U.S. Department
of Transportation

Federal Aviation Administration

Advisory Circular

Subject: ANNOUNCEMENT OF AVAILABILITY--REPORT NO. DOT/FAA/PP/92-5, GUIDELINES FOR THE SOUND INSULATION OF RESIDENCES EXPOSED TO AIRCRAFT OPERATIONS

Date: 7/2/93
Initiated by: APP-510

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Change:

1. **PURPOSE.** This advisory circular announces the availability of the report "Guidelines for the Sound Insulation of Residences Exposed to Aircraft Operations."

2. **BACKGROUND.** The Federal Aviation Administration's Office of Environment and Energy and Office of Airport Planning and Programming and the Naval Facilities Engineering Command contracted with Wyle Research to develop a report containing guidelines for the sound insulation of residences exposed to aircraft operations. The report provides a project management handbook for studying, initiating, and implementing residential sound insulation programs in neighborhoods around military and civilian airports. The information in the report is based on fundamental acoustic principles supported by practical experience gained in numerous residential sound insulation projects across the country. The most successful solutions to problems typically encountered in these projects have been incorporated in this report.

3. **HOW TO ORDER.**

a. The report may be purchased from the National Technical Information Service (NTIS), 5285 Port Royal Road, Springfield, Virginia 22161 (703-487-4650).

b. Orders should include the complete title and order number (ADA 258032). Customers should include a check or money order made payable to the National Technical Information Service in the amount of $36.[illegible], plus a $3.00 handling fee, for a total of $39.50.

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WYLE
LABORATORIES SCIENTIFIC SERVICES & SYSTEMS GROUP

REPORT

WYLE RESEARCH REPORT
WR 89-7

GUIDELINES FOR THE SOUND INSULATION OF RESIDENCES EXPOSED TO AIRCRAFT OPERATIONS

Prepared For:

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Guidelines for the Sound Insulation of Residences Exposed to Aircraft Operations

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1.0 EXECUTIVE SUMMARY

1.1 Introduction

The effect of aircraft noise on communities surrounding airfields concerns airport operators and their neighbors. Since 1973, when the Department of Defense initiated the Air Installation Compatible Use Zones (AICUZ) Program, there has been a systematic attempt to minimize the negative impact of local community growth on air operations and of these operations on communities. Similarly, in 1981 the FAA published Part 150 of the Federal Aviation Regulations establishing a single system of noise measurement appropriate to human response to aviation noise and identifying land uses normally compatible with various levels of noise exposure.

There are substantial mutual benefits in having communities located near airfields. Such benefits include improved economic development for the community and provision of services to the air installation. However, there are also continuing problems associated with having close neighbors, not the least of which is noise impact. Airfield neighbors become annoyed at the noise generated by flight operations and they exert pressure on airfield operators to take appropriate action to minimize the noise.

The need to safeguard military and civilian flight operations must be balanced with the need to protect local residents from excessive aircraft noise exposure. This challenge can be addressed in several ways. Solutions can be directed at the noise source, by developing quieter aircraft and by modifying flight procedures and flight tracks. Because military aircraft are designed for the performance of specific functions, it is not usually feasible to quiet them. Both military and civilian airport operators, however, do consider flight procedure and flight track changes to minimize noise impact.

The alternative is to protect the community members from noise impact where they live – in their homes and other activity centers – through land-use controls and sound insulation. The Navy's AICUZ program and the FAA's Land-Use Compatibility guidelines identify compatible land usage and encourage land-use controls. These recommendations appear in Tables 1-1 and 1-2. This guide provides a project management handbook for studying, initiating, and implementing residential sound insulation programs in neighborhoods around military and civilian airports.

The information presented in this guide is based on fundamental acoustic principles supported by practical experience gained in numerous residential sound insulation projects across the country. The most successful solutions to problems typically encountered in these projects have been incorporated.

The two primary goals of a residential sound insulation project are the improvement of the noise environment for community members and better relations between the installation and its neighbors. These goals, and the methods used to achieve them, must take into account the sometimes conflicting needs of the parties concerned. The existence of federal recommendations for noise exposure provides clear-cut, objective noise goals which can be aimed toward and complied with.

1.2 Use of This Handbook

This handbook is divided into four sections plus appendices. The Executive Summary, Section 1.0, provides an introduction to the Guidelines, this discussion of how to use the text, and a brief discussion of some of the topics covered in the handbook. Specific instructions are highlighted and useful data tables are reproduced from other Guidelines sections. Section 1.3 describes dwelling categories, their noise reduction, and common geographic distribution patterns. Suggested dwelling type modifications are given in Section 1.4. A brief discussion of project costs follows in Section 1.5.

The material in the Executive Summary is a condensed version of some of the topics covered more completely in the body of the handbook. It is intended to provide an overview of the general types of sound insulation and their associated costs. It is not intended to be an adequate substitute for a full explanation of the concepts and practices involved in a home sound insulation program which is provided in the main body of the document.

It is assumed that not all readers will need to study all parts of this document. The guidelines have been structured to make it easy to find topics of particular interest to a wide variety of users. The reader is urged to become familiar with the background material and detailed instructions provided in the sections which apply to his or her specific needs.

Table 1-11

Air Installation Compatible Use Zone Suggested Land-Use Guidelines (Department of Defense)

Land Use		Noise Zones/DNL Levels in L_{dn}						
SLUCM No.	Name	A 0-55	B 55-65	C-1 65-70	C-2 70-75	D-1 75-80	D-2 80-85	D-3 85+
10	**Residential**							
11	Household units.							
11.11	Single units — detached	Y	Y*	25[1]	30[1]	N	N	N
11.12	Single units — semidetached	Y	Y*	25[1]	30[1]	N	N	N
11.13	Single units — attached row	Y	Y*	25[1]	30[1]	N	N	N
11.21	Two units — side-by-side	Y	Y*	25[1]	30[1]	N	N	N
11.22	Two Units — one above the other	Y	Y*	25[1]	30[1]	N	N	N
11.31	Apartments — walk up	Y	Y*	25[1]	30[1]	N	N	N
11.32	Apartments — elevator	Y	Y*	25[1]	30[1]	N	N	N
12	Group quarters	Y	Y*	25[1]	30[1]	N	N	N
13	Residential hotels	Y	Y*	25[1]	30[1]	N	N	N
14	Mobile home parks or courts	Y	Y*	N	N	N	N	N
15	Transient lodgings	Y	Y*	25[1]	30[1]	35[1]	N	N
16	Other residential	Y	Y*	25[1]	30[1]	N	N	N
20	**Manufacturing**							
21	Food and kindred products — manufacturing	Y	Y	Y	Y[2]	Y[3]	Y[4]	N
22	Textile mill products — manufacturing	Y	Y	Y	Y[2]	Y[3]	Y[4]	N
23	Apparel and other finished products made from fabrics, leather, and similar materials — manufacturing	Y	Y	Y	Y[2]	Y[3]	Y[4]	N
24	Lumber and wood products (except furniture) — manufacturing	Y	Y	Y	Y[2]	Y[3]	Y[4]	N
25	Furniture and fixtures — manufacturing	Y	Y	Y	Y[2]	Y[3]	Y[4]	N
26	Paper and allied products — manufacturing	Y	Y	Y	Y[2]	Y[3]	Y[4]	N
27	Printing, publishing, and allied industries	Y	Y	Y	Y[2]	Y[3]	Y[4]	N
28	Chemicals and allied products — manufacturing	Y	Y	Y	Y[2]	Y[3]	Y[4]	N
29	Petroleum refining and related industries	Y	Y	Y	Y[2]	Y[3]	Y[4]	N

*The designation of these uses as "compatible" in this zone reflects individual Federal agencies' consideration of general cost and feasibility factors as well as past community experiences and program objectives. Localities, when evaluating the application of these guidelines to specific situations, may have different concerns or goals to consider. For an indication of possible community reaction in residential environments at various levels of cumulative noise, Table D-1 in Appendix D should be consulted.

NOTES FOR TABLE 2

a) Although local conditions may require residential use, it is discouraged in C-1 and strongly discouraged in C-2. The absence of viable alternative development options should be determined and an evaluation indicating that a demonstrated community need for residential use would not be met if development were prohibited in these zones should be conducted prior to approvals.

b) Where the community determines that residential uses must be allowed, measures to achieve outdoor to indoor Noise Level Reduction (NLR) of at least 25 dB (Zone C-1) and 30 dB (Zone C-2) should be incorporated into building codes and be considered in individual approvals. Normal 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 and closed windows year round. Additional consideration should be given to modifying NLR levels based on peak noise levels.

c) 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 particularly from ground level sources. *Measures that reduce noise at a site should be used wherever practical in preference to measures which only protect interior spaces.*

Table 1-2[2]

Federal Aviation Administration Definitions of Land-Use Compatibility With Yearly Day-Night Average Sound Levels

Land use	Yearly day-night average sound level (L_{dn}) in decibels					
	Below 65	65–70	70–75	75–80	80–85	Over 85
Residential						
Residential, other than mobile homes and transient lodgings.	Y	N(1)	N(1)	N	N	N
Mobile home parks	Y	N	N	N	N	N
Transient lodgings	Y	N(1)	N(1)	N(1)	N	N
Public Use						
Schools	Y	N(1)	N(1)	N	N	N
Hospitals and nursing homes	Y	25	30	N	N	N
Churches, auditoriums, and concert halls	Y	25	30	N	N	N
Governmental services	Y	Y	25	30	N	N
Transportation	Y	Y	Y(2)	Y(3)	Y(4)	Y(4)
Parking	Y	Y	Y(2)	Y(3)	Y(4)	N
Commercial Use						
Offices, business and professional	Y	Y	25	30	N	N
Wholesale and retail—building materials, hardware and farm equipment.	Y	Y	Y(2)	Y(3)	Y(4)	N
Retail trade—general	Y	Y	25	30	N	N
Utilities	Y	Y	Y(2)	Y(3)	Y(4)	N
Communication	Y	Y	25	30	N	N
Manufacturing and Production						
Manufacturing, general	Y	Y	Y(2)	Y(3)	Y(4)	N
Photographic and optical	Y	Y	25	30	N	N
Agriculture (except livestock) and forestry	Y	Y(6)	Y(7)	Y(8)	Y(8)	Y(8)
Livestock farming and breeding	Y	Y(6)	Y(7)	N	N	N
Mining and fishing, resource production and extraction.	Y	Y	Y	Y	Y	Y
Recreational						
Outdoor sports arenas and spectator sports	Y	Y(5)	Y(5)	N	N	N
Outdoor music shells, amphitheaters	Y	N	N	N	N	N
Nature exhibits and zoos	Y	Y	N	N	N	N
Amusements, parks, resorts and camps	Y	Y	Y	N	N	N
Golf courses, riding stables and water recreation.	Y	Y	25	30	N	N

Numbers in parentheses refer to notes.

*The designations contained in this table do not constitute a Federal determination that any use of land covered by the program is acceptable or unacceptable under Federal, State, or local law. The responsibility for determining the acceptable and permissible land uses and the relationship between specific properties and specific noise contours rests with the local authorities. FAA determinations under Part 150 are not intended to substitute federally determined land uses for those determined to be appropriate by local authorities in response to locally determined needs and values in achieving noise compatible land uses.

KEY TO TABLE 1

SLUCM = Standard Land Use Coding Manual.
Y (Yes) = Land Use and related structures compatible without restrictions.
N (No) = Land Use and related structures are not compatible and should be prohibited.
NLR = Noise Level Reduction (outdoor to indoor) to be achieved through incorporation of noise attenuation into the design and construction of the structure.
25, 30, or 35 = Land use and related structures generally compatible; measures to achieve NLR of 25, 30, or 35 dB must be incorporated into design and construction of structure.

NOTES FOR TABLE 1

(1) Where the community determines that residential or school uses must be allowed, measures to achieve outdoor to indoor Noise Level Reduction (NLR) of at least 25 dB and 30 dB should be incorporated into building codes and be considered in individual approvals. Normal residential 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 and closed windows year round. However, the use of NLR criteria will not eliminate outdoor noise problems.
(2) Measures to achieve NLR 25 dB 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 dB 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 35 dB 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 level is low.
(5) Land use compatible provided special sound reinforcement systems are installed.
(6) Residential buildings require an NLR of 25.
(7) Residential buildings require an NLR of 30.
(8) Residential buildings not permitted.

Section 2.0 covers the basic concepts involved in improving the acoustic performance of residences exposed to aircraft noise. It includes a statement of the goals of a sound insulation project. The terms and metrics used to describe noise levels and sound insulation are defined in this section. The paths by which sound enters a dwelling, the effects of aircraft noise intrusion, and fundamental sound insulation concepts are also described.

Section 3.0 examines project formulation and implementation methods. This section addresses issues concerned with identifying which houses need to be treated and the types of treatment available. Dwelling categories are defined and explained, and a comprehensive nationwide dwelling type data base is provided. Instructions for performing acoustic measurements are given along with the criteria for determining appropriate noise reduction objectives.

Sound insulation techniques useful for the various parts of a dwelling are presented as options to be combined in the total dwelling treatment package. Recommended modification packages are identified along with costs to implement them. A detailed example shows how to develop project costs from the information provided.

Section 4.0 provides guidelines on project management and implementation, discussing program management in greater detail. All aspects of program planning, initiation, implementation, supervision, and follow-up evaluation are covered.

Worksheets for developing detailed cost estimates are provided in Appendix A. Other appendices provide a bibliography, glossary, and sample forms for surveys and inspection.

1.3 Dwelling Category Summary

The sound insulation modifications required to achieve a specific acoustic goal depend on the existing sound insulation characteristics of the dwelling. The existing sound insulation performance of a dwelling is determined by the construction methods and materials used, as well as the condition of the home. Section 3.2 explains how to categorize dwellings based on these acoustically significant building features. Table 1–3, taken from Section 3.2.3 and presented here, shows the External Wall Rating (EWR) of a number of these construction elements. EWR is a measure of sound insulation capability and is explained in Section 2.3.

Because construction practices vary from one geographic region to another, it is desirable to identify those that are typical in different parts of the country. Figure 1-1 shows eleven regions where the housing types near major airports are similar. Section 3.2.2 gives more information on these regions and the dwelling patterns found in them. Table 1-4 presents the results of national housing surveys showing the most typical dwelling categories for each of the 11 regions.

Table 1-5 gives the average house size in each geographical region, which influences the sound insulation cost of a dwelling.

1.4 Recommended Modification and Construction Practices

Section 3.5, Sound Insulation Methods, gives detailed instructions on how to modify an existing house or alter the design of a new house to improve its sound insulation performance. There are many specific techniques used in acoustic treatments which must be performed properly and with careful attention to detail, in order for them to be effective. Acoustic windows, for example, must be installed according to the manufacturer's detailed instructions or their insulation performance will be seriously degraded. In general, acoustic insulation construction requirements are stricter than those necessary for standard home construction. The reader is urged to study the principles and practices of Section 3.5 for a thorough understanding of sound insulation construction.

Summary Tables 1-6 through 1-13 provide guidelines for improving the sound insulation performance of different building elements. They will be useful for easy reference after the reader has become familiar with the supporting information in Section 3.5.

1.5 Dwelling Modification Packages and Costs

Based on the compatible land-use recommendations given in Tables 1-1 and 1-2, it is possible to set sound insulation goals for dwellings exposed to aircraft noise. This involves knowing the external noise environment, the required noise reduction for residences, and the existing noise reduction of the dwelling.

Airport operators can provide mapped noise exposure contours (Sections 2.1 and 2.2) showing

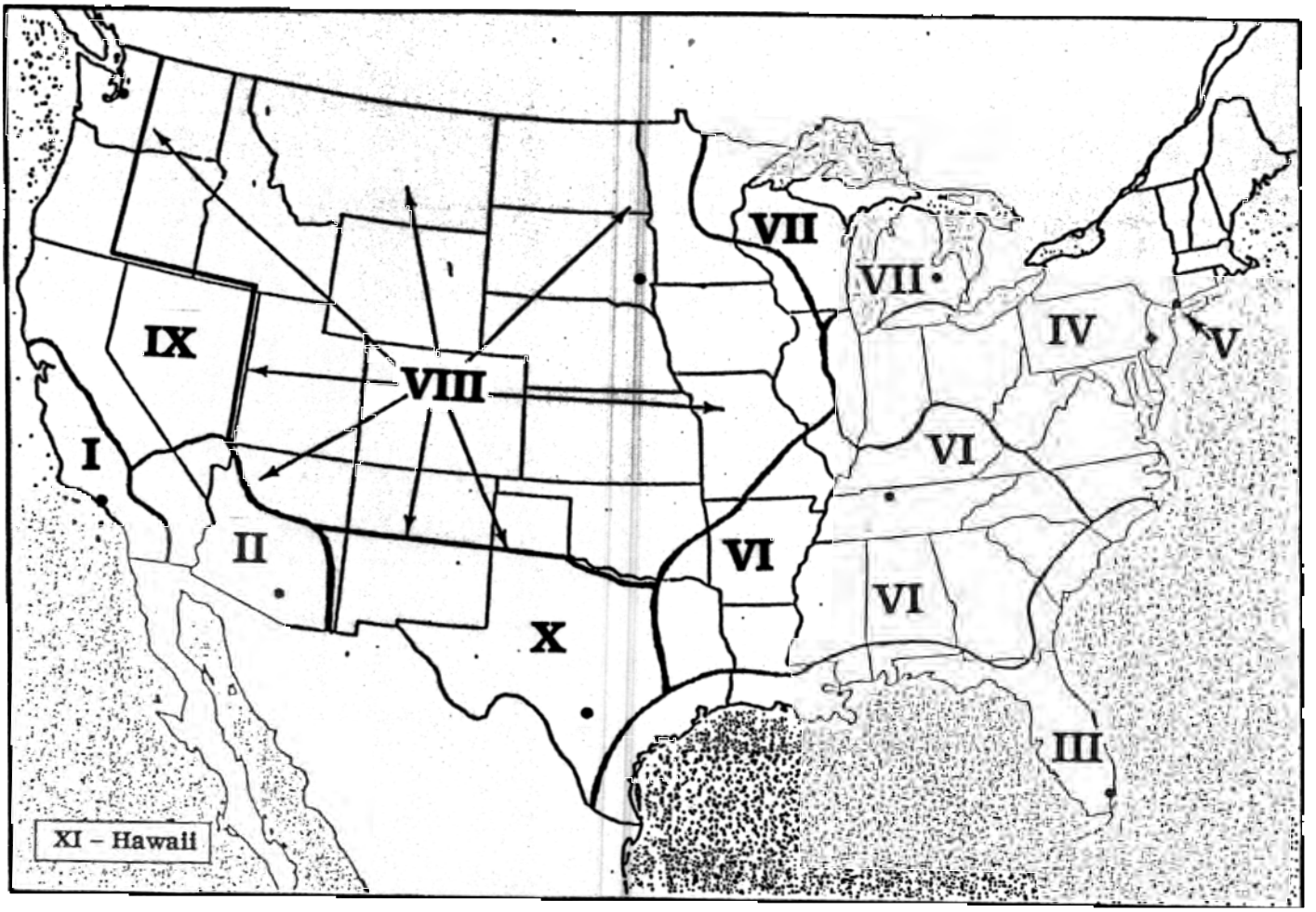
Table 1-3

EWR Ratings for Common Construction Elements

BASIC CATEGORIES	
EXTERIOR WALLS	EWR (dB)
1. Aluminum or Wood Siding	37
2. Stucco	43
3. Brick or Veneer	54
4. Concrete	58
5. Hollow Concrete Block	49
ROOFS	
1. Vented Attic (With/Without Absorption)	50/47
2. Single Joist – Light	41
3. Single Joist – Heavy	44
4. Exposed Roof – Light	33
5. Exposed Roof – Heavy	39

SUBCATEGORIES	
FLOORS	
1. Slab	∞
2. Vented Crawlspace	49
3. Basement	49
WINDOWS	
1. Double-Strength Glazing	25/28*
DOORS	
1. Hollow Core (HC)	20/22*
2. Solid Core (SC)	24/27*
3. Sliding Glass (SGD)	27/31*

* Poor/Good Weatherstripping Condition



• Indicates location of airport used in field survey described in Reference 3

Figure 1-1. Regions of Differing Construction Practices.

(Repeated as Figure 3-3.)

Table 1-4
(Repeated as Table 3-2)

Percentages of Dwellings in Each Construction Category
and Floor Constructions for Each Region

Construction Category*	Region and Airport										
	I	II	III	IV	V	VI	VII	VIII	IX	X	XI
	LAX	TUS	JAX	PHL	LGA	BNA	LAN	FSD	SEA	SAT	HNL
Siding/VA	15	--	35	30	15	15	40	55	70	60	--
" /SJL	--	--	15	35	50	--	45	30	20	--	100
" /ECL	--	--	--	--	--	--	--	--	5	--	--
Stucco/VA	80	5	--	--	--	--	--	--	--	5	--
" /SJL	5	5	--	--	--	--	--	--	--	--	--
Brick/VA	--	80	15	10	5	80	10	--	5	35	--
" SJL	--	10	--	10	10	5	5	--	--	--	--
" /SJH	--	--	--	--	15	--	--	--	--	--	--
Concrete/VA	--	--	--	5	--	--	--	10	--	--	--
" /SJL	--	--	--	10	5	--	--	5	--	--	--
HC Block/VA	--	--	30	--	--	--	--	--	--	--	--
" /SJL	--	--	5	--	--	--	--	--	--	--	--
Slab Floor	50	100	70	15	5	--	10	5	--	90	100
Crawlspace	50	--	30	5	10	15	--	--	70	10	--
Basement	--	--	--	80	85	85	90	95	30	--	

* VA – Vented Attic;
SJL – Single-Joist Roof, Light;
SJH – Single-Joist Roof, Heavy;
ECL – Exposed Ceiling, Light

LAX =Los Angeles, CA
TUS =Tucson, AZ
JAX =Jacksonville, FL
PHL =Philadelphia, PA
LGA =LaGuardia, New York, NY
BNA =Nashville, TN

LAN = Lansing, MI
FSD = Sioux Falls, SD
SEA = Seattle, WA
SAN = San Antonio, TX
HNL = Honolulu, Oahu, HI

Table 1-5
(Repeated as Table 3-48)

1987 Average Dwelling Size for New Construction

Region	I	II	III	IV	V	VI	VII	VIII	IX	X	XI
Sq. Ft.	1,765	1,765	1,800	1,815	1,840	1,800	1,795	1,785	1,765	1,800	1,765

Table 1-6
(Repeated as Table 3-8)

Summary of Methods for Improving Window Sound Insulation

1. Increase glazing thickness up to 1/2 inch to increase mass and to reduce vibration.
2. Use laminated glazing, typically two layers of glazing with a 30 mil polyvinyl butyral interlayer, to achieve limpness and provide damping which reduces coincidence effects. For double-lite constructions, place the laminated lite on the warm side of the window because cold climate conditions may result in loss of damping effect for the interlayer. Laminated glazing constructions can result in an increase of 3 dB in the STC rating over monolithic glazing of the same thickness.
3. Use double-lite constructions with at least a 2–inch-wide spacing between the lites. Each doubling of the airspace between the lites results in an increase of 3 dB in the STC rating. Glazing thickness should be in a ratio of 2:1 so lites have different resonance frequencies.
4. Do not use lightweight frames where flanking sound paths may limit window transmission loss performance. Use separate heavy aluminum frames connected together with a thermal break.
5. Mount lites in soft neoprene edge gaskets which wrap around the bottom of the glazing sash channel. This minimizes structureborne sound transmission between the glazing and the window sash.
6. Operable double windows with separate sashes provide greater transmission loss than a single sash with double glazing. Non-operable windows have STC ratings which are 3 dB higher than operable windows of similar construction.
7. Do not evaluate windows needed to isolate low-frequency noise (such as occurs with aircraft overflights) based on STC ratings alone. This is because the STC rating does not include transmission loss performance below 125 Hz, where aircraft noise may be significant. For example, single lites with STC ratings identical to double-lite constructions will generally perform better at low frequencies due to their greater overall weight. Installation is critical in order to maintain the sound isolation performance of the window assembly.
8. Windows need to fit with a minimum perimeter gap between the window frame and opening. All voids need to be caulked and closed off with wood trim and blocking. Ensure that all sound flanking and air infiltration paths have been closed off. Remember, if air can pass through, so can sound.

Table 1-7
(Repeated as Table 3-9)

Summary of Methods for Improving Door Sound Insulation

1. Increase the weight of the door. This results in higher transmission loss characteristics.
2. Use solid-core wood doors or hollow-core metal doors filled with fibrous fill. Special acoustical wood and metal doors are available which can be specified for optimum results.
3. Fill hollow metal door frames with fiberglass or use solid wood door frames. Caulk around door frames at the wall.
4. Door frames and hardware should be reinforced to handle the extra weight of acoustical doors. Use ball-bearing hinges and long screws for attachment to framing members.
5. Provide full seals and weatherstripping at the perimeter of the door jamb and head to minimize perimeter air infiltration.
6. Provide a drop seal at the door bottom which makes full contact with a raised threshold. The drop seal should be adjustable to compensate for misalignment of the door.
7. Vision lites should have similar transmission loss characteristics to the door. Use two layers of 1/4–inch laminated glass separated by an airspace. Provide full seals and gasketing at the window perimeter.
8. Add a second sliding glass door in parallel with the existing sliding glass door. Position the new sliding glass door so it is a minimum of 2 inches from the existing sliding glass door.

Table 1-8
(Repeated as Table 3-12)

Summary of Methods for Improving Attic and Ceiling Sound Insulation

1. Install baffles on attic vents where practical.
2. Add acoustically absorptive material to a thickness equal to R–19 to the attic space to reduce reverberant sound level buildup. Apply material evenly throughout the attic space, taking care to keep it away from eave vents and openings.
3. Add one layer of 5/8-inch fire-code gypsumboard to the interior finish ceiling for dormer, non-attic, lightweight, or deteriorated roofs.
4. For greater noise control in attics add 5/8–inch plywood or gypsumboard to the rafters or add plywood flooring to the joists. Use absorptive material equivalent to R–19 between the rafters or joists.
5. Cover exposed beam ceilings with interior finish ceilings or partial enclosures.
6. For higher noise insulation on non-attic roofs: strip off existing exterior surface, add 3.5-inch rigid insulation assembly, 1/2–inch plywood sheathing, and new roofing material.
7. Remove whole-house attic exhaust fans and repair the interior ceiling to match the existing conditions.

Table 1-9
(Repeated as Table 3-13)

Summary of Methods for Improving Interior Wall Sound Insulation

1. Use heavy gypsumboard such as fire-rated products in 5/8-inch thickness. Adding one layer of 5/8-inch gypsumboard increases the wall STC rating by 3 dB.
2. Use a discontinuous construction between the existing wall and the new wall finish. This can be achieved by adhesive attachment of gypsumboard and sound-deadening board to the existing wall or by furring out a separate wall. Increases of 6 dB and 12 dB, respectively, to the STC rating are achieved.
3. Use light-gauge metal channel studs (25–gauge or lighter) because they are less stiff than wood or load-bearing metal studs. The use of wide (3.5–inch) metal channel studs will increase the transmission loss at low frequencies.
4. Use 3-inch-thick sound-absorbing blankets in the wall cavity. Install blankets tightly between studs using friction fit or with fasteners to the studs to prevent sagging.
5. Cut new gypsumboard so that it fits tightly against walls, floor, and ceiling.
6. Apply acoustical caulking around perimeter of new gypsumboard and around all electrical outlets and switches to eliminate sound flanking.

Table 1-10
(Repeated as Table 3-15)

Components of Ducted Air Heating, Cooling and Ventilation System

1. Circulation fan capable of supplying the required air volume exchange through the ducting in each room.
2. For climates where heating is necessary, forced hot air heating, cooling, and ventilation capabilities through appropriate heating and cooling coils and condenser unit.
3. Fresh air inlet located on the shaded side of the dwelling provided that side is not exposed directly to the flight path. It should also be adjacent to a return air plenum to facilitate mixing the fresh air with the recirculated air.
4. Supply and return air diffusers in each room to circulate the air. The supply air diffusers should be adjustable to allow redirection or shut-off of the airflow. In systems without a furnace, the return plenum should be located near the ceiling to encourage recirculation of rising warm air. Furnaces have return-air plenums as part of the system.
5. Flexible ducting connecting the fan air supply vents and the return plenum to each room and to the exterior. Sheetmetal ducting should be used to provide superior sound insulation in attics and crawlspaces.
6. Control switch with on/off and at least two fan speeds, the lower of which provides the minimum required air circulation. The switch should permit air to be circulated without activating the heating or cooling elements. Existing radiant heat can be used as a "backup" system.

Table 1-11
(Repeated at Table 3-16)

Recommendations for Noise and Vibration Control in Residential HVAC Systems

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

Table 1-12
(Repeated as Table 3-18)

Summary of Methods for Improving Noise Reduction in Manufactured Homes

Roofs:

1. Upgrade attic insulation to R-19, or better, where feasible.
2. Remove skylight and repair roof to existing condition.

Walls:

3. Add mass under exterior siding, or under interior decorative finish surface, by mounting sheathing, gypsumboard, or sound-deadening board.

Windows and Doors:

4. Mount secondary windows and sliding glass doors at least 2 inches away from existing elements on the dwelling exterior.
5. Replace existing windows and doors with highest STC rated products available.

Air Infiltration Paths:

6. Seal gaps and openings in external envelope.
7. Baffle vents.
8. Repair or replace weatherstripping.
9. Check and repair seals between modular units in double and triple-wide homes. Re-level home if necessary to prevent recurring problem.

Ventilation:

10. Upgrade existing system, as necessary, to provide air replenishment, circulation, heating and/or cooling to enable homeowner to keep windows and doors closed year-round.

Table 1-13
(Repeated as Table 3-14)

Suggested Guidelines for Design of New Construction

1. Do not build homes where DNL is 75 dB or greater.
2. Orient homes on the lot so noise-sensitive areas, such as TV rooms and bedrooms, are shielded from the flight track.
3. Use more massive external cladding, such as brick or other masonry, in place of siding wherever practical.
4. Where siding is used, or the noise exposure is high, use sound-deadening board, multi-layer gypsumboard, or a furred-out interior wall construction as discussed in Section 3.5.2.4.
5. Use heavy roofing materials, preferably with an attic rather than single-joist construction. Use R–19 or better insulating batts in the attic and R-11 to R-15 insulating batts in the walls. Use open-beam ceilings with extreme caution.
6. Use acoustical windows of an appropriate STC rating, properly installed.
7. Avoid large picture windows and sliding glass doors on sides of the dwelling which face the flight track.
8. Use solid-core doors with storm doors or, preferably, specialty acoustical doors.
9. Give careful attention to weatherstripping and seals.
10. Eliminate unnecessary openings such as through-the-wall air conditioners, vents, chimneys, skylights, and whole-house attic fans. Baffle or shield those that are used.
11. Provide a forced-air HVAC system with fresh air replenishment as described in Section 3.5.3.2.

the expected noise levels in residential communities around airfields. Tables 1-1 and 1-2 define the required noise reduction for each noise impact zone.

The existing noise reduction can be determined either by acoustic field measurements (Section 3.3) at a dwelling, or by using calculations based on the EWR and STC ratings of the building components and materials. The wall ratings in Table 1-3 cannot be used directly for these estimates because they do not account for the presence of windows or doors. STC, or Sound Transmission Class, ratings are conceptually similar to EWR ratings. They are discussed in Sections 2.3 and 3.5. The noise reduction provided by different dwelling categories and various construction schemes is given in Sections 3.2.3, 3.5.1, and 3.5.2.

Twenty-six different housing categories have been identified as representing most of the common types of residences across the country. A computerized cost optimization model has been used to identify the most cost-effective package of dwelling modifications satisfying the noise reduction goals for each house. This design tool was exercised for each of four noise impact zones. The 26 housing types are defined in Table 1-13. Of these 26, the most common types found in each of the 11 geographic regions of the country are listed in Table 1-14. Table 1-15 defines the modification codes used in the tables which follow it. Then Tables 1-16 to 1-41 provide, room by room, suggested modifications for each house. Section 3.6.1 discusses this information and the decisions involved in the design process.

At the bottom of each column in the modifications tables, a cost per square foot is provided to show the expense of implementing the suggested modifications package. This figure can be multiplied by the size of the house, in square feet of living space, to give the total cost of remodeling the dwelling. Table 1-5 provides the average size of homes in different parts of the country.

Construction material costs and labor rates vary from one part of the country to another. For this reason it is desirable to find local costs which are equivalent to the baseline costs given in the modifications tables. Table 1-43 gives geographic cost factors to facilitate calculating the equivalent cost in each region of the country. To use these factors, simply identify the target region, find the appropriate cost multiplier in Table 1-43, and multiply the modification cost by this factor. Either the cost per square foot or the whole house cost can be used for this calculation.

In order to estimate the cost of using these construction features in new construction rather than remodeling, multiply the remodeling cost by 0.70.

A sample cost development sheet is provided here as Figure 1-2. Its use is discussed in Section 3.6.3, where a full example is provided.

To use the Single Noise Zone Modification Cost Worksheet, the following information is needed:

- Geographical Region – if needed to identify typical house types or sizes (Tables 1-4 and 1-15).
- Noise Exposure Zone.
- Number of Houses of each type.
- Cost to modify each type of house in given noise zone (Tables 1-17 to 1-42).
- House size (Table 1-5, if necessary).
- Geographical Cost Factor (Table 1-43).

The cost to modify houses in the specified noise zone can be calculated according to the instructions in Section 3.6.