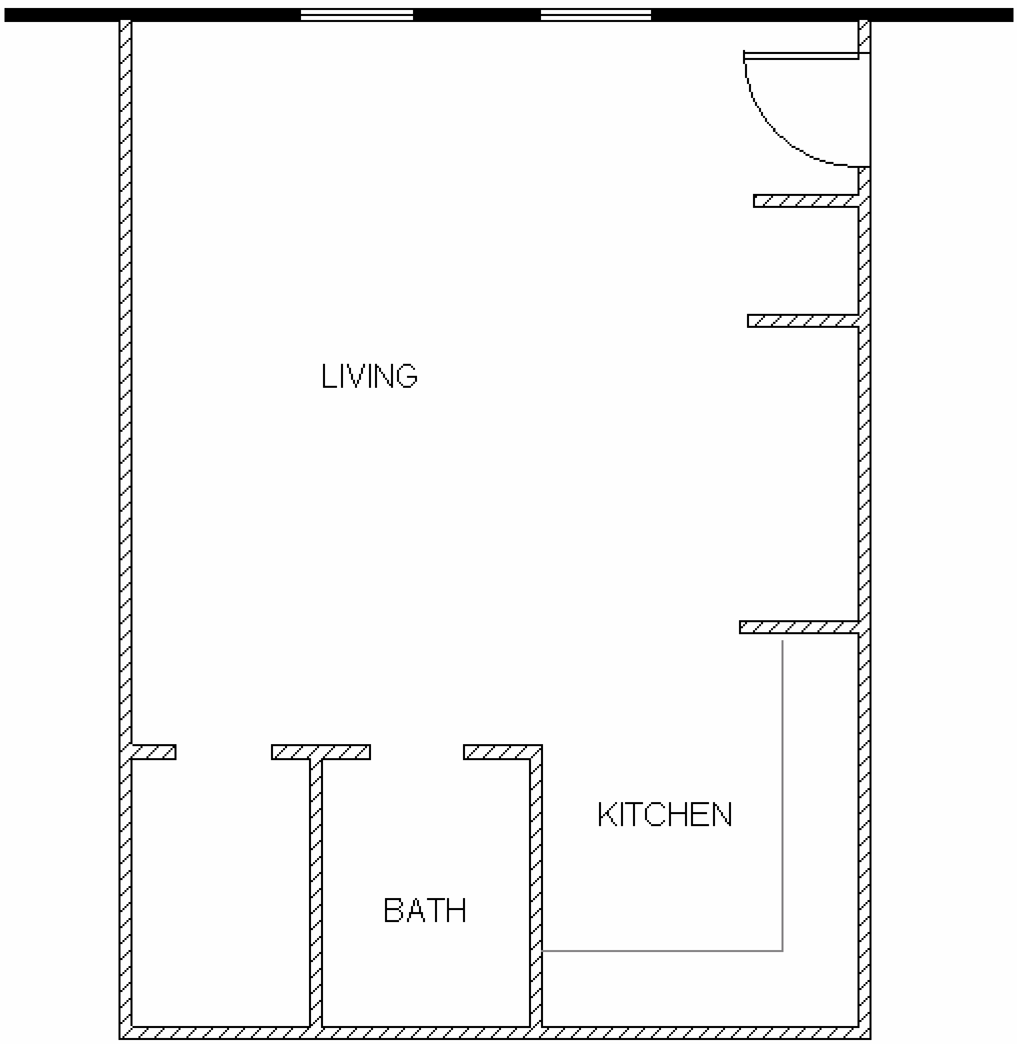
Roof: Vented attic with sloped roof

House 14: Efficiency Apartment with Brick Walls and Through-Wall A/C



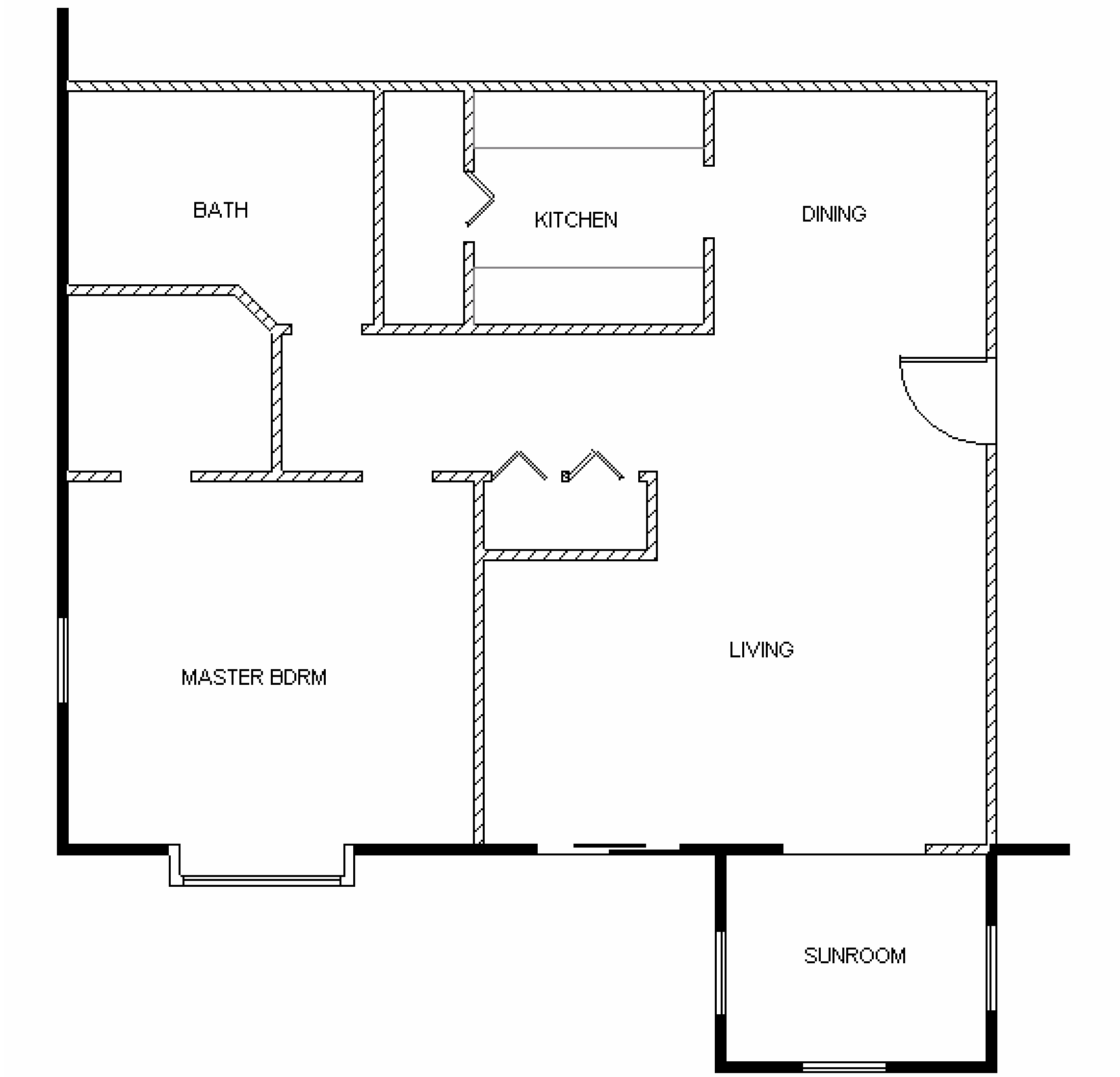
Walls:	Brick
Windows:	Double pane glass; A/C under one window
Ceilings:	8′ high
Roof:	Additional apartment above

House 15: Top Floor Efficiency Apartment with Brick Walls



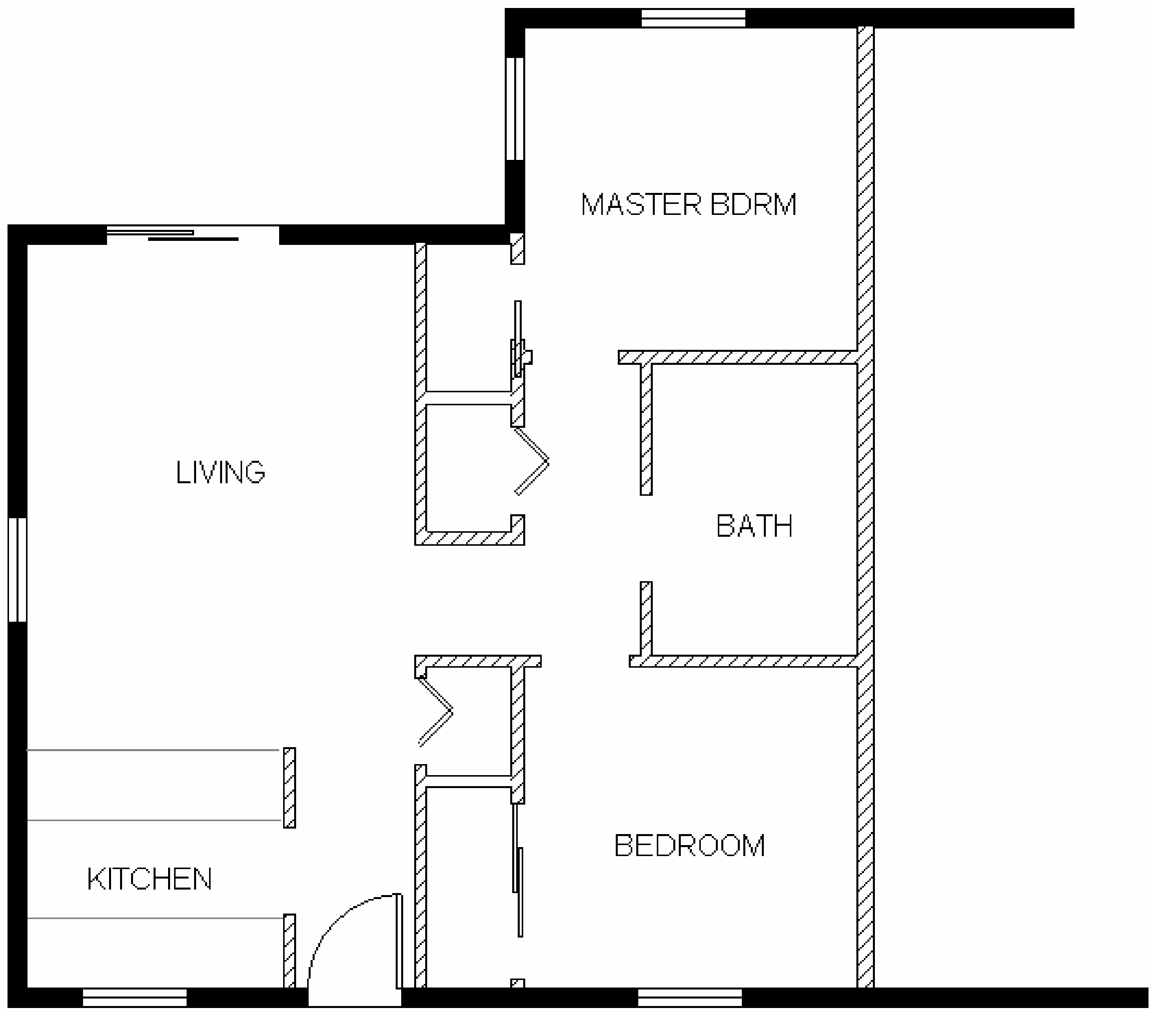
Walls:	Brick
Windows:	Double pane glass
Ceilings:	9′ high
Roof:	Flat built-up roof

House 16: Corner Top-Floor Apartment with Sided Walls



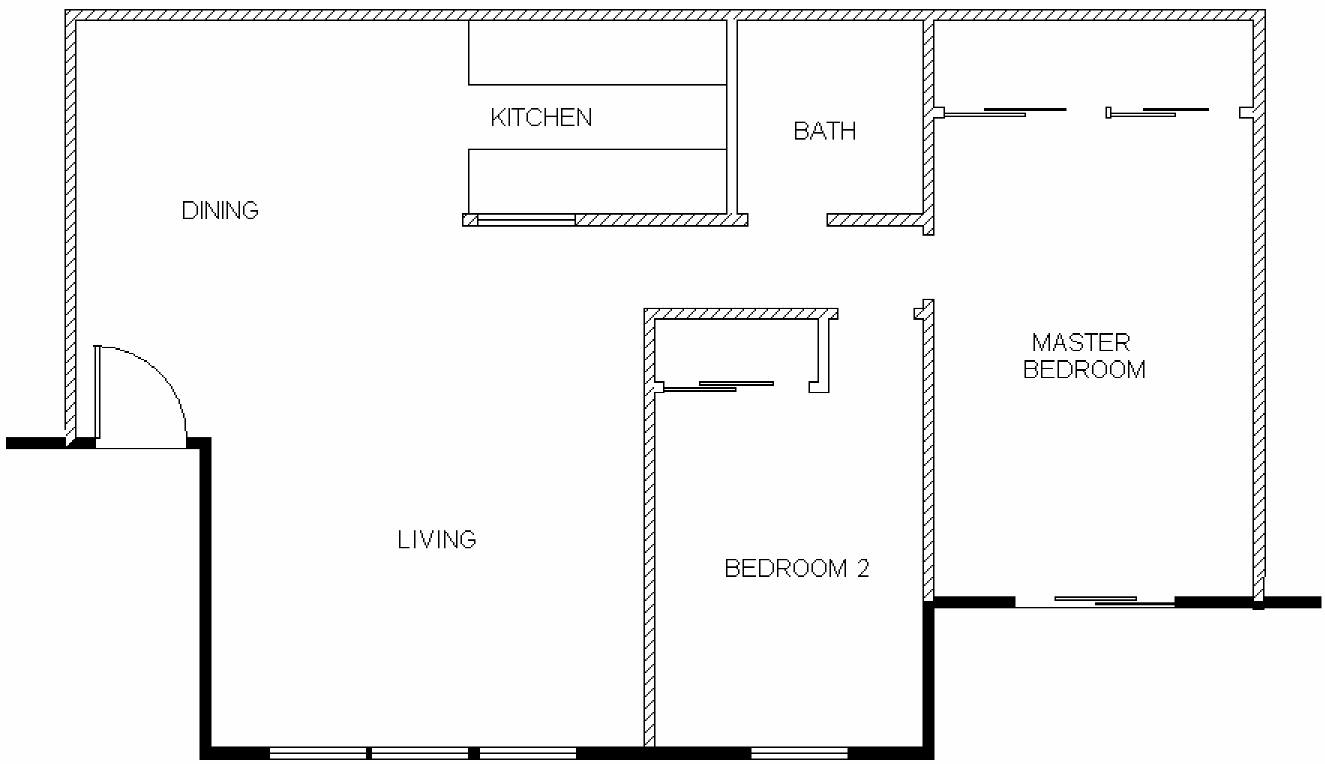
Walls:	Siding on 2x4 wood studs
Windows:	Double pane glass
Ceilings:	8′ high
Roof:	Flat built-up roof

House 17: End Apartment with Sided Walls



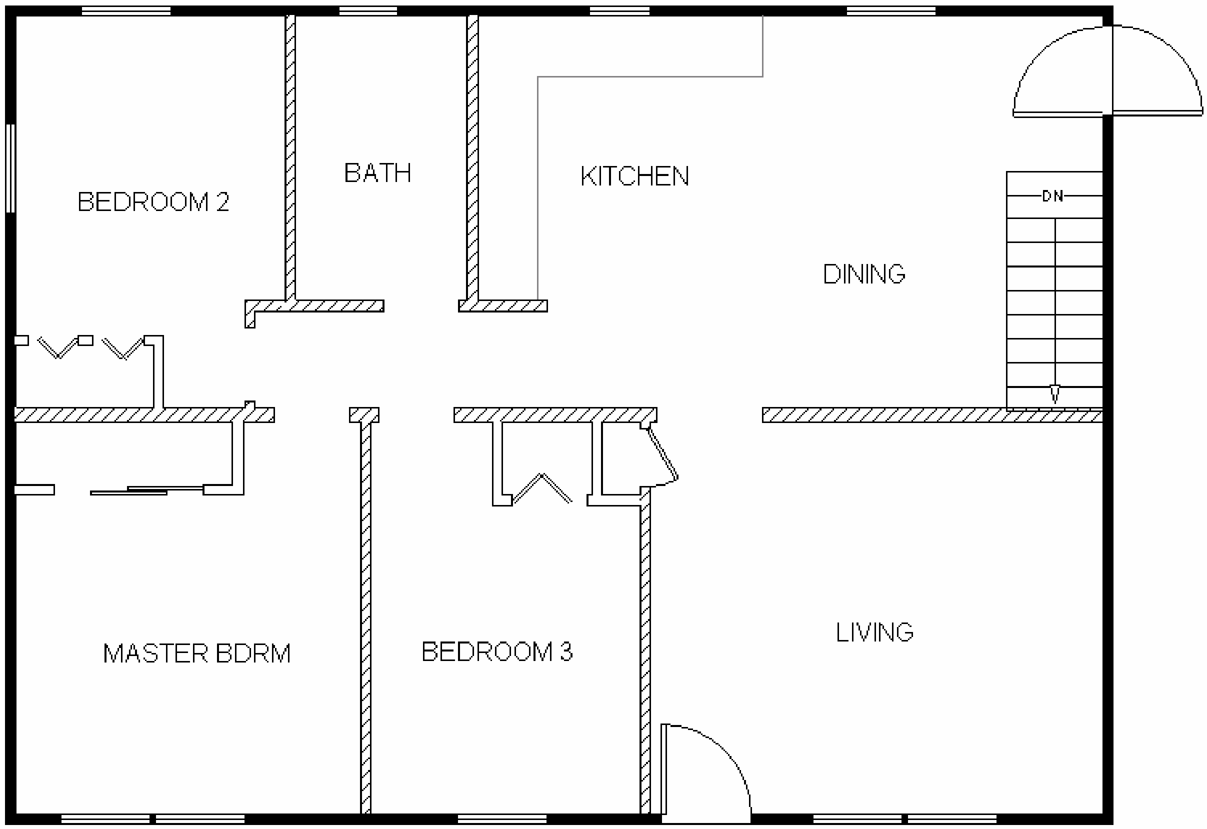
Walls:	Siding on 2x4 wood studs
Windows:	Double pane glass
Ceilings:	8′ high
Roof:	Additional apartment above

House 18: Top Floor Apartment with Sided Walls



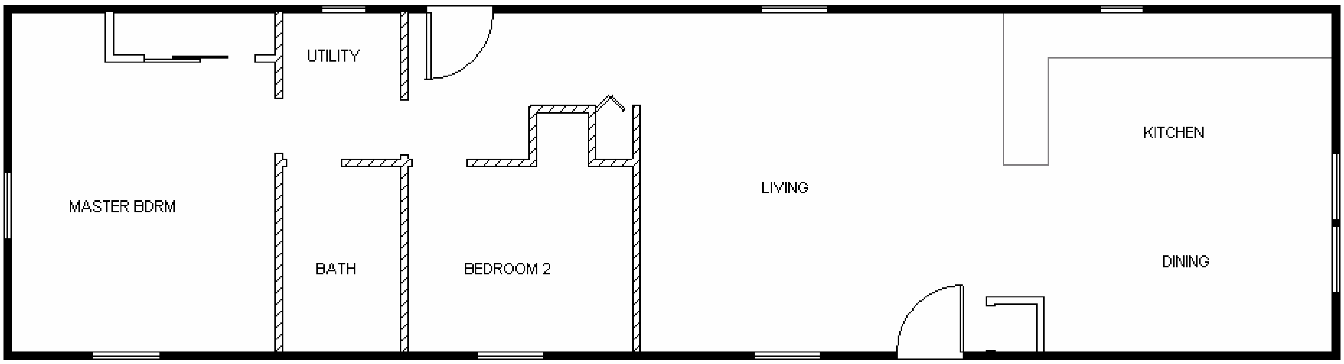
Walls:	Siding on 2x4 wood studs
Windows:	Double pane glass
Ceilings:	9′ high
Roof:	Vented attic with sloped roof

House 19: One-Story Modular Home with Sided Walls



Walls:	Siding on 2x4 wood studs
Windows:	Double pane glass
Ceilings:	8′ high
Roof:	Vented attic with sloped roof (Vaulted ceiling in bedrooms)

House 20: Small Manufactured Home with Sided Walls



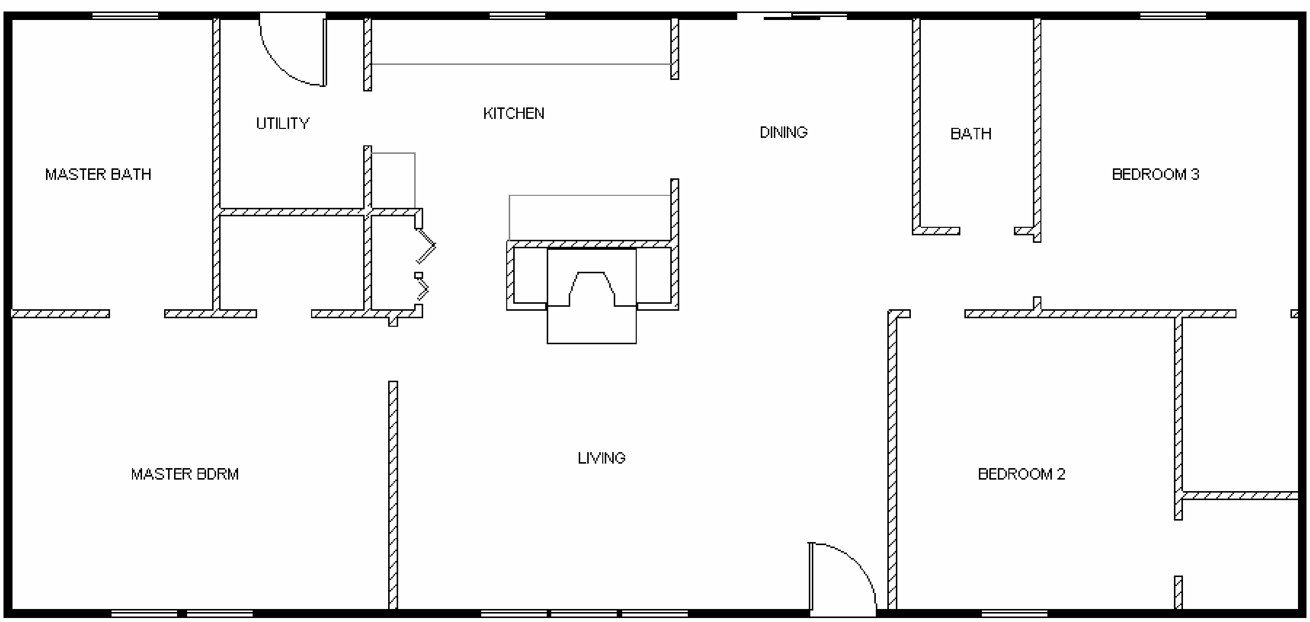
Walls: Siding on 2x6 wood studs

Windows: Single pane glass with removable storm windows

Ceilings: 8′ high

Roof: Vaulted ceiling

House 21: Large Manufactured Home with Sided Walls



Walls: Siding on 2x4 wood studs

Windows: Single pane glass with removable storm windows

Ceilings: 8′ high

Roof: Vaulted ceiling

Appendix B

Basic Concepts

Appendix B:

Basic Concepts

Descriptors Used in Noise Control

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 document.

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" or "dB(A)" are often used to highlight the fact that the sound level measurement has been A-weighted (this weighting system is described below).

In most cases, the noise exposure in areas around airbases and airports is expressed in terms of the Day-Night Average Sound Level, which is abbreviated by "DNL" in text and "Ldn" 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 flight operations being counted more heavily as described below. The unit of DNL is also the decibel. In California, noise exposure around airbases and airports is expressed in terms of the Community Noise Equivalent Level (CNEL). CNEL is identical to DNL except that, in addition to the penalty added to nighttime flight operations, there is a penalty added to evening operations – those occurring between 7 PM and 10 PM.

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.

A-Weighted Sound Level

The two most obvious characteristics of sound are the level and frequency. Sound Level is essentially a measure of loudness and refers to how much energy or power a sound has when we hear it. Frequency is essentially a measure of pitch. A deep-voiced baritone singer has a lower frequency (or pitch) than a soprano voice, though they may be equally loud. Hertz (abbreviated Hz) is the unit used to indicate frequency and is equal to the number of sound waves (cycles) per second. For reference, middle C on a piano has a frequency of exactly 256 Hz. The normal human ear can detect sound frequencies ranging from about 20 Hz to about 15,000 Hz. People do not hear all sounds over this wide range of frequencies equally well, however. The human ear is most sensitive to sounds in the 1,000 to 6,000 Hz range.

In order to reflect the differences in hearing sensitivity to different frequencies, sounds are usually described in terms of A-weighted sound levels. When a sound is A-weighted, sound levels measured in the 1,000 to 6,000 Hz frequency range are *increased* by a specified amount to account for the fact that the ear perceives them as louder compared to other frequencies. Similarly, sound levels measured at frequencies outside this range are *decreased* because the ear is less sensitive in those regions.

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 air installations where the average noise level can be expected to fall within the ranges specified by the contour lines. The Department of Defense (DoD) suggests that in areas with a noise exposure of DNL 65 dB and higher residential use is discouraged. Most noise contour maps show contour levels of DNL/CNEL 65 dB and above in 5 dB increments.

The acoustic metric used for noise contours is typically either the Day-Night Average Sound Level (DNL or Ldn) or Community Noise Equivalent Level (CNEL). Both DNL and CNEL are cumulative measures 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. In addition, for CNEL (but not DNL) there is a 5 dB penalty added to evening events occurring between 7 pm and 10 pm. Both DNL and CNEL result from averaging the A-weighted sound pressure level over 24 hours for aircraft activities taking place on an average day. For air installation noise contours, the average day is determined by analyzing flight activity over the period of one full year. This gives an indication of the year-round average noise exposure for the community. Some installations use noise contours that have been generated for an average "busy" day rather than an annual average day. This reflects the noise exposure when base activity is high, rather than averaging all days together throughout the year.

Since the DNL is a function of both the aircraft noise level and the number of aircraft operations, there is no simple relationship between the DNL and the maximum noise level. For a given DNL, the maximum noise level is higher when there are fewer aircraft operations. Consider two houses exposed to a DNL of 70 dB: one near a busy, large airfield, and one near a smaller, less busy airfield. The maximum noise level will generally be higher at the smaller airfield since the DNL is determined based on only a few aircraft overflights.

Sound insulation metrics

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 (octave bands) and give an indication of how a building product or assembly responds differently to sounds at different frequencies.

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

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.

Outdoor to Indoor Transmission Class (OITC)

OITC is a single-number rating of the ability of a facade or facade element to sound insulate against transportation noise.[3] It is similar to the more commonly-used Sound Transmission Class (STC) rating; the general difference is that OITC was developed to assess the annoyance of transportation noise while STC was developed to assess the interference with speech. Specifically, OITC differs from STC in two main respects: (1) it includes lower frequencies common in transportation noise but absent in speech, and (2) it is calculated by summing sound contributions at all frequencies, while STC is calculated (in part) based on noise at individual frequencies. Therefore, if a home is exposed to strong low-frequency noise, as would be the case when aircraft primarily depart away from a house located near the end of a runway, the OITC rating would be a more appropriate measure than STC of the sound insulating ability of a product or assembly.

Effective Wall Rating (EWR)

EWR is a single-number rating calculated in a similar manner to STC. The primary difference between EWR and STC is that EWR is determined more by the low-frequency performance of the system and was developed specifically to rate the ability of a system to block the transmission of transportation noise indoors. Since EWR is not in common use today it was not used to express recommendations in this report.

Noise insulation from aircraft operations

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 evoke the most complaints. However, after a home has been sound insulated, residents

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[2] STC is described in ASTM Standard E413.

[3] The OITC rating is determined based on sound transmission loss data using ASTM E 1332 "Standard Classification for Determination of Outdoor-Indoor Transmission Class."

notice improvements in their ability to carry out these normal activities as well as to fall asleep and to 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 airports 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.

Aircraft Noise Characteristics

Noise intrusion from aircraft activities is perceived as more disturbing than other kinds of noise because of two primary characteristics. First, 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 second quality of aircraft noise that makes it more intrusive than other types of community noise is its higher level at homes very near the air installation. Of course, 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).

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 250 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 against which sound insulation protects residents. Most materials and construction methods are more effective at insulating in one part of the frequency spectrum than other parts, and materials vary from one another in this regard. Knowing the noise characteristics helps in choosing the best materials for sound insulation. These *Guidelines* have been designed specifically to protect against military jet aircraft noise rather than highway noise or some other problem.

Most of the sound energy from military jet aircraft operations is found at lower and middle frequencies. While much of this energy is below the most sensitive region of people's hearing range, it can be heard well enough to be annoying and it can cause disturbing structural vibration in a dwelling. The next section discusses the process by which sound is transmitted into a dwelling interior.

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, penetrating the building perimeter. This happens in one of two basic ways: through the solid structural elements and directly through the air. Figure B-1 illustrates the sound transmission through a wall constructed with brick exterior, wood studs, an interior finish, and absorbent material in the stud cavities.

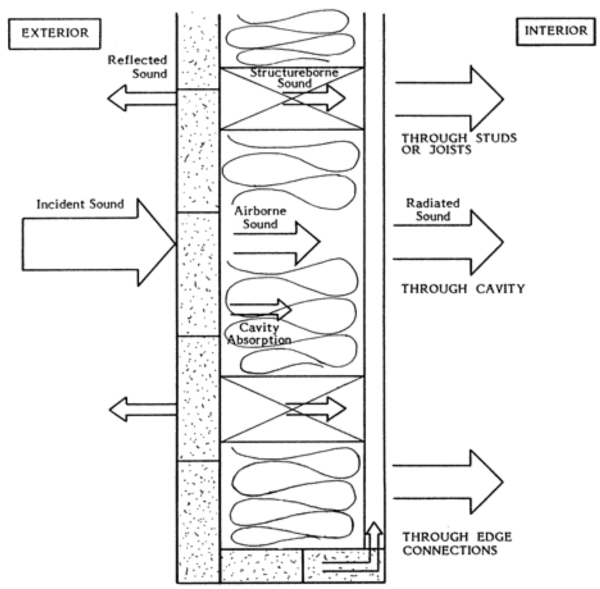

Figure B-1. Pictorial Representation of Sound Transmission Through Built Construction

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, joist and crawlspaces.

Figure B-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.

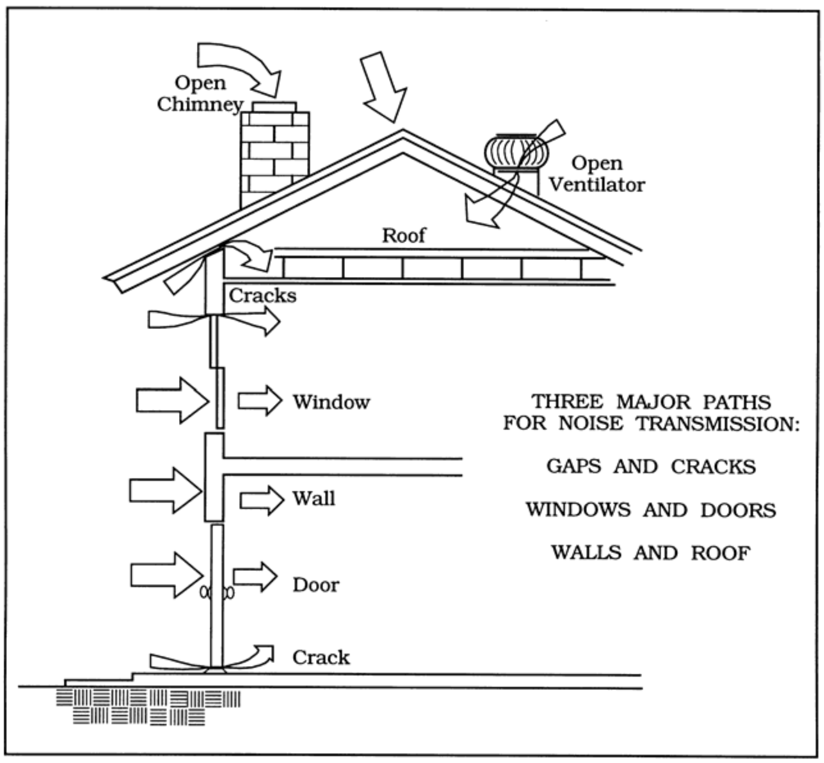

Figure B-2. Sound Transmission Paths Into Dwelling Interiors

Low-frequency sound is most efficiently transmitted through lightweight 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 overall 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. In summary, 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 sound insulated perimeter. The concept of designing sound insulation treatments so that all parts of the exterior perform equally well – avoiding "weak links" – is called *balanced design*.

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. The mass law mentioned above suggests that a brick wall would protect better against sound than siding and this is true when these materials alone are compared. However, 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 wall will give much better noise level reduction than building a weak window into a brick wall.

The STC rating, defined in Appendix G, is a measure of a material's ability to insulate against sound; the higher the STC rating, the better the insulator.

In most cases, when all 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 also require high STC ratings. Depending on the noise level reduction goal, other elements may become important. Ceilings and exterior walls may require special construction, particularly in the higher DNL/CNEL noise zones. Treatments for these paths and others are discussed in Appendix C – Sound Insulation Methods.

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 significantly less sound insulation than acoustical windows or walls, and are frequently the weak link in the building perimeter. However, thermal treatments usually eliminate air infiltration and may serve to improve the acoustical performance of a dwelling for that reason. The presence of thermal 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.

In general, a new dwelling should be oriented on the lot so that bedrooms and TV-viewing rooms face away from the flight track. This will reduce the need to add extra sound insulation components to protect these noise-sensitive living areas.

Appendix C

Sound Insulation Methods

Appendix C:
Sound Insulation Methods

This section provides specific guidelines for modifying standard construction designs and practices to meet the need for aircraft sound insulation. A general discussion of construction materials and methods is given below. Individual sections address techniques for use with weatherstripping, windows, doors, walls and ceilings, attics, floors, HVAC systems, and other miscellaneous elements.

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 aircraft noise. This guide has taken the ability of typical products to block military jet aircraft noise into account. The recommended materials listed in Sections 3 and 4 (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 brick 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 roof deck, 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.

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 points, 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 doorframe. Also, felt and fibrous weatherstripping materials tend to deteriorate more quickly than neoprene and must be replaced more often.

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 Sections 3 and 4.

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 often provide ratings from 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, and the weatherstripping and seals are more substantial. Most importantly, they have additional lites. The two most common types of acoustical windows are a double pane window with a storm unit attached ("combination window"), or an assembly of two single or double pane windows connected together ("dual window"). All of these measures are necessary to provide the high degree of sound insulation required for the window assembly. Figure C-1 shows a typical combination window installation with the most important features noted. Figure C-2 shows schematically the features of a dual window. Combination or dual 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. A list of acoustically-tested window manufacturers is included in Appendix E. They are considerably more expensive than typical residential windows.

For renovation the acoustical performance of a new window required to meet the noise reduction reguirements of section 2 is related to the performance of the existing windows. That is, if the existing windows are better than average it would be more difficult to reduce noise levels noticeably (by 5 dB). Conversely, if the existing windows are worse than average it would be easier to achieve a 5 dB reduction in noise level. The condition of the existing windows was not considered when developing the recommendations in section 3 due to the wide variations in existing conditions and the difficulty in evaluating the acoustical performance of existing windows. Therefore, if you believe your existing windows would have a better-than-average acoustical performance, it would be necessary to use an STC rating higher than is indicated in Table 3-2.

Also, not all new windows of the same construction provide the same acoustical performance. Fixed windows tend to out-perform sliding and hung windows, while casement and awning windows tend to perform more poorly. Also, for some window designs smaller windows perform better due to the relatively smaller proportion of glass, while for other window designs larger windows perform better due to the relatively smaller proportion of frame.

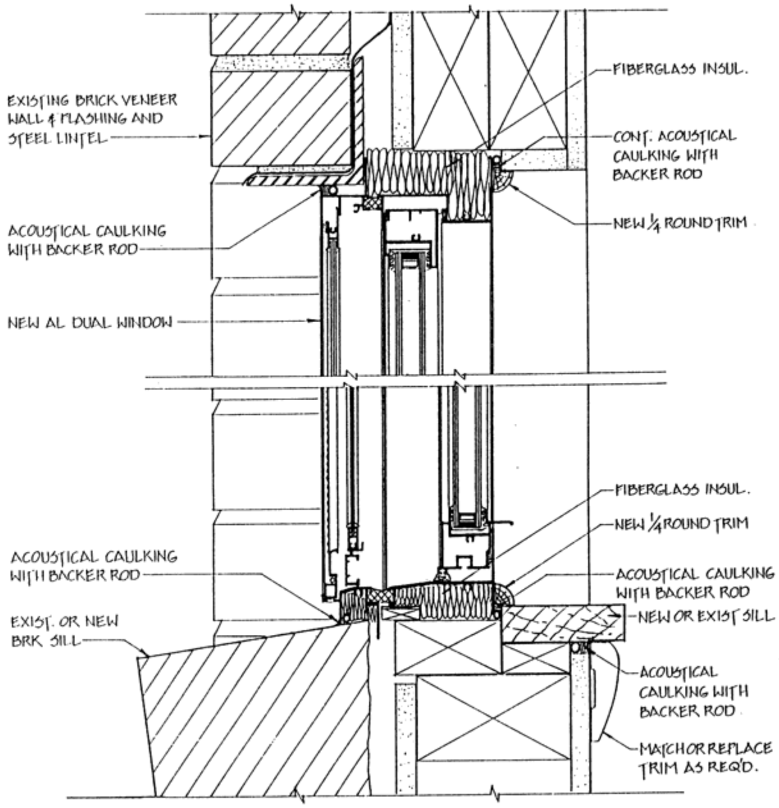

Figure C-1. Typical Combination Window Detail

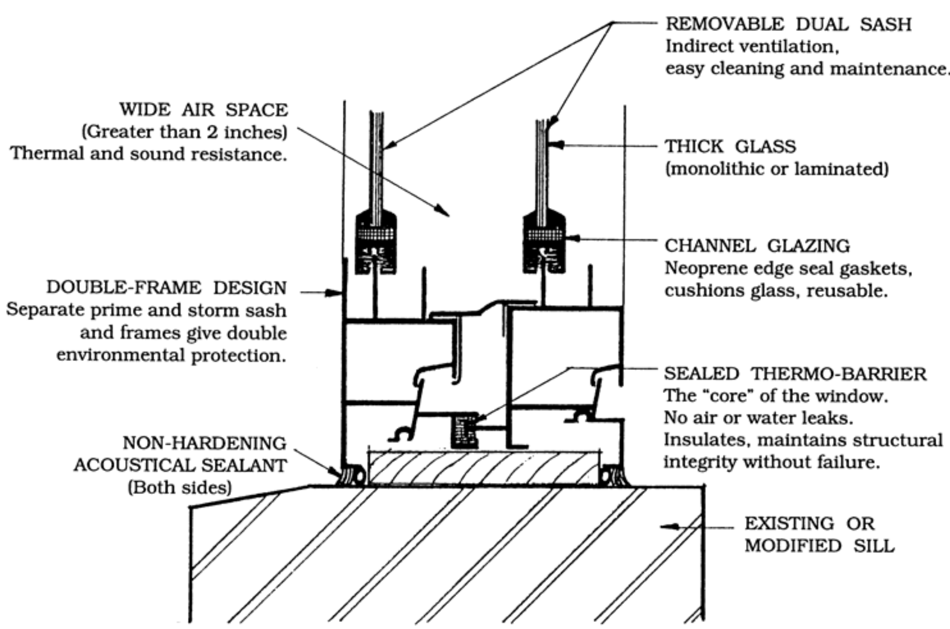

Figure C-2. Typical Dual Window Detail

Typical Combination Window

Thermal Performance

Insulated glass windows 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 significantly less air infiltration and have a higher R-value (a measure of thermal resistance) than most off-the-shelf single pane and double pane windows.

Installation Considerations

For the windows to provide the required noise reduction they must remain tightly closed. Ways to maintain ventilation will be discussed below in the section titled, "Mechanical Systems and Building Penetrations." It is important to note, however, that this requirement precludes the use of jalousie (louvered) windows in a sound insulation design. Any type (such as double-hung, single-hung, horizontal sliding, casement, fixed, awning/hopper, etc.) of window is acceptable for noise reduction, provided it has the required STC rating.

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.

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: hollow core wood, solid core wood, 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, and
- Quality of seals and weatherstripping and how tightly they seal.

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

1. Installation of a new swinging door with gaskets,
2. Installation of a tightly fitting storm door with thick (or laminated) glass,
3. Use of a specialty acoustical swinging door,
4. Use of a specialty acoustical swinging storm door,
5. Use of thicker glass in sliding glass doors, and
6. Specialty acoustical sliding glass doors.

Standard Doors

Standard entrance doors can be expected to have ratings of STC 21 to 27. STC requirements are outlined in Sections 3 and 4 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 common in many parts of the country and can improve the STC rating by 5 to 19 points. In order for storm doors to be effective for sound insulation, they should incorporate thick glass (ideally 1/4-inch-thick laminated glass) and have a heavy core. Storm doors must be mounted year-round. 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 E.

Typical STC 29 Door

Acoustical Swinging Doors

Acoustical doors, with a typical rating of STC 29 to 43, are similar in appearance to standard entrance doors. Because of their specialized construction and superior sealing design they provide a very noticeable improvement in noise reduction. While metal doors are available, wood doors often have higher STC ratings and are preferred by many homeowners. 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 lbs 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. Due to the high cost of acoustical doors, it is often preferable instead to use more typical residential doors with acoustical storm 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 are that the user must 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 hinged patio 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 sliding glass door generally requires building a second frame positioned to mount the door approximately 2 to 3 inches away from the primary door. This dual-door assembly has proven successful in that it raises the STC rating by 5 to 7 points or more. Figure C-3 shows a system of two sliding glass doors with the secondary door mounted outside of the typical door position.

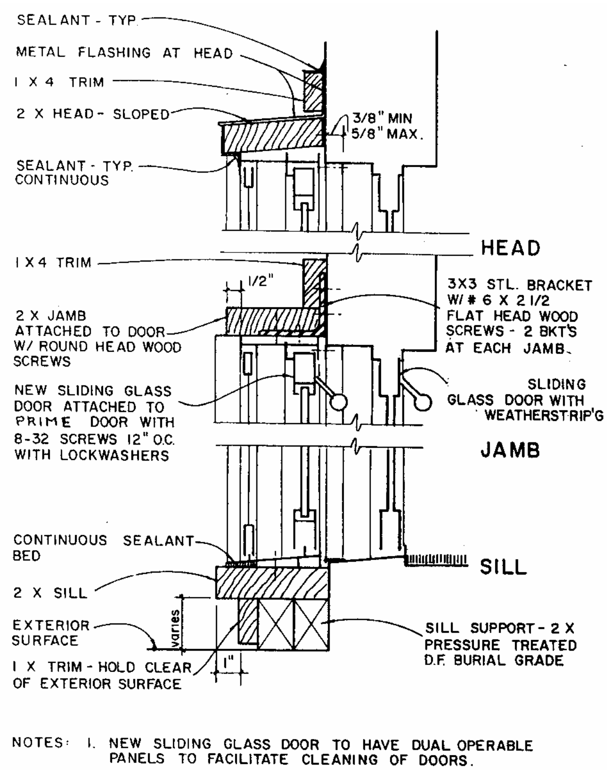

Figure C-3. Secondary Sliding Glass Door Detail

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 acoustical performance of the door. Sound attenuation through standard doors can be improved by fitting them with special acoustical seals, such as 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.

Walls and Ceilings

Determining Wall and Ceiling 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, aluminum, asbestos, cement board, asphalt, or wood siding, shakes or shingles on wood or steel studs require improvements such as additional layers of gypsumboard, staggered studs, or resilient channels in the highest noise impact zones. Dwellings which use brick, concrete block, insulated concrete forms (ICF), concrete, and other masonry materials typically do not; in very high noise zones the performance of these systems can be improved by using 6” to 8” thick masonry or concrete.

For the purposes of this design guide, the following materials can be grouped:

1) Brick, Concrete Block, or ICF Construction: At least 4-inch-thick mansonry or concrete and 1/2" gypsumboard at the interior. The entire exterior wall is constructed of masonry or concrete, not just a portion.
2) Stucco on Wood Frame Construction: Stucco or EIFS over sheathing on wood or metal studs, and 1/2" gypsumboard at the interior. Entire exterior wall is stucco or EIFS, not partial siding or other material.
3) Siding on Wood Frame Construction: All types of siding, shakes, and shingles on sheathing on wood or metal studs, and 1/2" gypsum board at interior.

Thin stone (up to 1-1/2”) can be grouped with stucco construction while thick stone (2” or greater) can be grouped with brick construction.

Many buildings combine siding with other exterior construction materials such as brick veneer, stone, or stucco. For the purposes of this Guide, the siding and siding-combination constructions are taken to have approximately the same sound insulation performance. Because noise penetrates through the weakest available element, unless the siding area is very limited, noise will penetrate through that part of the building envelope. Generally, if a particular wall is shielded from the flight track or is protected by a heavily roofed porch, the need for supplementary wall treatments is reduced.

Improved ceilings are sometimes necessary where there is an attic over habitable or noise-sensitive rooms such as bedrooms, 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.

In some regions of the country it is appropriate to use a vapor barrier either on the interior or exterior surface of walls or ceilings. However, it is never appropriate to use two vapor barriers in the same wall or ceiling, since this can trap moisture and cause rot and mold. When there is no existing vapor barrier it may be appropriate to add one during renovation. In some northern climates it is appropriate to use vapor barriers at the interior side of walls and ceilings. In such cases, impermeable paint could be used as a vapor barrier.

Specific Wall Designs

Brick, concrete block, and ICF walls generally need no modifications. Sided wood-framed walls and some stucco wood-framed walls require improvements in high noise zones.

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 typical sided wood frame construction. The resilient 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 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.

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 sided wood frame 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 C-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 typical sided wood frame construction. At windows and doors it is necessary to use 2 x 6 studs; therefore, the acoustical benefit of staggered studs is dramatically reduced when there are many windows and doors. A larger space between the interior and exterior panels will yield a greater STC improvement.

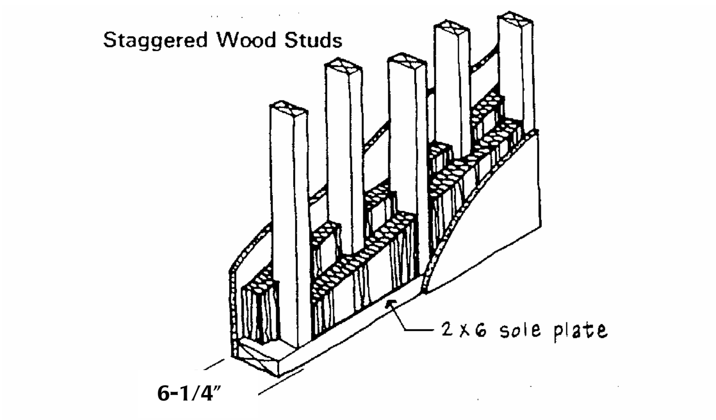

Figure C-4. Staggered Wood Stud Construction

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

Table C-1. Acoustical Wall Designs and STC Ratings

	Exterior Side	Studs	Interior Side	STC Rating
Resilient Channel on 2x4 studs	Vinyl Siding, 7/16" OSB sheathing	2x4 16″ O.C. with batt insulation	RC on studs, 1 layer ½″ gypsumboard	43
Resilient Channel on 2x6 studs	Vinyl Siding, 7/16" OSB sheathing	2x6 16″ O.C. with batt insulation	RC on studs, 1 layer ½″ gypsumboard	47
Staggered 2x4 on 2x6 base	Vinyl Siding, 7/16" OSB 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

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. Although blown-in insulation should be used for existing walls, it is not recommended in new walls for acoustical purposes because of the tendency to compact over time.

Installation of Blown-in Insulation

Although stucco wood-framed walls perform better than sided wood-framed walls they often need modifications in high noise zones. The modifications discussed above would also work for stucco walls. An additional modification for stucco walls is to use ½" thick cement stucco in lieu of 1/8" thick finish.

The wall assemblies discussed so far use materials in common use today. There are advanced materials available that are not widely used. One such material is a constrained layer visco-elastic polymer panel. This is essentially a gypsum board panel with layers of steel or vinyl and adhesive inside. The steel or vinyl add mass to the assembly while the adhesive adds damping; massive, damped panels have better sound insulation performance than regular gypsum board panels. Two examples of this product are the QuietRock™ QR-530 "Serenity" panel by Quiet Solution, Inc., and the Hush Rock HR-300 panel by BRD Noise and Vibration Control Inc.

Another new product is the resilient sound isolation clip (RSIC) by PAC International and the ISOMax resilient sound isolation wall and ceiling clip by Kinetics Noise Control. These are similar to a traditional "resilient channel" in concept, but with better sound insulation performance. With these systems a clip is screwed into the wood studs, a thick steel channel is snapped onto or slid into the clips, and gypsum board is screwed into the channels. Sound insulation is provided by the rubber isolator that is part of the clips. Note that the wall thickness is 1-1/8" greater with the PAC International assembly than with traditional resilient channels, and 7/16" greater with the Kinetics System.

Specific 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. A typical roof construction is asphalt shingles, 7/16" OSB sheathing, 14" trusses at 16" O.C., batt insulation, and 1/2" gypsumboard at the interior. This design has an STC 45 rating. Resilient channels mounted perpendicular to the ceiling joists, on the bottom of the joists, with one layer of ½" gypsumboard attached to the channels, will increase the rating to approximately STC 55.

Attic access panels, pull-down stairs, and whole-house ceiling fans should have movable or operable covers consisting of ¾" plywood, or another equally massive material, with continuous neoprene perimeter seals.

Attics and Roofs

Options Overview

Home designs incorporating unoccupied attic space over all living areas are recommended for dwellings exposed to aircraft noise. Skylights can be used if 1/4-inch-thick glazing or insulated thermopane glass is used at the bottom of the skylight well to supplement whatever glazing is used at the top of the well. In addition to these basic rules, it may be necessary to used improved roof, attic, or ceiling designs. Improvements could include baffles in the attic vents, extra insulation to absorb sound reverberating in the attic space, and an upgraded roof deck.

The use of cathedral ceilings is strongly discouraged for homes exposed to aircraft noise, particularly where the necessary NLR is 30 dB or higher. Rather than a true open-beam or cathedral ceiling, a mock-cathedral or vaulted ceiling with a small attic space above is recommended. Open-beam ceilings should never be used when the necessary NLR is 20 dB or higher.

Sound Transmission Paths

Sound enters through the roof in two paths: directly through vents and other leaks; and by vibrating the roof itself, thereby radiating acoustical energy into the air within the attic. If there is no attic the sound passes immediately into the living space under the roof. This is why homes with open-beam or cathedral ceilings often have very limited noise level reduction through the roof. Where there is an attic, the sound enters and reflects off of the attic surfaces, reverberating in the space. Since much of the sound energy has been dissipated, less sound passes through the finished ceiling to the room below.

Attic Vents

Attics typically have open-air vents at the ends (for a gabled roof), in the roof deck, or a combination of ridge and soffit vents. The sound entering through these vents may be significant. Off-the-shelf acoustical louvers can be applied to baffle the sound passing through gable end vents. Most off-the-shelf noise control baffles are rectangular and this requires the use of rectangular vents in the dwelling design. Soffit vents under the eaves can be left unmodified when other measures are implemented, since they are somewhat shielded from direct exposure to the aircraft noise.

Any type of attic vent that opens directly through the roof toward the aircraft flight tracks is discouraged. This includes gravity vents, vents in the roof deck, and some active or positive ventilation systems. If these vents are used, built-in-place baffles can be used under them to reduce noise intrusion. Built-in-place baffles consist of pieces of 3/4″ thick plywood covered with 2″ 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. These baffles could also be used for ridge vents. In general, acoustical louvers are preferred over built-in-place baffles due to the possibility that the built-in-place baffles may reduce ventilation through the attic. Figure C-5 shows a typical built-in-place gable vent baffle design.

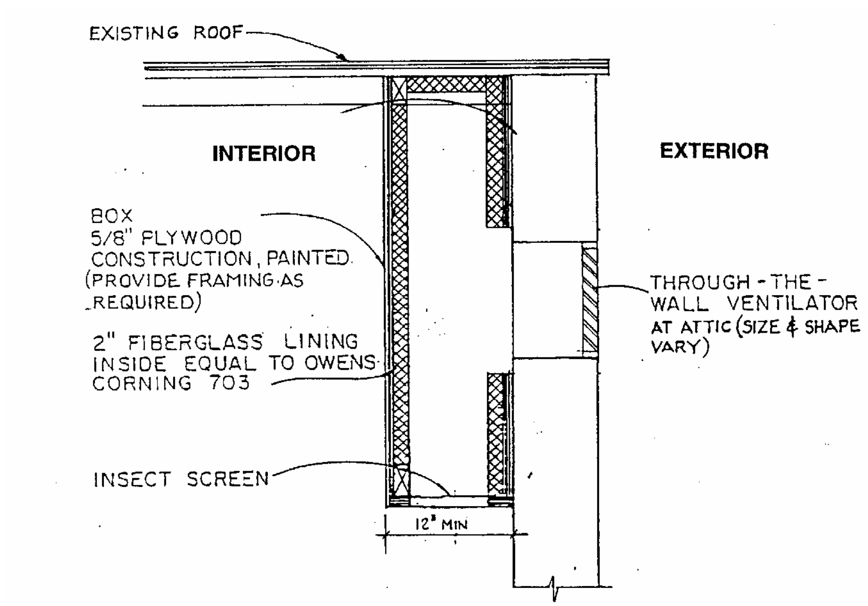

Figure C-5. Built-in-place Gable Baffle

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, between the ceiling joists, or in conjunction with a plywood or gypsumboard barrier. To prevent fires knob-and-tube wiring in attics should be replaced with modern insulated wiring before adding thermal or sound-absorbing insulation in the attic.

The absorption of a material should not be confused with noise level reduction (NLR). There is no direct relationship between a material's 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 C-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 C-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

Floors, Basements, and Crawl Spaces

Options Overview

Dwellings will usually have one of these four types of floor systems:

1. Concrete slab
2. Crawlspace
3. Basement
4. Pylons (beach houses)

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

Concrete slabs require no treatment. Crawl spaces, basements, and pylons will be discussed below.

Crawl Spaces

One common floor system consists of wood joist construction over a vented crawl space. Using insulation batts between joists is also very effective acoustically. 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; 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.

Basements

Basements can be modified with a combination of methods discussed in other sections of this guide. Windows should have 1/4-inch-thick laminated glass or insulated glass units. Storm windows and doors can be added for further protection. Large vents or openings should be baffled if the exposed wall faces the flight track. Dryer vents and other vents should be constructed of sheet metal (rather than plastic or flexible ducts) to limit the amount of noise that will enter through them and then pass through the duct wall to the surrounding room. Thermal insulation can be installed between the joists to absorb sound reverberating in the basement.

Garages

Fire codes may prohibit the use of exposed insulating material above garages. If part of the basement consists of a garage with a garage-door facing the flight path, a fire-rated gypsumboard ceiling may be used. Also, a gypsumboard or plywood barrier or a finished ceiling can be hung under the first-floor with R-11 insulation between the joists, similar to the treatment discussed for attics.

Pylons

Elevated beach houses allow noise to enter through the floor. The depth of the floor trusses should be maximized, a thick layer of insulation must be provided between the trusses, the subfloor should consist of ¾″ thick OSB or plywood, and at last ½″ (nominal) thick OSB or plywood should be used at the bottom of the trusses.

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 often do not directly affect the sound insulation performance, but they enable residents to keep the windows and doors shut year-round and benefit from the sound insulation modifications. Some of the following information is not referenced in Sections 3 and 4 but the ventilation features discussed here are strongly recommended.

Wall or Ceiling Units

Any mechanical unit that penetrates exterior walls or the ceiling allows aircraft noise to enter the house. This includes in-window or through-wall air conditioners, through-wall or ducted range fans, whole-house ceiling fans, and evaporative coolers ("swamp coolers"). In most sound-insulated homes these units must be removed and their function restored elsewhere by using new ducted central air-conditioning systems or recirculating range fans. Evaporative coolers are also not appropriate due to concerns about the build-up of moisture in tight sound-insulated houses. If the units must remain, operable covers can be installed consisting of ¾" plywood and continuous perimeter neoprene bulb seals. Central (ceiling-mounted) evaporative coolers can be retrofitted with 2" internally sound-lined five-foot long sheet metal ducts in the attic.

Gravity Heating Systems

Gravity heating systems are combustion-driven appliances located in a crawl space used to heat a home by allowing the warm air to enter the house through a hole in the floor. Theses systems should be removed from existing sound insulated homes and not used in new homes. Instead use a forced air or hot water-based heating system that does not require a hole in the building envelope.

Fresh Air and Air Circulation

New homes and many existing homes in much of the country 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, the system in a sound-insulated house should, at a minimum, 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. Also, in cold climates we recommend using re-heat coils, heat recovery ventilation (HRV) or energy recovery ventilators (ERV) to minimize heat loss in winter. ERVs are similar to HRVs, except they exchange moisture as well as heat. An HRV or ERV system has four ducts: (1) a fresh air intake duct connecting the outdoors to a fan unit, (2) a fresh air supply duct connecting the fan unit to habitable areas of the home (typically connected to a central forced air duct system), (3) an exhaust air return duct connecting bathrooms and/or kitchens to the fan unit, and (4) an exhaust discharge duct connecting the fan unit to the outdoors.

The licensed professional designing the mechanical system must ensure that the building code requirements for fresh airflow volume are met. Guidance in ASHRAE 62.2-2003 is useful to determine the appropriate amount of fresh air. Care must be exercised to ensure that condensation does not form on ducts in exterior walls, attics, crawl spaces, and other poorly insulated areas. Condensation can lead to water damage, rot, and mold.

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.

Combustion Air Intake and Exhaust

Fuel-burning appliances such as gas furnaces, oil boilers, 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 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.

There is a separate concern that the appliance's exhaust duct, as well as the combustion air enforcer, will allow aircraft noise to enter the house. This is only a concern if the appliance is in a habitable room, which they rarely are. The solution in low noise zones is to use a double-wall rigid metal duct. In high noise zones the solution is to enclose the unit in a closet or enclose the duct in a chase.

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. Taking the steps outlined below will help to minimize the noise from fans, airflow, equipment vibration, and aircraft noise sources:

1. Provide vibration isolation mounting for all equipment and locate it so that the structure-borne sound and vibration are kept to a minimum.
2. Use ducting materials appropriate to the location to minimize the sound transmitted through the system. Flexible ductwork should not be used in attics and crawl spaces; heavier sheet metal ducts will provide better sound insulation.

3. Ducts to the outside, whether intake or exhaust, and all 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 C-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.
4. 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.

Kitchen and Bath Fans

Most kitchen and bathroom designs for new homes already incorporate fans for ventilation purposes. 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. Ideally, the vents will be on the side of the roof facing away from the flight path.

Dryers

Dryers exhaust ducts can also be paths for noise to enter a home. Dryers must not be located in habitable spaces. If electric dryers are located near bedrooms or other habitable spaces they may be located in enclosed closets with solid (non-louvered) doors. Always use rigid metal dryer ducts instead of flexible ducts to minimize aircraft noise entering the house.

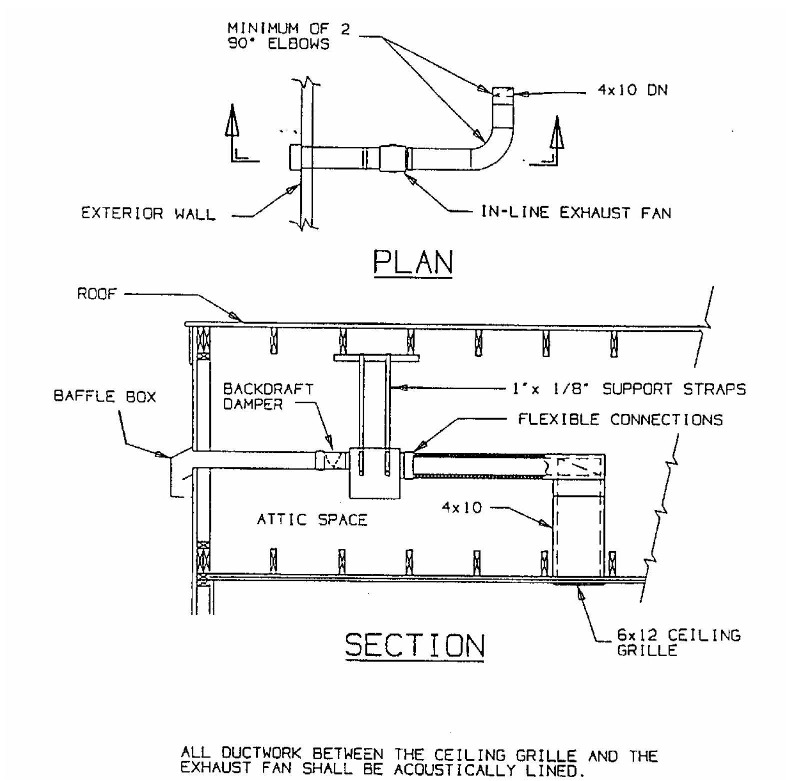

Figure C-6. Controlling Noise Entering Through Ducts in Attic Space

Fireplaces, Prefabricated Units, and Wood Stoves

Frequently, homes with fireplaces or gas-powered prefabricated units will require some type of design modification. This is especially true if the outside noise exposure is high, or the fireplace or prefabricated unit is in a room used for watching TV or sleeping. The treatment package consists of two parts. First, glass doors are mounted at the front of the fireplace or prefabricated unit. Second, the in-chimney damper must be installed so that all edges seal around the damper. Any air gaps or leaks will allow sound to pass through. The glass doors by themselves provide a noticeable improvement and these two treatments, in combination, have proven to be very effective at reducing the noise entering along this path. Chimney-top dampers have also been used successfully when tightly installed.

Wood stoves with indoor exhaust ducts present a greater sound leak than fireplaces. Using a double-wall rigid duct will help block noise, but in many cases it is necessary to remove the wood stove and patch the wall or ceiling finish in order to meet the acoustical design goal.

Appendix D

Model Building Code

Noise Level Reduction Design Requirements

Appendix D:
Model Building Code
Noise Level Reduction Design Requirements

SECTION 1: PURPOSE

Exterior noise may be isolated and reduced in homes through construction techniques that selectively increase the sound 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 specified NLR requirement.

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" for all sashes.

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 habitable spaces that are fully open to each other shall 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 12 feet tall it shall count as two exterior walls. Partial walls count as one exterior wall.

N. The phrase “wood-framed walls” refers to any walls that do not have brick veneer, concrete blocks, or poured concrete.

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) or masonry walls, where present, shall contain at least 4” thick normal weight concrete or masonry throughout the surface of the wall.

B. Windows

1. For rooms that have at least one wood-framed exterior wall: Windows 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 at top floor. Ceilings at top floor 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. Batt or blanket insulation shall be used at sloped ceilings.

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 constructed of 3/4″ thick plywood and shall have continuous neoprene perimeter bulb seals.

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. In flood zones use double-swing plywood flood gates in lieu of vents to the extent allowable by code.

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 be rigid metal and contain at least two 90° bends, or one 90° bend and a total length of at least 20 feet (or the maximum length allowed by the dryer manufacturer).

7. Vented domestic range fans shall be not used.

8. Vented wood stoves shall not be used. Where vented fireplaces or vented gas-powered prefabricated units are used provide acoustical chimney top dampers and use tight-fitting 1/4" tempered glass fireplace doors.

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

10. Whole-house fans shall not be provided.

11. All ducts in attics shall be rigid metal.

12. Dryers 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. 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) or masonry walls, where present, shall contain at least 4" thick normal weight concrete or masonry throughout the surface of the wall.

B. Windows

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

   a. If there is only 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 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 only 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 at least one wood-framed wall:

    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 at top floor. Ceilings at top floor shall be substantially airtight with a minimum number of penetrations. Where recessed lights are used in top-floor ceilings provide a gypsum board enclosure around the lighting fixture and seal the gypsum board joints with caulk or joint compound.

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. Batt or blanket insulation shall be used at sloped ceilings.

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 constructed of 3/4" thick plywood and shall have continuous neoprene perimeter bulb seals.

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. In flood zones use double-swing plywood flood gates in lieu of vents to the extent allowable by code.

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 be rigid metal and contain at least two 90° bends, or one 90° bend and a total length of at least 20 feet (or the maximum length allowed by the dryer manufacturer).

7. Vented domestic range fans shall be not used.

8. Vented wood stoves shall not be used. Where vented fireplaces or vented gas-powered prefabricated units are used provide acoustical chimney top dampers and use tight-fitting 1/4″ tempered glass fireplace doors.

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

10. Whole-house fans shall not be provided.

11. All ducts in attics shall be rigid metal.

12. Dryers 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) or masonry walls, where present, shall contain at least 4" thick normal weight concrete or masonry throughout the surface of the wall.

B. Windows

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

   a. If there is only 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 only 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 only 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 only 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 at top floor. Ceilings at top floor shall be substantially airtight with a minimum number of penetrations. Where recessed lights are used in top-floor ceilings provide a gypsum board enclosure around the lighting fixture and seal the gypsum board joints with caulk or joint compound.

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. Batt or blanket insulation shall be used at sloped ceilings.

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 constructed of 3/4″ thick plywood and shall have continuous neoprene perimeter bulb seals.

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. Use acoustical louvers for all vents. In flood zones use double-swing plywood flood gates in lieu of vents to the extent allowable by code.

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 be rigid metal and contain at least two 90° bends, or one 90° bend and a total length of at least 20 feet (or the maximum length allowed by the dryer manufacturer).

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 habitable spaces (e.g, kitchens, living rooms, bedrooms, etc.). Vent ducts for fuel-burning appliances in non-habitable spaces (e.g., closets and attics) shall have double-wall sheet metal construction.

10. Whole-house fans shall not be provided.

11. All ducts in attics shall be rigid metal.

12. Dryers 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) or masonry walls, where present, shall contain at least 4" thick normal weight concrete or masonry throughout the surface of the wall.

B. Windows

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

   a. If there is only 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 only 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 only 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 only 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 at top floor. Single-leaf resilient channels shall be used to hang the gypsum board at top floor. Ceilings at top floor shall be substantially airtight with a minimum number of penetrations. Recessed lights shall not be used in top-floor ceilings.

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. Batt or blanket insulation shall be used at sloped ceilings.

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 constructed of 3/4″ thick plywood and shall have continuous neoprene perimeter bulb seals.

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. Use acoustical louvers for all vents. In flood zones use double-swing plywood flood gates in lieu of vents to the extent allowable by code.

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 be rigid metal and contain at least two 90° bends, or one 90° bend and a total length of at least 20 feet (or the maximum length allowed by the dryer manufacturer).

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 habitable spaces (e.g, kitchens, living rooms, bedrooms, etc.). Vent ducts for fuel-burning driven appliances in non-habitable spaces (e.g., closets and attics) shall have double-wall sheet metal construction.

10. Whole-house fans shall not be provided.

11. All ducts in attics shall be rigid metal.

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

Appendix E

Manufacturers and Suppliers

Appendix E:
Manufacturers of Acoustical Materials

This list represents a partial list of typical manufacturers 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 or the Navy.

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 AND ACOUSTICAL LOUVERS AND DAMPERS

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

RMR Products
11011 Glenoaks Blvd. #1
Pacoima, CA 91331
Tel: 818-890-0896

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

Devac
(see Mon-Ray, Inc.)

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

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

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 AND CEILING TREATMENT

BRD Noise and Vibration Control Inc.
112 Fairview Ave., P.O. Box 127
Wind Gap, PA 18091
Tel: 610-863-6300
www.brd-nonoise.com

Kinetics Noise Control
6300 Irelan Place
Dublin, OH 43017
Tel: 877-457-2695
www.kineticsnoise.com

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 F

Testing Laboratories

Appendix F:

Testing Laboratories

This list represents a partial list of Certified Acoustical Testing Laboratories that have the capability to perform tests in accordance with ASTM E90. This standard is used to determine the tramission loss and STC ratings of building systems and components. 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
415 East St., Elmo Road
P.O. Box 3610
Austin, TX 78764
Tel: 512-444-1961
www.acousticsystems.com

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

Intertek Testing Services
3933 US Route 11
Cortland, NY 13045
Tel: 607-758-6215
www.intertek.com

Johns Manville Technical Center
10100 West Ute Ave.
Littleton, CO 80162
Tel: 303-978-3611
www.jm.com/mtc/appliedtechnology

National Gypsum Co.
(NGC) Testing Services
1650 Military Road
Buffalo, NY 14217-1198
Tel: 716-873-9750
www.ngctestingservices.com

Orfield Laboratories, Inc.
2709 E. 25th Street
Minneapolis, MN 55406
Tel: 612-721-2455
www.orfieldlabs.com

Riverbank Acoustical Labs, Inc.
1512 S. Batavia Avenue
Geneva, IL 60134
Tel: 630-232-0104
www.riverbank.alionscience.com

Steelcase Acoustical Test Laboratory
P.O. Box 1967
Mail Stop CD2W06
Grand Rapids, MI 49501
Tel: 616-698-5527

Stork-Twin City Testing, Inc.
662 Cromwell Avenue
St. Paul, MN 55114-1776
Tel: 651-645-3601
www.storkct.com

United States Gypsum Co.
(USG) Research Construction
Systems Laboratory
700 N. Highway 45
Libertyville, IL 60048-1296
Tel: 847-970-5255
www.usg.com

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

Appendix G

Glossary of Acoustical Terms

Appendix G:

Glossary of Acoustical Terms

Absorption (or Sound Absorption: The ability of sound-absorbing materials to trap sound and convert it to heat. In a room, materials such as carpeting and upholstered furniture absorb some of the sound, giving a quieter room overall regardless of the source of the sound.

Absorption Coefficient: The sound-absorbing ability of a material, which is a function of the frequency of the sound in the space. The values of sound absorption coefficients usually range from about 0.01 (for hard, smooth surfaces that do not absorb much sound) 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 (as is the case with "structure-borne sound").

Ambient Noise Level: Sometimes called the "background" noise but actually slightly different (see the definition of background sound level, below), the level of noise that is all-encompassing within a given environment, whether indoors or outside. It is usually made up of many different sounds, some originating near to and others farther from the receiver. The ambient sound level typically varies throughout the day.

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

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. Website: www.ashrae.org

American Society for Testing and Materials (ASTM): An organization that develops and publishes recommended practices and standards for a broad range of testing and material properties issues. Website: www.astm.org

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

Attenuation: The reduction of sound.

A-Weighted Sound Level (dBA): Sound levels are denoted in decibels (see the definition of decibel, below). A-weighting of the decibel level 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: That part of the ambient noise that is unrelated to any particular sound. Other, identifiable, sounds are heard against the background sound level. Some sounds that form the ambient level are not part of the background sound level because they are normally recognized as distinct sources.

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.*

Composite Sound Transmission Loss: A measure of the ability of a construction assembly to reduce sound passing through it. A complex assembly contains two or more elements that exhibit different individual sound transmission loss properties. A window in a wall is an example of a composite assembly; the composite sound transmission loss of the assembly is not the same as the separate sound transmission losses of the parts.

Dampen: To cause a reduction, usually through dissipation, of the sound energy. For example, lead tends to dampen sound more than wood. This is part of the overall sound transmission loss of a material or assembly.

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 noise between 10:00 p.m. to 7:00 a.m.

Decibel (dB): The term used to describe sound levels. The decibel is a logarithmic quantity so decibels do not add or subtract according to standard rules for arithmetic. For example, 60 dB + 60 dB = 63 dB (not 120 dB).

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). Sounds with a high frequency have a high pitch, sounds with a low frequency have a lower, more bass sound.

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: A perceptual attribute of sound intensity 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 waveform 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 that is undesirable because it interferes with speech and hearing, 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, and 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 year, a working life, or a lifetime).

Noise Level Reduction (NLR): The difference between A-weighted sound levels indoors and outdoors. It is calculated, in part, based on the Noise Reduction values calculated at various frequencies.

Noise Reduction (NR): (1) 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). NR values are typically expressed at various frequencies while NLR relates to overall (A-weighted) sound levels; therefore, a single room has many NR values and only one A-weighted NLR value. (2) The reduction of noise levels within a space.

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 that is one octave wide. Standard octave bands are designated by their center frequency. For example, the octave band centered at 125 Hz includes all the frequencies between 89.1 and 178 Hz.

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.

Receiver: The listener who hears a sound or the measuring microphone that detects the sound transmitted by the source. The receiving room is the room where the sound level is being assessed, with the source of the sound generally being outside the room.

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 and the room is too reverberant (also see the definition of absorptions, above).

Shielding: The ability of hills or structures to physically block sound or create shadow zones where sound levels are reduced. For a house near an airport, the rooms on the side away from the airport will be "shielded" somewhat from the noise.

Sound Insulation: Reducing the sound level inside a building through the use of specific building construction materials, methods and component assemblies that 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-insulting properties of built construction against sounds such as speech, radio, and television. STC ratings are available for many common building materials.

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

Source: Something that generates sound. Common sound sources in a suburban community include factories, rock concerts, airplanes, cars, lawnmowers, stereo systems, TVs, and people talking.

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

Spectral Characteristics/Spectrum: The frequency content of the noise produced by the source. The spectral content of a sound influences how far it travels, how well it penetrates buildings, whether or not it makes things rattle, and how annoying people find it to be.

Structure-borne Sound: Sound energy transmitted through a solid medium such as the building structure. The building structure may radiate the sound as "airborne sound" in another room.

Thermal Insulation: A material or assembly of materials used primarily to provide resistance to heat flow. In a home, thermal insulation is provided by the basic building materials (brick, wood, and glass, for example), by the air spaces between things (such as the air gap in a "thermo-pane" window) and by thermal insulation materials such as fiberglass in walls and attics.

TL: *See Sound Transmission Loss.*

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

Appendix H

Bibliography

Appendix H:
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