Guidelines for Ensuring Longevity in Airport Sound Insulation Programs

DETAILS

48 pages | 8.5 x 11 | PAPERBACK
ISBN 978-0-309-28379-3 | DOI 10.17226/22439

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AIRPORT COOPERATIVE RESEARCH PROGRAM

ACRP REPORT 105

Guidelines for Ensuring Longevity in Airport Sound Insulation Programs

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Subscriber Categories
Aviation • Construction

Research sponsored by the Federal Aviation Administration

TRANSPORTATION RESEARCH BOARD

WASHINGTON, D.C.
2014
www.TRB.org

AIRPORT COOPERATIVE RESEARCH PROGRAM

Airports are vital national resources. They serve a key role in transportation of people and goods and in regional, national, and international commerce. They are where the nation's aviation system connects with other modes of transportation and where federal responsibility for managing and regulating air traffic operations intersects with the role of state and local governments that own and operate most airports. Research is necessary to solve common operating problems, to adapt appropriate new technologies from other industries, and to introduce innovations into the airport industry. The Airport Cooperative Research Program (ACRP) serves as one of the principal means by which the airport industry can develop innovative near-term solutions to meet demands placed on it.

The need for ACRP was identified in *TRB Special Report 272: Airport Research Needs: Cooperative Solutions* in 2003, based on a study sponsored by the Federal Aviation Administration (FAA). The ACRP carries out applied research on problems that are shared by airport operating agencies and are not being adequately addressed by existing federal research programs. It is modeled after the successful National Cooperative Highway Research Program and Transit Cooperative Research Program. The ACRP undertakes research and other technical activities in a variety of airport subject areas, including design, construction, maintenance, operations, safety, security, policy, planning, human resources, and administration. The ACRP provides a forum where airport operators can cooperatively address common operational problems.

The ACRP was authorized in December 2003 as part of the Vision 100-Century of Aviation Reauthorization Act. The primary participants in the ACRP are (1) an independent governing board, the ACRP Oversight Committee (AOC), appointed by the Secretary of the U.S. Department of Transportation with representation from airport operating agencies, other stakeholders, and relevant industry organizations such as the Airports Council International-North America (ACI-NA), the American Association of Airport Executives (AAAE), the National Association of State Aviation Officials (NASAO), Airlines for America (A4A), and the Airport Consultants Council (ACC) as vital links to the airport community; (2) the TRB as program manager and secretariat for the governing board; and (3) the FAA as program sponsor. In October 2005, the FAA executed a contract with the National Academies formally initiating the program.

The ACRP benefits from the cooperation and participation of airport professionals, air carriers, shippers, state and local government officials, equipment and service suppliers, other airport users, and research organizations. Each of these participants has different interests and responsibilities, and each is an integral part of this cooperative research effort.

Research problem statements for the ACRP are solicited periodically but may be submitted to the TRB by anyone at any time. It is the responsibility of the AOC to formulate the research program by identifying the highest priority projects and defining funding levels and expected products.

Once selected, each ACRP project is assigned to an expert panel, appointed by the TRB. Panels include experienced practitioners and research specialists; heavy emphasis is placed on including airport professionals, the intended users of the research products. The panels prepare project statements (requests for proposals), select contractors, and provide technical guidance and counsel throughout the life of the project. The process for developing research problem statements and selecting research agencies has been used by TRB in managing cooperative research programs since 1962. As in other TRB activities, ACRP project panels serve voluntarily without compensation.

Primary emphasis is placed on disseminating ACRP results to the intended end-users of the research: airport operating agencies, service providers, and suppliers. The ACRP produces a series of research reports for use by airport operators, local agencies, the FAA, and other interested parties, and industry associations may arrange for workshops, training aids, field visits, and other activities to ensure that results are implemented by airport-industry practitioners.

ACRP REPORT 105

Project 02-31
ISSN 1935-9802
ISBN 978-0-309-28379-3
Library of Congress Control Number 2013957499

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Published reports of the

AIRPORT COOPERATIVE RESEARCH PROGRAM

are available from:

Transportation Research Board
Business Office
500 Fifth Street, NW
Washington, DC 20001

and can be ordered through the Internet at

http://www.national-academies.org/trb/bookstore

Printed in the United States of America

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AUTHOR ACKNOWLEDGMENTS

The authors would like to express their gratitude to their Wyle colleagues Joanna Norris, Jane Verbeck, Mel Baker, Rod Royales, John Kaytor, and Joe Czech for their assistance in preparing and reviewing this guidance document.

In addition we would like to thank the following individuals who provided insight on products and quality control in the manufacturing process:

- Alan Peterson, St. Cloud Window, Inc.
- Brian Kiesling, JLS Enterprises
- S.A. (Casey) Mahon, St. Cloud Window, Inc.
- Joe Dupuy, Milgard Manufacturing Inc.
- Michael R. Ghezavat, Specialty Door Company, Inc.
- Paul Pratt, Glore & Associates
- Shawn P. Hulsey, Graham Architectural Products

FOREWORD

By Marci A. Greenberger
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ACRP Report 105: Guidelines for Ensuring Longevity in Airport Sound Insulation Programs provides best practices in all phases of a sound insulation program to reduce or eliminate future deterioration issues. This report complements *ACRP Report 89: Guidelines for Airport Sound Insulation Programs,* which addresses an overall sound insulation program. *ACRP Report 105* focuses on ensuring that the program continues to be effective for the homeowner or building occupants and will be useful to any program manager responsible for designing and implementing a sound insulation program.

Sound insulation programs have been in existence since the 1980s and have successfully improved the quality of life for homeowners living near airports. There have been significant improvements in materials, treatments, and techniques in the last 30 years and many lessons learned. However, there isn't a single reference that documents best practices, nor an evaluation of the continuing effectiveness of those early programs.

Wyle, as part of ACRP Project 02-31, was tasked with evaluating the degree and causes of any deterioration in the acoustic performance of homes and buildings from those early sound insulation programs and with providing guidance to airports to ensure the durability and attenuation performance for current and future sound insulation programs. The results of their research are provided in *ACRP Report 105: Guidelines for Ensuring Longevity in Airport Sound Insulation Programs*. In addition, the results of their field studies, which involved recreating the testing process in homes from those early programs, can be found in the Contractor's Final Report for ACRP Project 02-31 on the TRB website.

These guidelines complement *ACRP Report 89: Guidelines for Airport Sound Insulation Programs,* which provides guidance to airports pertaining to the management of sound insulation programs, and which includes a discussion on the relatively new guidance provided by the FAA in Program Guidance Letter (PGL) 12-09, "AIP Eligibility and Justification Requirements for Noise Insulation Projects, August 2012."

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Note: Many of the photographs, figures, and tables in this report have been converted from color to grayscale for printing. The electronic version of the report (posted on the Web at www.trb.org) retains the color versions.

Introduction

ACRP Project 02-31 was designed to provide a thorough investigation of airport sound insulation products and procedures to identify possible causes for deterioration in sound insulation performance over the years. The investigation included researching project documents and identification of installation methods, treatments, and materials used in early projects. The plan was to define the chronology in the evolution of sound insulation programs in the United States, so that changes in methods and procedures from early to current programs and the relationship of these changes to changes in acoustic performance could be identified. The chronology was subsequently used to evaluate how program changes may have affected acoustic performance. This effort was followed by actual acoustical testing and architectural evaluations of a representative sample of dwelling units that were insulated in the early years.

The purpose of this guidance document is to summarize the information collected and the analyses performed into practical guidelines that can be applied by program sponsors, designers, and contractors to improve the longevity of acoustic performance in airport sound insulation programs.

Summary of ACRP Project 02-31 Findings on Deterioration

The results of tests conducted at multiple sites of two sound insulation programs showed that there has been less deterioration in performance over the years than expected. This is consistent with the lack of reported deterioration in performance obtained from a survey of U.S. programs (Sharp, Gurovich, Fazeli, & Miller, 2013). In most cases, any deterioration in performance is more likely to be the result of homeowner modifications, poor maintenance, extreme weather, and, in some cases, poor installation, and less likely to be due to deterioration in the products themselves.

This finding does not imply that there have been no problems with products or installation procedures. Many programs have reported such issues, but, to a large extent, these have been identified by the program sponsors (or their consultants) and corrected by the product manufacturers or contractors. The lessons learned along the way have led to changes in products, installation, and quality control procedures that have reduced the frequency of such problems.

Using *ACRP Report 105* in Conjunction with Other Guidelines

This report provides guidance on the materials, design criteria, installation criteria, and maintenance required to ensure longevity in sound insulation programs as well as describing the detailed steps necessary to prevent and/or address specific problems and the detailed inspection procedures needed to implement such programs.

The guidelines presented in *ACRP Report 89: Guidelines for Airport Sound Insulation Programs* (Payne et al., 2013) cover program development, community outreach, design strategies, treatment of historical structures, green initiatives, and program cost development and funding. The report also includes some general information on construction and contracting, products, and closeout.

This guidance document is a companion document to *ACRP Report 89* with a focus on improving the durability and longevity of sound insulation programs. Sections 1 through 7 discuss the following areas:

- Durability issues,
- Program management,
- Design process and bid documents,
- Current and future products,
- Construction administration,
- Quality control, and
- Maintenance.

The sections are organized to discuss durability issues and the findings of other research projects and connect the findings to the day-to-day tasks of a sound insulation project from program management to project closeout and maintenance. Although other guidelines are frequently referenced throughout this report, in some cases it was necessary to briefly discuss a topic in order to provide needed clarity and context. In addition, a short summary of best practice points as they relate to longevity is provided at the end of each section.

SECTION 1

Durability Issues

Deterioration of building structures, in general, and of various building components such as windows or doors, in particular, is related to the durability and life expectancy of building materials and products. Durability is typically defined as the ability of a material, product, or building to maintain its intended function for its intended life expectancy with intended levels of maintenance under intended conditions of use (NAHB Research Center, Inc., 2002). Somewhat different definitions of durability can be found in the literature (European Commission, 2004; Kesik, 2002; Hoff, 2009; Athena, 2006), but all of them indicate the dependency of durability on the intended use of the product and its service environment.

Construction deterioration is due to environmental loading and failure of the environmental separation (such as the building envelope) with the result of reduced durability (A. Sebastian Engineering and Investigation Services, n.d.). The manner in which materials and buildings degrade over time depends on their physical make-up, how they were installed, and the environmental conditions to which they are subjected. The *Durability by Design* guide (NAHB Research Center, Inc., 2002) lists factors affecting building durability such as moisture, sunlight (UV radiation), temperature, chemicals, insects, fungi, natural hazards, and wear and tear. Most notable of these factors are moisture, UV radiation from sunlight, and temperature. Other problems, such as mold and indoor air quality, are also related to moisture.

1.1 Common Problems with Existing Products and Installation

A survey of early sound insulation programs, established programs, and current programs has identified some areas of concern and documented the steps that programs have taken to deal with these issues (see Table 1-1).

1.2 How to Identify Potential Issues

As sound insulation programs have progressed, many of the issues described in Table 1-1 have been resolved due to the attention of program sponsors or the availability of newer and improved products. Some of the remaining issues can be detected with diligent inspections. Some issues are detectable by creating a thorough punch list and performing a final inspection before acceptance of projects. Other issues will appear during the warranty period or even after the warranty period has lapsed. Issues such as incorrect glass thickness can be detected during product inspection by utilizing special devices. Delamination of wood doors is one of the ongoing issues that sound insulation programs still face. A skilled construction manager will be able to minimize the problem by making sure that the doors are stored and finished according to the instructions of the manufacturer and the contract documents. Any sign of warpage must be identified as soon as it appears, documented, and brought to the contractor/manufacturer's attention during the construction phase. Some items, such as moisture damage of the framing due to incorrect installation or door warpage due to insufficient finishing, might not be apparent until long after the construction is completed. It is critical to discuss any concerns with owners and make sure that they perform periodic inspection and contact the contractor and/or the manufacturer as soon as any issue becomes apparent.

1.3 How to Avoid Durability Issues

Although many of the issues mentioned in Table 1-1 have been resolved, there are still ongoing issues with windows and doors that can be avoided. A summary of these items is presented and discussed in more detail throughout this guidance document.

Table 1-1. Common issues and resolutions.

Delamination of doors	**Description:** Delamination of doors was one of the main issues from the early years of sound insulation programs and continues to cause problems. Acoustical wood doors contain different layers of insulation material and veneer bonded together. This combination is susceptible to moisture, which can cause the door to delaminate. Delamination is not exclusive to wood doors and has been experienced with aluminum metal prime doors, where there is a full glass storm door over a dark-colored door in full sun exposure.
	Resolution: • Include finishing instructions for the door leaf in the technical specification, including the number of required paint or varnish coats, the field condition under which the door finish is applied, and/or a requirement to finish all edges and holes/cuts. • Require pre-primed doors or application of sealer/primer and first coat in a warehouse, in a dry, controlled environment. • Have seasoned construction managers inspect the door finish, especially at the door edges and holes cut through the door for hardware. As technology has advanced, construction of the door core and the way it is bonded to the door skin has improved, allowing door manufacturers to increase the warranty period from 1 or 2 years to 5 years. However, the warranty language requires a 4-ft overhang or installation of a storm door to protect the wood doors. The vulnerability of acoustic wood doors to moisture is an ongoing issue and requires further improvements or design change.
Warpage of the entire door panel	**Description:** About 25% of all complaints about doors are related to door warpage. Warpage can occur due to the condition of the wood products; the manufacturing process; environmental conditions at the site, including temperature fluctuation and moisture; the environmental conditions of the warehouse where the door was stored before installation; faulty finishing; and/or faulty installation.
	Resolution: • Advances in technology to design an improved core. • Improvements in the manufacturing process for attachment of the door skin to door core. • Improvement in technical specifications to include finishing instructions. • Specification of how doors are to be stored in the warehouse. • Having seasoned construction managers ensure that the requirements of the technical specifications are followed. Manufacturers routinely honor the warranty of the door if warpage occurs during the warranty period provided that other requirements of the warranty language are met.
Automatic door bottom seals	**Description:** Automatic bottom seals were a continual problem in early sound insulation programs. They required regular maintenance, or they would lose their tightness, alignment, and/or would break entirely.
	Resolution: Most programs have replaced automatic door bottom seals with alternative fixed in-place seals.
Difficulties installing the door leaf within the existing door frame	**Description:** During the early years of sound insulation programs, only door leaves were replaced. This caused many issues during installation. It was often difficult to fit the new door within the existing frame or to add the necessary air/acoustic seals.
	Resolution: Pre-hung doors are now specified, including both door leaf and door frame. If new frames are not specified, the existing door frames should be modified to accommodate kerfed-in seal.
S-88 smoke seals or bulb seals peeled off easily	**Description:** During the early years, programs received complaints regarding this seal peeling off and leaving a gap for noise to penetrate the dwelling units.
	Resolution: Many programs discontinued the use of this seal and replaced it with a combination of rigid seals and kerfed-in seals. This remedy, along with the issues mentioned in the previous item, required specifying new door frames that could accommodate the kerfed-in seals. The use of S-88 (smoke seals) is limited to garage access doors for meeting the requirements of building codes.
Misalignment of aluminum windows	**Description:** Early acoustic windows were aluminum, tended to be somewhat flimsy, and were subject to misalignment as screws were tightened during installation.
	Resolution: Specifications included requirements for aluminum frame alloy and/or thickness.

Table 1-1. (Continued).

Improper operation of hardware	**Description:** Improper operation of hardware interfering with closure of doors and windows.
	Resolution: There have been numerous advancements in hardware technology, and manufacturers dealt with this issue on the spot or incorporated changes into their manufacturing process, quality control, and/or design to minimize problems related to hardware malfunction.
Weather strip deterioration	**Description:** Weather strips are vulnerable to wear and tear and need regular maintenance.
	Resolution: Due to improvements in technology, manufacturers now use more durable weather strips in acoustical window products.
Condensation	**Description:** Condensation in double window assemblies.
	Resolution: Improved edge sealing can be used to exclude air and moisture infiltration.
Sagging of casement windows	**Description:** During the early years, sagging of casement windows created problems with closing the windows and loss of acoustical effectiveness. Although sagging is inherent in this type of the window because of its weight, there were two other major contributors to this issue: • Windows were specified without consideration of the maximum size set by the manufacturers. The limits set for the size of these windows were too high, contributing to additional weight and, as a result, sagging. • Faulty installation also contributed to the sagging. The windows were installed without proper connections to the structure or adequate support at the sill.
	Resolution: • Specifying solid continuous blocking along the whole length of the window to completely support the window at its sill. • Ensuring that the window is securely attached to the structure at the window jambs according to manufacturers' installation instructions. • Setting size limitations for casement windows to deal with window weight. Contractor performance directly affects window sagging. Programs with high standards of construction management have most effectively controlled this issue.
Dirt buildup on sliding tracks	**Description:** Dirt buildup on sliding tracks of horizontal slider windows and sliding glass doors can cause difficult operation.
	Resolution: • Bringing the issue to the owner's attention during the design or construction phases. • Provision of a design (by one window manufacturer) where the roller sits on a rail rather than rolling on a flat surface of the window track, alleviating issues related to the roller and dirt buildup in the track. (The major aluminum and vinyl window manufacturers did not take this issue into consideration for any design changes.)
Oversized windows	**Description:** Oversized windows, like casement windows, experienced issues with sagging or operation, which can decrease acoustical performance.
	Resolution: See resolution for sagging casement windows.
Thermal break failure in some aluminum windows	**Description:** The material used to create the thermal break deteriorated over time and broke down in climates with weather extremes, leaving gaps in the gasket that water could leak through. In wet weather conditions, water would run down the glass, into the gaps in the deteriorated gasket, and into the wall.
	Resolution: • Following lab reports, site visits of affected facilities, and communication with the window manufacturer, it was decided that that type of window would not be used in sound insulation projects in colder climates. • Some programs specify iso-bar thermal breaks and are moving away from poured and de-bridged thermal breaks.
Incorrect maximum sizes	**Description:** Incorrect maximum sizes for 3-lite sliders, which caused the frames to deflect.
	Resolution: New windows of a different configuration had to be installed.
Incorrect glass thickness	**Description:** Incorrect glass thickness was detected in the full-lite, self-storing storm doors where ⅛-in. glass was substituted for ¼-in. glass.
	Resolution: Storm doors were replaced by the manufacturer.
Failure to install tension clips	**Description:** Failure to install tension clips on self-storing doors.
	Resolution: Clips were installed after construction was completed.

(continued on next page)

Table 1-1. (Continued).

Corrosion of aluminum windows	**Description:** In close proximity to salt water, aluminum frames showed corrosion due to salt-laden air.
	Resolution: With advances in technology, more effective and longer-lasting coatings have become available to manufacturers, who have taken advantage of the technology to improve the longevity of their products.
R-values of thermal insulation deteriorating over time due to settling	**Description:** The compaction of loose cellulose fill reduces the volume of air spaces within the fiber and its insulation value.
	Resolution: Some programs use fiberglass batt insulation in ceilings whenever possible.
Compliance	**Description:** Compliance with building codes and other applicable local or federal regulations.
	Resolution: Specifications and inspections should require that products installed meet or exceed the applicable requirements. Close attention should be paid to any updates/changes in requirements. Mandates have been placed on air infiltration, water tests, and structural tests, including the maximum force required to open windows/sliding doors, and they were added to technical specifications. Although only a few programs use field testing on installed products, this seems like an effective quality control measure for identifying window manufacturing problems. One program has removed two manufacturers because of test failures.
Achieving a healthy interior environment	**Description:** In order to achieve a healthy interior environment, air exchange requirements within codes and regulations must be followed.
	Resolution: The solution has been incorporating relief vents or mechanical ventilation to overcome the pressurized interior space in order to guarantee the code-required air exchange between exterior and interior and provide fresh air in dwellings. This has improved the interior environment of the dwelling unit and reduced the need for opening windows/doors. Similarly, the addition of Energy Recovery Ventilation Systems in every home has reduced moisture problems without causing acoustic problems.
Double sliding glass doors	**Description:** Double sliding glass doors were massive and difficult to open.
	Resolution: STC-rated sliding glass doors have been introduced into projects. This advancement eliminated the necessity of adding storm doors to existing sliding glass doors.

1.3.1 Proper Design

Proper design is the first step to ensuring that products perform to their potential. The following list indicates areas for special attention:

- **Specification of appropriate products.** Suitable products should be specified during design considering the circumstance of each project.
- **Climate.** The aspects of climate that most affect longevity are precipitation, wind, and temperature fluctuations. Products facing wet and windy environments or those impacted by high seasonal or daily temperature fluctuations require a specific set of characteristics and protections. While design should take into account environmental factors and be accurately executed during construction, utilizing building materials that are more resistant to each of these factors is equally important. Excessive exposure to moisture is a common cause of damage to many types of building components and materials. Also, it can lead to unhealthy indoor living environments (Dacquisto, Crandell, & Lyons, 2004). Other examples of climates distressing products are the effect of coastal environments on aluminum products and the susceptibility of thermal breaks to failure in colder climates.
- **Codes, regulations, and standards.** Although the main purpose of building codes is to protect public health and safety, they also contain provisions that directly affect the durability of products. Envelope flashing requirements or hurricane codes are some examples of specific codes that promote longevity. Incorporating these requirements into design and enforcing them through the construction phase ensures longevity. It is useful to incorporate the indoor air quality, ventilation, and commissioning standards of the American Society of Heating, Refrigerating, and Air-Conditioning Engineers (ASHRAE) or regulations for interior air in states such as California, New Jersey, and Washington. These standards and regulations not only promote healthy and comfortable interior air, but also indirectly contribute to the durability of buildings.
- **Warranty restrictions and solutions to these restrictions.** For instance, if wooden door manufacturers require a 4-ft overhang or storm door in order to honor the warranty, the requirement should be added to the design.
- **Proper detailing.** Accurate details need to be created, ensuring that attachments and flashing issues are accurately

designed, and unique cases need to be reviewed so that necessary details can be created.

- **Manufacturer's limitation.** Close attention should be paid to the manufacturer's limitation on windows and doors sizes.
- **Lessons learned.** Lessons learned from previous projects need to be reviewed and incorporated into new designs.

1.3.2 Selection of Durable and High-Performing Material

Materials with proven durability should be specified. The technical specifications should include third-party certifications when available. In addition, when specifying new products, the test data should be carefully reviewed to assess durability, and proof of durability should be obtained from the manufacturers or suppliers.

1.3.3 Accurate and Sufficient Detailing

Insufficient or inaccurate details are a major factor in products not performing to their potential. Accurate details should be provided to clearly identify structural integrity, necessary support, sufficient attachments, compatible adjacent material, required drainage, flashing, and ventilation. In creation of details, the opinions of construction managers and the contractor should be sought to ensure that the details are buildable. In addition, lessons learned from previous phases of the construction can provide valuable information on the workability of a given detail or necessary additional details. It is always beneficial to create forgiving details that provide a way for a worker to deal easily with inaccuracies. Most traditional details that evolve over a period of many years, and incorporate features that make them easier and more convenient for workers, are forgiving of inaccuracies and mistakes (Allen & Rand, 2007). For example, details should set dimensional tolerances that are realistic while providing the performance required by the sound insulation program.

1.3.4 Robust Construction Management and Contractor Training

The construction administration period is a crucial phase in any building construction project, especially in sound insulation projects, because of the number of details that need to be followed in order to reach the goal of the program. A thorough construction management procedure ensures that correct products are utilized in the project and the design intent of the project is followed precisely. The following list outlines some areas in construction management that can directly affect the durability of products along with examples of their application:

- **Transportation and storage.** Ensuring that products are transferred and stored in accordance with the manufacturers' instructions is critical in avoiding warpage of doors and damaging of windows. The product inspection phase is an opportunity to ensure that materials are being stored in accordance to the manufacturer's requirements.
- **Product inspection.** Product inspection provides an opportunity to detect and fix any problem with the products before their installation.
- **Adherence to details and design intent.** As a result of the acoustical properties required for the windows and doors, products are often heavier than windows and doors used in a regular residential project. Architects and manufacturer installation instructions might require special attachment systems or additional supports to handle the weight of the product. Contractors need to consider this fact, review the details, and make sure the intended installation procedure is followed. In addition, a seasoned construction manager will be able to identify any issue that is not in conformance with the design intent and require corrective action.
- **Contractor training.** Some manufacturers have training programs in place for contractors. It is always useful for programs to provide a day of training before the start of construction to discuss the nature and requirements of the project, the importance of the details, the expectations in adherence to details, the sequences of the construction, and lessons learned from previous phases.
- **Communications.** Before, during, and after construction, input from the contractors on the construction details and quality management procedures should be invited.

1.3.5 Strong Quality Assurance and Quality Control Procedures by Consultants, Subconsultants, and Manufacturers

Quality control is critically important for a successful construction project and ideally is incorporated on all levels of the project from conception to completion. A well-designed project results in a smooth construction phase. Costly repairs can be avoided by incorporating appropriate products, inspecting installation thoroughly, and ensuring that the design intent is followed. At the same time, inspections by cities and counties or other jurisdictions that have control over the project will ensure that the code and safety requirements are followed. The architect, engineers, construction managers, contractors, and permitting agencies should work together to deliver an accurate and well-designed project, a sound construction, and a strong inspection, as well as identifying deficiencies, proposing corrective actions, and maintaining complete documentation of the project.

1.3.6 Effective Maintenance

A review and investigation of many projects to evaluate the effectiveness of sound insulation modifications in early programs suggest that proper maintenance is a key factor in sustaining the acoustical performance of sound insulation products. Section 7 of this report discusses maintenance after completion of the project in more detail.

Summary—Avoid Durability Issues

1. Provide a suitable design with sufficient detailing and specify appropriate and durable products.
2. Incorporate a well-established and strong quality assurance and quality control plan.
3. Incorporate robust construction management.
4. Communicate the importance of maintenance to owners.

SECTION 2

Program Management

Managing a sound insulation program effectively is critical in meeting all project requirements regardless of competing demands and unexpected changes. As part of program initiation, a fully detailed timeline must be developed to identify critical path milestones for measuring progress and to ensure that all critical paths remain on schedule. The timeline must be reviewed for streamlining the program and maintaining program completion.

As part of program management and planning, the following factors should be considered:

- Provide ongoing liaison among project sponsor, project stakeholders (i.e., homeowners and contractors), and consultants;
- Develop a fully detailed timeline;
- Ensure optimal response to project requirements and provide expected deliverables;
- Provide for continuous monitoring of work quantity and quality, time schedules, and budgets, with the ability to take corrective actions as required;
- Provide timely and effective reviews of design and testing milestones;
- Update project records daily and provide regular reports to the client; and
- Document design progress frequently.

Furthermore, consultants should work as multidisciplinary teams to achieve project requirements. Weekly and monthly project meetings should be conducted to discuss workload, scheduling, and potential issues. The program team may consist of the following disciplines in the form of primary consultants or subconsultants: program manager, architect, acoustical engineer, hazardous materials professional, sustainability experts, electrical engineer, mechanical engineer, structural engineer, construction manager, and commissioner. Chapter 2 of *ACRP Report 89* discusses the role of each team member in detail (Payne et al., 2013).

2.1 Incorporating this Guidance Material into Project Management and Planning

This guidance document is created to provide hands-on direction for performing a sound insulation project. The following points underscore areas of management and planning that will be affected by this guidance:

- Providing leadership and oversight to make sure that the guideline is incorporated,
- Defining the project,
- Developing a task list,
- Selecting a team,
- Engaging employees so that they are prepared to support the project,
- Ensuring quality assurance and quality control,
- Developing schedules, and
- Developing checklists.

2.2 Establishing a Quality Assurance Plan

The main goal of a quality assurance plan is to make sure that the program adheres to standards, policy, and procedures; ensures quality throughout the course of the project; and results in the client's satisfaction (the clients being the program sponsor and the homeowner). In this regard, it is advisable to pursue accreditation such as ISO 9001 and follow the appropriate criteria. The following criteria for establishing a quality assurance plan are built on the steps listed in *How to Build a Quality Assurance Program* (Richards, n.d.) and a vast amount of experience gained through managing sound insulation programs:

- **Develop standards.** It is important to know the standards, from the codes and regulations governing the program to the client's expectations and contractual obligations.

- **Develop a policy and procedures manual in conjunction with the standards.** The manual should clearly define the objectives of the program, show the steps necessary to achieve these objectives, and indicate ways to measure and review conformance. The manual should periodically be reviewed and updated.
- **Review the best practices in the field and determine how these practices can be incorporated into the program.**
- **Clearly designate staff members' roles and assign them the responsibilities required to achieve the objectives of the program.** In addition, define the role of the subconsultant(s) in the project and the coordination necessary among all stakeholders.
- **Train staff and offer refresher courses to make sure they understand the workflow and are up-to-date with any changes, such as building code updates.**
- **Establish a realistic timeline for each task.** Develop check points for these tasks at which they will be reviewed for accuracy, compliance with the objectives of the program, and adherence to timelines.
- **Set up procedures to ensure that any necessary measurement and test equipment is calibrated to the applicable standard.**
- **Establish quality control oversight that includes individuals not involved directly in the day-to-day operations of the program (such as principal of the company or clients) to review the quality assurance plan, reports, and improvements and provide constructive feedback.**
- **Perform an analysis of the "lessons learned" at the end of each project and keep the results in a database for future reference.** This database can be used for issues faced during projects, durability problems, system requirements, maintenance requirements, and constructibility issues and will be a great resource in the future.

Summary—Program Management

1. Establish a quality assurance plan.
2. Understand the standards.
3. Develop a comprehensive policy and procedures manual.

SECTION 3

Design Process and Bid Documents

This section provides an overview of the design process and explains each step of the process in detail. In construction projects, proper design, specification of appropriate products, and accurate detailing optimize the longevity of the final product and ensure that the products meet their potential performance goal.

3.1 Eligibility and Objectives

The goal of a sound insulation project is to effectively reduce the noise that enters the living spaces of homes or other sensitive receptors in eligible areas in accordance with an airport's Part 150 mitigation program, as approved by the FAA.

Per the Airport Improvement Program (AIP) Handbook, *Order 5100.38C* (APP-520, 2005), and Program Guidance Letter (PGL) 12-09, "Eligibility and Justification Requirements for Noise Insulation Projects" (November 7, 2012), the FAA further requires that eligible properties must be (1) built prior to October 1, 1998, and be (2) located in an existing Day-Night Average Sound Level (DNL) 65 decibel (dB) or Community Noise Equivalent Level (CNEL) 65 dB noise contour, with an interior noise level equal to or greater than DNL/CNEL 45 dB. The FAA also requires that noise insulation efforts be designed to achieve interior noise levels of 45 dB in habitable rooms, but with a minimum increase in noise level reduction of 5 dB.

Please refer to *ACRP Report 89* for more information on history (Payne et al., 2013), the AIP Handbook (APP-520, 2005) program development, and design goals.

3.2 Process Overview

Plans and specifications for modifications designed to achieve the noise goals listed in the previous section are required for three purposes (Wyle, 1992):

1. To document the implementation plan and form part of the grant application package when FAA funds or other funds are being sought,
2. To form the basis for soliciting bids from contractors to perform the work, and
3. To allow local building departments to issue construction permits.

Figure 3-1 presents an overview of the process. The following paragraphs explain the details for preparing the construction documents.

3.3 Initial Site Visits

The initial contact with property owners is usually through the program sponsor or program management consultant who receives an application for participation in the program. After the application process is completed and the site is deemed eligible for sound insulation improvements, the initial site surveys are conducted. For preparation of existing floor plans, accurate measurements are taken and any item that may require acoustical modification for sound insulation purposes is noted. Detailed field survey checklists can be used to compile adequate information for program design and construction documents. This checklist may include the following:

- Type of existing fenestration with measurement of size and sill height and presence of windows, shutters, inset window treatment, window air-conditioning unit, alarms, security bars, and any other interfering factors;
- Type of door with size measurements and notation, if applicable, of a secondary door, alarms, mail slots, and pet doors;
- Number and size of attic vents, vents with motorized fan, attic insulation and amount, knob and tube wiring, location and number of recessed lights, if any;
- Rooms with flat roof ceiling or exposed beam ceiling and information regarding the existing roof structure;
- Range hood, recirculating fans, microwave fan, smoke hole, and indication of whether these items exhaust through the exterior of the house;

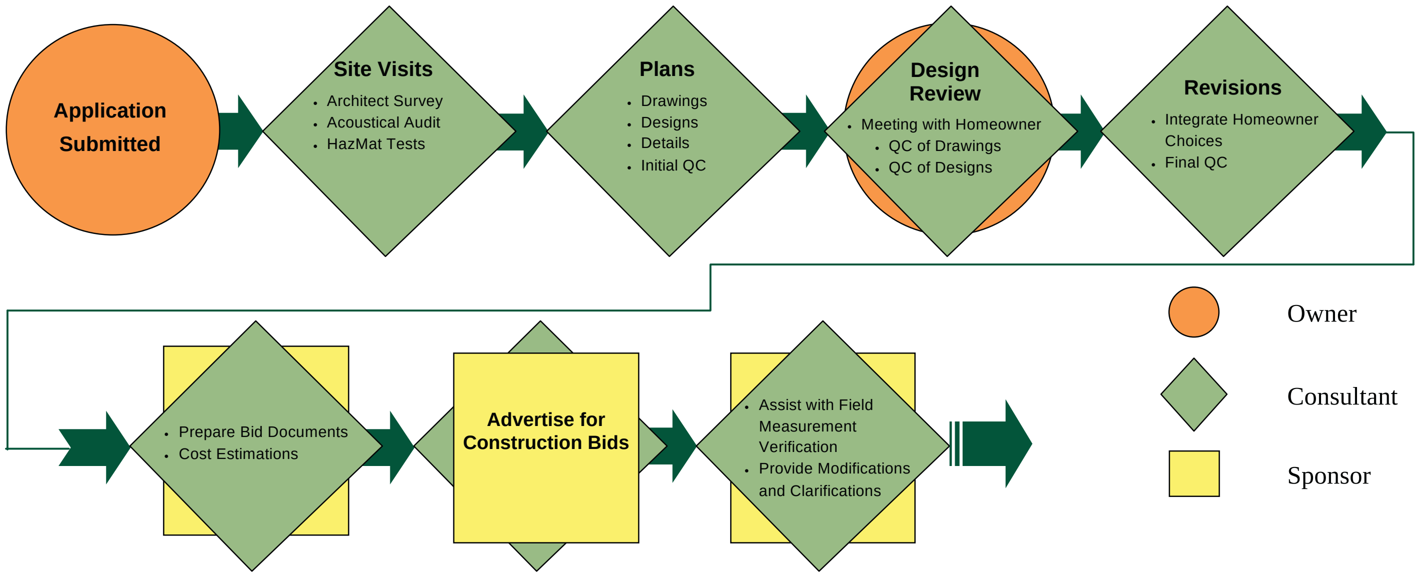


Figure 3-1. Overview of the design process.

- Existing electrical and mechanical information;
- Existing gas service; and
- Existing mail service (i.e., mail slots).

Accurate measurements of the floor plan and all affected items must be taken and deficiencies such as termite damage, dry rot, water damage, and code deficiencies must be identified as part of the initial survey.

Code deficiency surveys can assist programs in deciding whether to include a property or not. This survey includes potential violations such as the following:

- Garage conversion,
- Apparent additions,
- Bedrooms with no windows,
- Lack of bathroom exhaust fans,
- Missing ground-fault circuit interrupters (GFCI) outlets,
- Missing smoke detectors,
- Apparent structural issues,
- Illegal wiring,
- Knob and tube, and
- Mechanical/electrical issues.

A survey report along with pictures is the first working document produced for any property entering the system. Most programs will fix minor deficiencies such as smoke alarms or carbon monoxide detectors. However, participation of a dwelling with a major code deficiency is contingent upon the owners fixing the problems and submitting documentation to show the issue is remedied.

Hazardous material testing can be performed at the same visit to identify lead-based paint and asbestos-containing materials that would impact construction. Acoustical testing is performed on a sample of homes to confirm baseline conditions and required acoustical modifications. These sample homes are referred to as "control homes." The acoustical testing is repeated after construction modifications are completed on these control homes in order to document the improvement to the dwelling units and confirm success in meeting the program goals.

The site survey information allows design staff to develop an initial design for the dwelling unit considering the impact of sound transmission paths such as windows, doors, chimneys, attic baffles, and other building elements. In addition, any existing conditions (such as lightweight construction, historical homes, egress requirements, and existing structural integrity) that may impact design and construction should be identified.

3.4 Preparation of Plans

After documenting existing conditions, architectural plans in the form of drawings and textual documents containing a thorough description of the existing conditions are prepared for each dwelling. This information will be used in the acoustical analysis for preparation of designs.

Upon completion of the architectural plans, either a standard set of acoustical designs will be applied to each individual dwelling or new acoustical designs will be prepared depending on the requirements of each program. Any special or unusual case will be carefully studied, and possible treatment options recommended. These options will be further investigated for selection of the best and most cost-effective treatment.

In order to meet the program's objectives (listed in Section 3.1), the following factors should be considered in developing the modifications that will be included in the acoustic design:

- Exterior DNL/CNEL at the dwelling location;
- Dwelling location, shielding, and orientation to the airport;
- Construction type; and
- Field inspection of site conditions.

Plans will consist of drawings, a scope of work, schedules, specifications, and details. Drawings may include the following:

- Scaled floor plans or dimensioned drawings;
- Size, form, location, and arrangement of various elements of the project;
- Overall dimensions of the dwelling;
- Exterior material and construction;
- Schedules of windows and doors;
- Construction details and connections between materials;
- Location and type of any penetration through the exterior envelope such as roof vents, air-conditioning systems, mail slots, and so forth; and
- Work limitations.

Experience has shown that wherever possible it is important to maintain a consistent treatment approach among eligible homes and neighborhoods. Such consistency ensures program continuity and prevents neighbors from feeling slighted because they received a substantially different package of modifications than someone else.

In addition, all plans should be in accordance with all applicable codes and regulations—building code, mechanical and electrical code, fire code, energy code, and environmental regulations. Each state has a different set of building codes that need to be followed. International Building Code (IBC) is a model building code that has been adopted by most states partially or in whole.

3.5 Design Reviews and Revisions

When initial plans outlining the modifications are ready, they should be reviewed with the owner. Although this review can be performed at the sponsor's or consultant's office, experience has shown that an on-site review at the participant's dwelling is a better option.

An on-site review allows the homeowner to relate the acoustical design plans with the various elements to be modified in the home and to make choices on various design options. The owner will be presented with the plans and a modification list for review and approval. At this stage, owners are informed of the construction process and asked to formally acknowledge their responsibilities as owners, such as providing access to areas that are affected by the construction. It is important for the design team to verify building elements and referenced details on the plans with building elements in the field, and to further ensure the constructibility of the design at this visit. Any unresolved property owner issues will be noted for further discussion. Once all final decisions are made, two copies of the plans are given to the property owner for signature representing concurrence with the plans. One copy is retained by the owner, and the other is for distribution.

3.6 Final Plans

Final plans are prepared incorporating owner choices and concerns expressed during the on-site review. Quality control checks are also performed at this stage before submission to plan check. The quality control review ensures that the design is consistent with the design criteria, maintains consistency throughout the program, minimizes change orders, and provides clear direction to the eventual contractor. The final plans consist of a floor plan; a written description of improvements; window and door schedules; heating, ventilation, and air-conditioning (HVAC) design; electrical design; and structural calculations and details as necessary.

At this stage of the process, building permit applications should be completed, final plans are submitted to the building department for plan check, and construction cost estimates are prepared.

3.7 Construction Cost Estimate

Construction cost estimates will be completed toward the end of design process, before submission of plans for plan check. Chapter 11 of *ACRP Report 89* outlines different approaches to construction cost estimating and the variables impacting cost (Payne et al., 2013).

The most effective method of estimating for established programs is to use material and labor costs, add overhead and profit, and include any contingencies. The labor rate can be determined by the estimate of anticipated hours for the job class and utilizing the prevailing wage published with the bid documents. Material costs can be obtained through resources such as R.S. Means or directly from product manufacturers. Since material costs fluctuate in today's market, this information must be updated periodically, and the estimation must consider the extent and frequency of price variations (Manfredonia, Majewsk, & Perryman, 2010). A sample of this approach is shown in Figure 3-2.

3.8 Corrections and Clarifications

Plan check corrections and potential FAA review recommendations should be incorporated into the design prior to obtaining owner concurrence for any changes and releasing the package for bidding.

			MATERIALS		LABOR		TOTAL
ITEM	Qty.	UNIT	UNIT COST	ESTIMATED MATERIAL	UNIT COST	ESTIMATED LABOR	ESTIMATED TOTAL COST
Division 02 – Existing Conditions							
Hazmat	1	lump		0	1120.00	1120	1120
Division 5 - Metal							
Access Ladder	0	ea.	1200.00	0	500.00	0	0
Division 06 – Wood, Plastics, and composites							
Lower Egress Window	0	ea.	10.00	0	450.00	0	0
Widen Egress Window	1	ea.	50.00	50	550.00	550	600
Attic Access (New/Enlarge)	1	ea.	175.00	175	150.00	150	325
Crawl Access Panel	2	ea.	50.00	100	50.00	100	200
Exhaust Fan Baffle	1	ea.	165.00	165	100.00	100	265
Mechanical Screens	0	ea.	275.00	0	500.00	0	0
Roof Scuttle	0	ea.	750.00	0	500.00	0	0
Vents - Fabricated	3	ea.	85.00	255	50.00	150	405
HVAC Duct Soffit/Chase	0	S.F.	5.50	0	20.50	0	0
Pet Door	0	ea.	250.00	0	150.00	0	0
Division 07 – Thermal and Moisture Protection							
Attic Insulation - 10" to 12" (blown-in)	0	S.F.	0.65	0		0	0
Attic Insulation - 10" to 12" (batt)	954	S.F.	1.50	1431		0	1431
Division 8 – Doors and Windows							
Solid Core Door (STC 40) w/frame	3	ea.	1100.00	3300	550.00	1650	4950
Sliding Glass Door (STC 40)	0	ea.	1650.00	0	400.00	0	0
Alum. Slider Window (STC 40)	0	ea.	575.00	0	150.00	0	0
Alum. Fixed Window (STC 40)	0	ea.	525.00	0	150.00	0	0
Alum. Double Hung Window (STC 40)	0	ea.	575.00	0	150.00	0	0
Alum. Casement Window (STC 40)	0	ea.	500.00	0	150.00	0	0
Secondary Skylight - Hinged	0	ea.	450.00	0	150.00	0	0
Secondary Skylight - Multi-hinged	0	ea.	650.00	0	250.00	0	0
Storm Door (STC 31)	0	ea.	600.00	0	200.00	0	0
Security Storm Door	0	ea.	750.00	0	200.00	0	0
Vinyl Slider Window (STC 40)	2	ea.	475.00	950	150.00	300	1250
Vinyl Fixed Window (STC 40)	0	ea.	425.00	0	150.00	0	0
Vinyl Double Hung Window (STC 40)	7	ea.	475.00	3325	150.00	1050	4375
Vinyl Casement Window (STC 40)	0	ea.	450.00	0	150.00	0	0
Remove and Install (E) Security Door	3	ea.	25.00	75	50.00	150	225
Remove (E) Security Bars Install	0	ea.	25.00	0	50.00	0	0
Division 9 – Finishes							
Drywall/Patching	20	S.F.	2.50	50	12.50	250	300
Painting	20	S.F.	1.50	30	6.00	120	150
Remove Existing Wall Heater	1	ea.	50.00	50	300.00	300	350
Seal Misc. openings	3	ea.	25.00	75	100.00	300	375
Division 10 – Specialties							
Chimney Dampers	0	ea.	350.00	0	150.00	0	0
Glass Fireplace Doors	0	ea.	725.00	0	100.00	0	0
Division 23 - HVAC							
New HVAC System	2.5	Ton	2500.00	6250	250.00	625	6875
Division 26 - Electrical							
Electrical upgrading to 200 AMP	1	ea.	3500.00	3500		0	3500
Knob & Tube	0	ea.	2500.00	0		0	0
Hard wired SD/CO alarm	4	ea.	30.00	120	50.00	200	320
Division 28 - Electronic Safety and Security							
Alarm replace control panel	1	ea.	130.00	130	500.00	500	630
Alarm contacts for HS window	0	ea.	200.00	0	500.00	0	0
Alarm contacts for CAS window	0	ea.	80.00	0	500.00	0	0
Alarm contacts for exterior doors	3	ea.	80.00	240	500.00	1500	1740
Total Construction Cost				**17605**		**4745**	**22350**
Overhead & Profit	**1.2**	**lump**					**26820**
Total Estimated Cost							**33550**

Figure 3-2. Sample cost estimation sheet.

3.9 Construction Documents

Construction documents are the written and graphic documents prepared for communication of the design and administering the contract for its construction (CSI, 1996). There are two major groups of construction documents:

1. Bidding requirements:
   - Bid solicitation (advertisement/invitation to bid),
   - Instructions to bidders,
   - Information available to bidders,
   - Bid forms and supplements; and
   - Addenda.
2. Contract documents:
   - Contract forms (agreement, required bonds, and certificates),
   - Conditions of the contract (general and supplementary conditions),
   - Specifications (organized in accordance with Master-Format Divisions 1–49),
   - Drawings,
   - Addenda, and
   - Modifications.

The project manual is the bound, written portion of the contract documents that provides the core set of project data. The project manual includes bidding requirements, contract forms, contract conditions, and specifications. The project manual is organized based on MasterFormat.

The Construction Specifications Institute's (CSI's) *Manual of Practice* (CSI, 1996) has an informative illustration for construction documents.

3.9.1 Specifications

The "Specifications" section of the contract documents accompanies the drawings and describes in detail the work, design, materials, quality of workmanship, any applicable codes, performance requirements, descriptions, and procedures for alternate material. The Specifications section should detail the requirements of the project and the quality of workmanship from manufacturing through installation and finishing. There are four different methods for preparing specifications (Rosen, Kalin, Weygant, & Regener, 2010):

1. Descriptive—provides description of materials and methods of installation in detail without using proprietary names.
2. Performance—specifies required results and the criteria for verification of the performance. The contractor is free to provide any material complying with the performance criteria.
3. Reference standard—references the established standards to which the specified products and processes should comply or conform.
4. Proprietary—specifies actual brand names, model numbers, and other proprietary information.

Any combination of the four methods mentioned above can be used for sound insulation projects as long as they are "open" specifications, that is, the type required for public work that are written in a way that does not limit competition. Proprietary specifications can be made "open" by adding the phrase "or equal to" after the specified products' trade, brand, model, or style.

Specification language should be clear, accurate, and concise so as not to leave room for interpretation. A well-written specification not only specifies appropriate products and systems, required performance, codes and standards, requirements for product submittals and shop drawings, quality of workmanship, and installation requirements; it also addresses the interrelationship between building products and provides directions for verification.

Additionally, specifications should be clearly organized so that the contractors, estimators, or any individual using the specifications can find the information easily. Organizing the specifications based on divisions of MasterFormat, as published by CSI, and further into its groups and subgroups creates the necessary uniformity with which the construction industry is familiar, minimizes the chance of omission and duplication, and has worked well in sound insulation projects for many years (Rosen, Kalin, Weygant, & Regener, 2010). In this format, the specifications are divided into three parts:

- Part 1—General. Describes the administrative requirements.
- Part 2—Products. Specifies products, equipment, material, and systems.
- Part 3—Execution. Describes the installation requirements from preparation to cleaning.

Table 3-1 is a sample of paragraph categories in a Master-Format section as published in *Construction Specifications Writing: Principles and Procedures* (Rosen, Kalin, Weygant, & Regener, 2010).

Table 3-1. Paragraph categories.

Technical	Non-technical
Materials	Scope of work
Fabrication	Delivery of material
Workmanship	Samples and shop drawings
Installation	Permits
Tests	Warranties
Schedules	Cleaning
Preparation	Job conditions

Although there is a tendency to think that specifications overrule drawings, specifications and drawings are complementary, and together provide the information required for a project. The course of action should be clear in the contract documents in cases where discrepancies become apparent.

A well-designed project accompanying organized and well-written specifications and details will result in a smooth construction process and a long-lasting outcome.

3.9.2 Details

Details are part of the graphic portion of contract documents and show small parts of design on a larger scale to indicate how components and parts are connected. Details enable contractors to construct an item as intended by the designer. In order to minimize confusion during the bidding and construction phase, sufficient details should be provided to cover challenging circumstances and, if necessary, be accompanied with comprehensive photographs. The items in the bulleted list that follows directly impact durability, as shown in previous research projects and also listed in literature such as *Durability Guidelines for Building Wall Envelopes* (Public Works & Government Services Canada, 1997) and *Architectural Detailing: Function—Constructibility—Aesthetic* (Allen & Rand, 2007); these items thereby require special attention in detailing of sound insulation projects:

- **Controlling moisture and water leakage.** There are a number of ways to keep water from penetrating gaps in building assemblies. Incorporating flashing, washes, and sufficient overlapping of weather-resistant material, as well as specifying reglets and rain caps is crucial in water control. When designing for fenestration replacements, it is important to determine the existing condition of the fenestration. In order to accurately prepare a detail for "pocket" installation or "going to the rough" installation, it is important to note any settlements, dry rot, and moisture damage, as well as the squareness of the opening and egress requirements. When replacing fenestration requires replacement of existing frames, details should design for new building paper installation, addition of flashing, and sufficient overlap of the existing building weather-resistant barriers and new ones. Water leakage is less of an issue for pocket installations. However, suitable caulking and sealing must be specified to meet the depth and size of the gaps, and backer rods must be specified when needed. In the event that portions of water-resistant barriers were cut out during fenestration installation, they must be replaced by lapping a proper width of a new piece of water-resistant barrier over the intact weather-resistant barrier, allowing sufficient overlapping, and sealing the overlapping material to the existing one. This will require the removal and replacement of a portion of façade.
- **Dimensional tolerances.** As noted in *Architectural Detailing: Function—Constructibility—Aesthetic*, "A dimensional tolerance is a maximum amount by which a dimension can be expected to vary from the intended measurement because of normal inaccuracies in manufacture and installation" (Allen & Rand, 2007). The joint between the fenestrations and the structure should be carefully detailed since noise will penetrate through the weakest point. For instance, it is acceptable for new window replacements to be somewhat smaller than the opening for ease of installation and for dealing with field conditions. In a sound insulation project, windows must be sized so there is no more than a ¼-in. gap at the sides and 3⁄16-in. gap at the top. In addition, backer wood stripping must be installed for any gaps larger than ⅛ in.
- **Proper support and adequate attachments.** The same amount of attention should be given to the detailing of smaller components of the building as is given to main framing to make sure that they contain the necessary support. For example, acoustical windows are much heavier than regular windows, and it is necessary for them to be sitting on a continuous solid sill to minimize any deflection in the window frame. For the same reason, these windows need to be tied directly to the jamb studs with sufficient attachment to withstand the weight of the window. Large, heavy doors need frames and frame-to-wall attachments. They also require hinges with adequate structural strength.
- **Accommodation of movement.** Allowances must be provided to allow for movements that result from variation in temperature or moisture, especially in design of joints, by specifying flexible sealants.
- **Compatibility of adjacent material.** Chemical compatibility of adjacent material should be considered in detailing. Dissimilar metals in contact with each other may cause galvanic action causing corrosion, and some aluminum alloys corrode rapidly when in contact with mortar or moist concrete. Figure 3-3 shows the aluminum frame of a sliding glass door damaged by magnesite, a common additive to concrete.
- **Control of heat flow.** Although insulation is used for multiple purposes, such as reducing energy consumption or controlling condensation, in sound insulation projects its main use is for noise absorption. Incorrect placement of insulation may cause condensation and affect the durability of building materials.
- **Adequate ventilation.** It is important to design for adequate ventilation in sound insulation projects. The interior of a building will become more airtight after a sound insulation project is complete. Lack of ventilation might contribute to product deterioration. Without improving the air quality, the chance for moisture built-up and mold increases, and this speeds up wear and tear on wood frames or sealants that can, in turn, contribute to failure of intended performance.

Source: THC

Figure 3-3. Damaged aluminum frame.

- **Constructibility.** A good detail should not be too difficult to achieve in order for construction to proceed smoothly and economically. A constructible detail will produce fewer defects and fewer disputes among the stakeholders. Constructibility can be summarized in three general guidelines (Allen & Rand, 2007):
  - A detail should be easy to assemble;
  - A detail should be forgiving of small inaccuracies and minor mistakes; and
  - A detail should be based on efficient use of construction facilities, tools, and labor.

Another item that the designer should pay close attention to in detailing for sound insulation projects is noise and vibration control of new mechanical systems. It is important to minimize the noise and vibration that the HVAC system generates as well as the noise it transmits from the exterior. Specifications for vibration isolators, determination of the best location of HVAC systems, utilization of correct duct material and size, and elimination of direct open air paths from exterior to interior are important considerations in detailing HVAC systems.

Organizations such as the ASTM International (ASTM), the American National Standards Institute (ANSI) or Underwriters Laboratories (UL) have created numerous standards for materials and construction assemblies that can be referenced for details and specifications to create a baseline of safety, performance, and quality in the work that meets code requirements and designers' expectations.

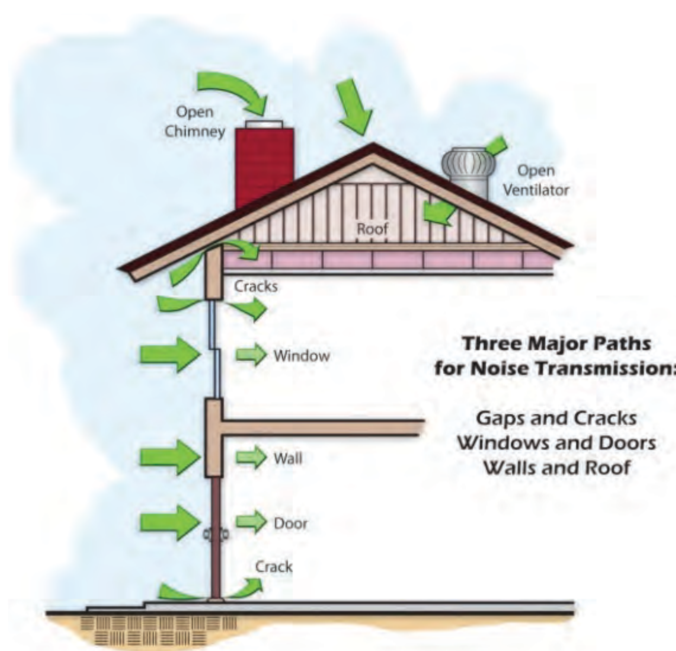
3.10 Treatment Options

Noise penetrates into a building either through direct paths—such as cracks in walls or joints between the fenestration and walls—or by vibrating the partition. In the case of aircraft sound insulation projects, the building envelope is the partition between the aircraft noise and the interior of the building. The main goal of a sound insulation project is to minimize the transfer of noise into the building. This goal can be achieved by following the steps presented below (Wyle, 1992) and illustrated in Figure 3-4:

- Eliminating openings and flanking paths,
- Reducing the vibration of the partition,
- Designing the interior surface to minimize the conversion of vibration into radiated sound, and
- Increasing absorption between the noise source and the interior.

Usually a standard design package of acoustic products and materials is created to ensure that the noise reduction goals are achieved. The envelope of the home, attic space, roof openings, mechanical penetrations to the exterior, and other passive openings to the exterior are acoustically treated. Interior walls, doors, garage windows, and so forth, do not require treatment.

Sound insulation programs mostly use a basic design principle of "like-for-like" that means, in most cases, windows and doors are replaced with new acoustic products of the same type and operation as those existing. Other treatment options



Source: Wyle

Figure 3-4. Noise paths.

are available, such as repairing or reinforcing fenestration, if replacement is not an option. Some examples follow:

- Example 1: Sliding glass doors will be replaced with new acoustic sliding glass doors.
- Example 2: French doors will be replaced with new acoustic French doors.
- Example 3: Windows must be replaced with new, similar acoustic windows. Remodeling and/or resizing existing window openings are accepted only for egress compliance or on a case-by-case basis, as permitted by the programs.

Guidelines for Sound Insulation of Residences Exposed to Aircraft Operations (Wyle, 1992) includes a complete discussion of how the building envelope behaves in the presence of aircraft noise, as well as treatment options for the building elements. Table 3-2 is built upon the infor-

Table 3-2. Treatment options.

Building Component	Treatment Option[1, 2, 3]
Wall	Adding one layer of gypsum wall board to the interior.
	Adding sound board and gypsum board.
	Hang the gypsum boards on resilient channels.
	Frame out the interior wall using 2x framing and add gypsum board and insulation.
Ceiling with attic	Add insulation as needed.
	Remove the existing ceiling tiles. Install a new 5/8" gypsum board ceiling hung using resilient channels with batt insulation above.
Vaulted ceiling	Add 5/8" gypsum board to existing ceiling.
	Add 5/8" gypsum board to existing exposed beams and add insulation above.
	Hang the ceiling gypsum board(s) using resilient channels and add insulation above.
Roof	No treatment.
	Add secondary roof.
Windows	Replace with STC-rated window.
	Improve weather stripping and add secondary window.
	Improve weather stripping.
	Replace glazing with 1/2" laminated glass.
	Add 1/4" secondary glazing.
Skylights	Replace skylight with STC-rated skylight.
	Add secondary skylight to the interior.
Swing doors	Replace door with new STC-rated door.
	Replace door and STC-rated storm door.
	Improve weather stripping and add storm doors.
	Improve weather stripping.
Garage access doors	Replace with solid core door and improve weather stripping.
Sliding glass doors	Replace door with new STC-rated door.
	Replace door and add STC-rated storm door.
	Improve weather stripping and add storm doors.
	Improve weather stripping.
Attic vents	Do not treat.
	Add noise control baffle.
Attic access panel	Replace with 1/2" plywood panel/attach insulation.
Crawl space	No treatment.
	Add underfloor noise control baffle to vents.
Fireplace	Add glass doors.
	Add chimney top damper.
	Add glass doors and chimney top damper.
Kitchen vents	Add noise control baffle.
Bathroom vents	No treatment.
Misc. opening	Close off.
	Add noise control baffle.
Ventilation and/or HVAC	To be added.

1. Comply with all codes and regulations.

2. Refer to ACRP Project 02-24 and *Guidelines for Sound Insulation of Residences Exposed to Aircraft Operations* (Wyle, 1992) for detailed information.

3. The acoustical consultant is to decide on appropriate treatment (i.e., not all projects need wall treatments, existing condition and the structure of the wall will contribute to decision for wall treatments).

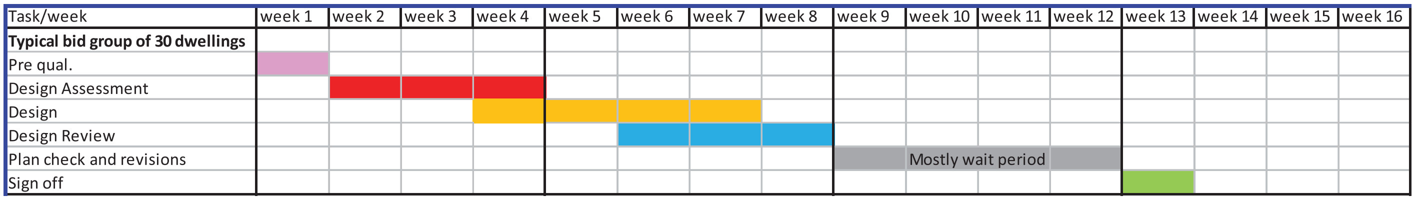


Figure 3-5. Design phase timeline.

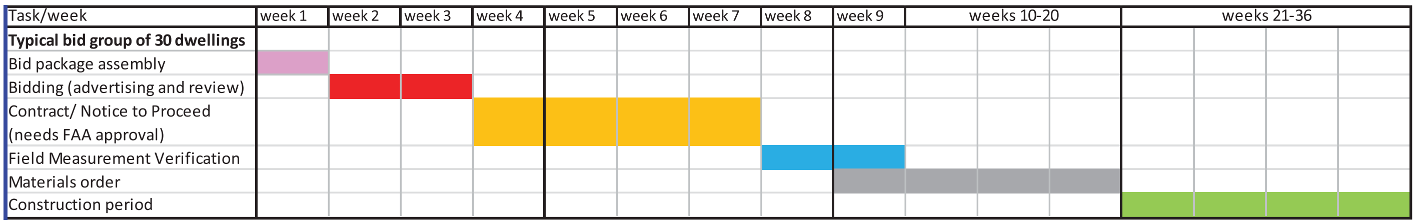


Figure 3-6. Construction administration phase timeline.

mation presented in *Guidelines* (Wyle, 1992), acoustical engineering, and experience gained through many years of performing sound insulation projects. The selection of each treatment option or combination of options is dependent on the existing condition of the building and its relation to the aircraft path, the cost, the acceptable standard package, and the owner's preference, as long as it is a viable option.

3.11 Timeline

The approximate timeline required for the design and construction administration phases for a bid group of 30 dwelling units is shown in Figures 3-5 and 3-6. This timeline can vary and be adjusted depending on program needs and the speed they require.

Section 4 discusses the products used for treatment options in more detail.

Summary—Design Options

1. Maintain a consistent treatment approach among eligible homes and neighborhoods. Create a standard design package to ensure that noise reduction goals are achieved.
2. Incorporate plan check corrections and potential FAA review recommendations into the design prior to obtaining owner concurrence for any changes and releasing the package for bidding.
3. Provide a clear course of action in the contract documents for any discrepancy between specifications and drawings.
4. Provide sufficient details to describe the work. Utilize details that are field tested and incorporate standards such as ASTM, ANSI, and UL for materials and construction assemblies when available. Pay special attention to detailing, especially for moisture control, and provide adequate fastening and proper support for new products.

SECTION 4

Current and Future Products

In the early days of airport sound insulation programs, acoustical products were hard to find, and those that were available were designed primarily for commercial applications. Over the intervening years, as sound insulation programs progressed and became more numerous, manufacturers responded to market needs and feedback from consultants and contractors with many new products.

However, due to the high cost involved and the lack of a substantial market to absorb this cost, further design changes in existing acoustical products and/or development of new products are not expected in the future. As one manufacturer has noted, "There is no market to drive the R&D [research and development] on new sound-attenuating products. It costs too much money to test and re-tool the plant to accommodate a new product, and the sound attenuation market is decreasing."[1]

It is important to note that some changes in the design of acoustical products have been incorporated and will continue to be incorporated to satisfy new energy and environmental codes. As these codes evolve or new building codes are introduced, changes in product material or design are expected.

4.1 Windows

From an acoustical and thermal perspective, exterior windows are one of the weakest parts of a building envelope. Even after all gaps and leaks have been repaired, the windows typically need to be modified in order to achieve the sound insulation goal. There are three treatment options for modifying windows:

- Replacing the window with a new non-acoustic window and adding a secondary window,
- Replacing the window unit with an acoustical window, or
- Adding a secondary window to the existing window.

[1] Sound Insulation Program Stakeholders Meeting Summary, March 6, 2013, Los Angeles, CA.

The most common option is to replace the windows with specially designed acoustic windows. Improvements in manufacturing processes and materials have made available high-quality windows with high Sound Transmission Class (STC) ratings in both vinyl and aluminum frames, as well as composite windows. Figures 4-1 and 4-2 are examples of the available acoustical window configurations. Section 9.4.1 of *ACRP Report 89* provides additional information on window materials (Payne et al., 2013).

Sound insulation programs have faced multiple issues in the past regarding window treatments. These issues are listed below, and close attention should be paid to these items during the sound insulation process:

- **Thermal break failure.** As explained in Table 1.1, thermal breaks are susceptible to damage in colder climates. Iso-bar thermal breaks have shown superior performance to poured and debridged thermal breaks and might be a better option for projects located in harsh climates.
- **Window frame thickness and alloy.** In early years, the thickness of window frame extrusion was not sufficient, and some of the windows experienced deformation. This issue can be resolved through requiring a minimum frame thickness or specifying stronger alloy.
- **Window sizing and minimum/maximum sizes.** Designers should review the minimum and maximum sizes constructible by each specified manufacturer before designing a window or door. These minimum and maximum sizes might be revised from time to time by manufacturers. It is advisable for architectural/engineering (A/E) firms to review their records with manufacturers and have a system to receive any updates as soon as they become available. There are times when manufacturers are willing to accommodate larger or smaller sizes than are indicated in the minimum/maximum sheets. In these circumstances, the manufacturer should confirm in writing that the new size is covered under the same warranty as their other supplied products. A/E firms

Figure 4-1. Acoustical windows (available in fixed, slider, and casement configurations).

also should ensure that the products operate without any problem and meet all requirements specified in the construction documents.

- **Adequate fastening and support.** Some of the issues observed in ACRP Project 02-31 related to sagging of the windows or malfunction because sufficient attachment to structural members was not provided, or the windows did not receive continuous support at the sill. While this fact should be taken into consideration in designs and sufficient and accurate details should be included, a thorough construction management should enforce the intended design.
- **Proper flashing.** Section 3.9 discusses the issue of water damage and the need for proper flashing.
- **Dirt buildup.** Buildup of dirt on the sliding tracks of horizontal slider windows and sliding glass doors can cause difficulty with operation. This is a maintenance issue and should be discussed with owners.
- **Finishes.** Proper finishing is discussed in Section 4.5.

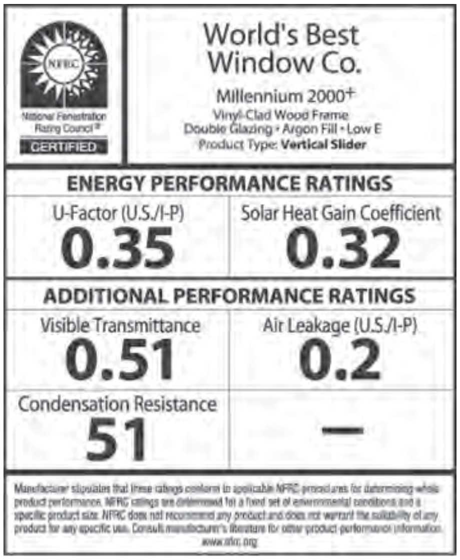
Figure 4-2. Example of non-rectangular acoustical window.

4.1.1 Code Requirements

There are multiple codes and regulations that must be considered during the manufacturing and design of window units, including building codes, environmental regulations, and energy codes. Building codes, including light and ventilation requirements as they relate to windows or egress windows, have been largely incorporated in designs.

In recent years, increased attention has been directed toward energy saving requirements in buildings. This has resulted in new energy codes for the efficiency of building components including windows, their design, and installation. These codes are becoming increasingly stringent and requiring greater efficiency. Because these codes are evolving, they require close attention, especially during manufacturing and specification of products. For example, there are now more stringent "U" Values and Solar Heat Gain Coefficient (SHGC) requirements in some states, along with new requirements for testing and labeling. Figure 4-3 shows an example of an approved label for fenestration by the National Fenestration Rating Council (NFRC). New requirements have prompted manufacturers, especially aluminum window manufacturers, to redesign their windows using different glass combinations and glass coating and/or introducing argon infill between the glass panes.

Windows incorporating these design changes are largely untested in sound insulation programs, but it is not likely that the changes will have much effect on the longevity of the products. Designers should review manufacturer changes to window design and consider compliance with additional



Source: NFRC

Figure 4-3. NFRC-approved temporary label.

standards if necessary. In addition, the necessity of maintenance and its effect on the longevity of the treatments should be discussed with owners. Post-construction follow-ups could also be considered. This will be discussed further in Section 7-2.

4.1.2 Performance Standards

Performance standards are used to rate windows on the basis of how they perform at a job site and to provide a uniform basis for comparing the performance of key attributes of different manufacturers' products (AAMA, 2006).

Acoustical performance is one of the most important attributes of windows in a sound insulation project. Sound transmission loss tests conducted by a laboratory accredited by the National Voluntary Laboratory Accreditation Program (NVLAP) in accordance with ASTM E90, "Standard Method for Laboratory Measurement of Airborne Sound Transmission Loss of Building Partitions," should be specified. The STC rating should be calculated in accordance with ASTM E413, "Standard Classification for Determination of Sound Transmission Class." Windows also should comply with AAMA/WDMA/CSA 101/I.S.2/A440 Standard/Specification for Windows, Doors and Unit Skylights, which is a voluntary standard/specification and covers requirements for windows, doors, and skylights in new construction and replacement applications. This standard covers testing procedures and performance rating for structural performance under wind loading and the level of resistance to air leakage, water penetration, and forced entry.

In addition to compliance with AAMA/WDMA/CSA 101/I.S.2/A440, sound insulation programs have benefitted from the following testing for acoustical windows, which is recommended for all programs:

- **Structural performance.** The uniform load structural performance should be tested in accordance with ASTM E330, "Test for Structural Performance of Exterior Windows, Curtain Walls, and Doors by Uniform Static Air Pressure Difference." Windows should be tested in both the summer and winter modes and show no glass breakage at positive and negative test pressure of 37.5 psf.
- **Operating force.** The maximum operating force for initiating motion or maintaining motion is determined by ASTM E 2068, "Standard Test Method for Determination of Operating Force of Sliding Windows and Doors," and should meet the requirements of the class of window and any applicable codes. Most sound insulation programs require the force not to exceed 25 lbf for horizontal sliding sashes, and 35 lbf for vertical sliding panels.
- **Air infiltration.** Air infiltration should be conducted in accordance with ASTM E283, "Standard Test Method for Determining Rate of Air Leakage through Exterior Windows, Curtain Walls, and Doors under Specified Pressure Differences across the Specimen." A value of less than 0.15 cfm/ft^2 when tested at 25 mph static test wind pressure load (1.57 lb/ft^2) has been specified for acoustical windows in most sound insulation programs.
- **Water penetration.** No leak should be evident when tested with a water test pressure of at least 4.5 psf cyclic static pressure at 5 gal/hr/ft^2 in accordance with ASTM E331 or ASTM E547, "Water Penetration of Exterior Windows, Skylights, Doors and Curtain Walls by Uniform (for E331) or Cyclic (for E547) Static Air Pressure."
- **Thermal performance.** The thermal transmittance U value should be measured in accordance with AAMA 1503, "Voluntary Test Method for Thermal Transmittance and Condensation Resistance of Windows, Doors and Glazed Wall Sections," by an AAMA-accredited laboratory. U-values and SHGC should meet the requirements of local codes and the criteria of any other required certifications, such as NFRC.
- **The condensation resistance factor (CRF).** CRF will be determined in accordance with AAMA 1503, "Voluntary Test Method for Thermal Transmittance and Condensation Resistance of Windows, Doors and Glazed Wall Sections," by an AAMA-accredited laboratory.

Refer to Section 9 of *ACRP Report 89* for additional details on performance testing and AAMA/WDMA/CSA 101/I.S.2/A440 (Payne et al., 2013).

4.2 Doors

Similar to windows, doors are a weak link in sound insulation performance. Almost all typical residential doors require replacement or modification in order to meet the sound insulation goals of a project. These modifications include repair or replacement of the existing door by adding secondary acoustical storm doors or replacing the existing doors with specially designed, high-STC-rated, acoustical doors. Acoustical doors are available in wood or steel.

4.2.1 Wood Doors

For aesthetic reasons, acoustical wood doors are more popular than metal doors for residential applications, despite the fact that sound insulation programs have encountered multiple problems with wood doors (see Figure 4-4 for examples of acoustic wood doors). As a result of feedback from sound insulation programs across the country, some of these problems have been resolved and designs greatly improved. Wood door manufacturers have introduced design changes over the years

Figure 4-4. Flush or glazed acoustic wood doors (also available with decorative grids).

to reduce the weight of the doors and enhance the core bonding with the veneer. However, there are ongoing issues related to wood doors that require attention and corrective action.

Delamination of the doors is one of the main issues from the early years of sound insulation programs that continues to cause problems. Acoustical wood doors are composed of different layers of insulation material and veneer bonded together, and this combination is susceptible to moisture absorption, which can cause the door to delaminate.

In general, the durability of wood products is closely related to how these products are maintained. Maintenance is crucial for making sure that the wood doors perform as intended for a long period of time.

It is equally important to properly finish the wood doors. Application of a sealer/primer and first coat in the warehouse, under dry, controlled conditions, or pre-primed doors should be specified. Additionally, close attention should be paid to finishing the edges and cutouts. Inspection of the door finish by a seasoned construction manager, especially at the door edges and at holes cut through the door for hardware, is an important step and should be followed strictly during the door installation.

As technology has advanced, the construction of the door core and the way it is bonded to the door skin has improved. This has allowed door manufacturers to increase the warranty period from 1 or 2 years to 5 years. However, in order for the warranty to be honored, restrictions and requirements such as these must be met:

- Overhangs of 4 ft or the installation of a storm door are required to protect wood doors against moisture and/or ultraviolet rays,
- Paint color is restricted,
- Combining stain and paint is not allowed, and
- Oil-based paints are required.

The vulnerability of acoustic wood doors to moisture is an ongoing issue and requires further improvement or a design change.

4.2.2 Sliding Glass Doors

Due to its large area of glass, a sliding glass door transmits a considerable amount of noise. In the early years of sound insulation programs, the treatment of sliding glass doors was limited to the installation of an additional sliding glass door assembly acting as a storm door. There were no high-STC-rated products available for replacements. Today, replacement sliding glass doors are available in both vinyl and aluminum with STC ratings as high as 38 (see Figure 4-5 for examples of acoustic sliding glass doors). Due to problems that programs have faced with secondary storm doors, replacement sliding glass doors are the best option. However, there are circumstances in which it is necessary to both replace a sliding glass door and add a secondary door. These circumstances include a high exterior noise level, the location of the property in relation to aircraft path, and environmental conditions.

Figure 4-5. Two-panel and four-panel acoustic sliding glass doors.

4.2.3 Storm Doors

Storm doors can be offered in many programs and currently can provide an STC rating of up to 32. Storm doors are used for the following:

- Achieving the acoustical goal,
- Maintaining the warranty of the prime door,
- When the owner declines replacement of an existing door, and
- Environmental conditions.

Storm doors are available in full glass or self-storing versions and can be combined with security grilles to also perform as security doors (See Figure 4-6 for examples of storm doors).

A substantial number of complaints related to malfunction of storm door hardware have been received from homeowners. In most cases, the manufacturers have replaced the faulty hardware and subsequently made simple design changes in order to minimize the problem.

Refer to Sections 5.2.5 B, 9.4.2, and 9.4.3 of *ACRP Report 89* for additional information on doors (Payne et al., 2013).

4.2.4 Code Requirements

Codes that have particularly affected wood doors are those related to exit doors, minimum width/height, safety glass requirements for glazed doors, fire rating, and threshold height requirements. As with windows, the sustainability and energy requirements in some jurisdictions have mandated new codes and regulations such as stringent U value and SHGC for doors with more than 50% glass area and caps on off-gassing of pollutants such as volatile organic compounds (VOCs) and formaldehyde. These requirements have prompted door manufacturers to carefully review their products and perform new testing for compliance with these regulations. In summary, as programs become greener, manufacturing becomes more difficult, new testing has to be performed, new maintenance manuals might need to be developed, and, in all the programs, additional involvement may be required after construction is complete.

4.2.5 Performance Standards

As with windows, it is essential to set standards for doors and test their performance.

The acoustical performance of doors is determined by laboratory sound transmission loss tests, and these are conducted in accordance with ASTM E90, "Standard Method for Laboratory Measurement of Airborne Sound Transmission Loss of Building Partitions," by an NVLAP-accredited laboratory. The STC rating should be calculated in accordance with ASTM E413, "Standard Classification for Determination of Sound Transmission Class."

Like windows, doors should comply with AAMA/WDMA/CSA 101/I.S.2/A440, Standard/Specification for Windows, Doors and Unit Skylights, a voluntary standard/specification. Other applicable performance tests include operating force for sliding glass doors, air infiltration, water penetration, and thermal performance.

Figure 4-6. Full glass and self-storing storm doors.

4.3 Window and Door Hardware

Specifying standards for the operable components of windows and doors is a critical step in ensuring the performance and longevity of the product. Window hardware includes everything from locks and handles to balances and ventilation stops. Door hardware includes everything from handles and locks to seals and thresholds.

The Builders Hardware Manufacturers Association (BHMA) is accredited by ANSI. BHMA is a private non-profit organization that administers and coordinates voluntary standardization to develop and maintain performance standards for builders' hardware. ANSI/BHMA standards set forth different product grades for door hardware products. These product grades are defined by progressive levels of performance benchmarks in each applicable standard:

- Grade 1 certification—a commercial quality lock designed for heavy use in commercial and public buildings;
- Grade 2 certification—a residential quality lock, designed and built for most residential applications and light commercial applications; and
- Grade 3 certification—the minimal acceptable quality for residential door locks.

For application to sound insulation programs, it is recommended to specify Grade 2 certification for door hardware.

In addition to adhering to the ANSI requirements, the following design features should be outlined in the specifications:

- Handle design (e.g., knob and lever),
- Lockset/deadbolt locking methods, and
- Finish options (most programs offer homeowners a selection of finishes for the door handle, lockset, and hinges).

Malfunction of window or door hardware is one of the reported reasons for failure of windows and doors in their sound insulation performance. In ACRP Project 02-31 research, many homeowners reported poor window functionality such as difficulties with opening and closing. Although the mechanical deterioration of windows and doors noted in this research did not necessarily translate into deficient acoustical performance, careful design and quality control by the manufacturer along with specifications of standards and verification during the construction process will provide better-functioning hardware. Additionally, all hardware must be carefully examined during construction and replaced subsequently if any issues are noticed.

4.4 Insulation

Thermal performance, sound control properties, code-related limitations, and green initiatives should be taken into account for selection of insulation products. Considering the overall life performance of insulation is particularly valuable due to the long-term performance goals associated with sound insulation programs. Blown loose-fill insulation will settle over time, and this fact directly affects the R value and acoustical performance of the installation. Settlement of thermal insulation with age is an important consideration in specifying insulation products. A review of the early sound insulation programs indicates that batt insulations outperformed blown loose-fill insulation.

It has been noted that few products are installed at one density and, over a short period of time, show a change in density (Derbyshire, 1980). However, cellulosic loose-fill thermal insulation is a product with such changing character. Because of this changing character, two terms, *initial density* and *settled density*, exist in the loose-fill thermal insulation industry to define the density at the time of installation and after installation, respectively (Derbyshire, 1980). Therefore, if specifying loose-fill insulation, the settled density should be considered and test methods accordingly specified. ISO 18393-1:2012 specifies a test method for the determination of settlement of blown loose-fill insulation applied horizontally in ventilated attics.

4.5 Finishes

4.5.1 Importance of Proper Finishing

Wood products in general are prone to moisture and ultraviolet damage, and therefore proper coating is immensely important in protecting wood products such as acoustical wood doors, wood frames, and cladding. Many new wood windows are protected by a durable exterior finish or cladding that prevents moisture from forming underneath (EWCG, 2011).

Likewise, aluminum frames, although strong and inherently corrosion resistant in most environments, are susceptible to corrosion in oceanside environments. Therefore, anodizing and properly sealing or painting the aluminum frames should be specified.

The technical specifications should indicate the type of paint that is suitable for the project, application methods and proper preparation of substrate, the environmental conditions under which the paint should be applied, the number of coats, and/or any other applicable information. The finish specifications should be carefully reviewed and compared with project specifications and applicable code. Plans should direct that the manufacturer's application guidelines be carefully followed.

4.5.2 Code Requirements

Construction activity may cause toxins, such as VOCs, to enter interior spaces through use of substances and material that off-gas—paint, flooring, stains, varnishes, plywood, carpeting, insulation, and other building products. The U.S.

Environmental Protection Agency (EPA) has established a nationwide VOC limit for interior/exterior coatings of 250 grams per liter (g/l) for paints and other similar caps for stains, sealers, primers, and other coatings. Nonetheless, many states and regional districts require significantly lower levels. Similar to national voluntary green rating systems such as LEED for homes and the ANSI National Green Building Standard, CALGreen 2010—the nation's first green building code—caps paint VOC content under the mandatory measures, at 50 g/l for flat products and 100 g/l for non-flat products. The South Coast Air Quality Management District (SCAQMD) in California, for instance, limits VOC emissions to 50 g/l for both flat and non-flat gloss level paints (primers are 100 g/l to allow for metal primers).

Requiring low VOC/formaldehyde content may mean revising installation instructions and/or post-construction care of affected products, such as wood doors, to ensure longevity.

4.5.3 How to Select

"Selecting Green Paint," an article published in the U.S. Green Building Council's *Green Home Guide*, points out that oil-based paints or finishes use binders derived from petrochemicals (Pennock, Cordaro, Landman, & Maas, 2009). Oil-based paints are very durable and water resistant and therefore appropriate for exterior applications or high-abuse applications such as kitchens, hallways, and schools. However, because of their petroleum-based binders and carriers, oil paints typically emit more VOCs than other paint types.

Water-based (latex) paints use water as the carrier rather than petroleum-based solvents. Latex paints have lower VOC levels than oil-based paints. Therefore, to meet project requirements, water-based (latex) paint can be substituted for oil-based paint. Latex paints are often blended with acrylics to improve performance; higher quality, 100%-pure acrylics are more durable (Erhlich, 2012). Low- and no-VOC latex paints perform well, and their performance has improved significantly in recent years. High-quality latex paint can be as durable as oil paint.

There are third-party certification systems that have tested and certified finishes for durability and sustainability. The most common third-party certifications are Green Seal and Master Painters Institute (MPI). MPI X-Green and Green Seal GS-11 both test for performance and environmental attributes. MPI, in particular, has specific criteria for each paint type, evaluating paint gloss levels, how scrubbable the paint is, its hiding power, and a number of other characteristics (Erhlich, 2012).

The American Architectural Manufacturers Association (AAMA) also has specifications, performance requirements, and test procedures for fenestration components that can be useful in finish specification. Examples are AAMA 633-11 (Voluntary Specification, Performance Requirements and Test Procedures for Exterior Stain Finishes on Wood, Cellulosic Composites and Fiber Reinforced Thermoset Window and Door Components) or AAMA 2605-11 (Voluntary Specification, Performance Requirements and Test Procedures for Superior Performing Organic Coatings on Aluminum Extrusions and Panels).

4.6 Caulk and Sealants

Caulk is an important tool in preventing air leaks, water penetration, and noise leaks. Due to structure settlement or aging, the caulking surrounding building components may crack or deteriorate with time. Test results of dwelling units tested under ACRP Project 02-31 have indicated that this factor can contribute to overall poor acoustical performance of a structure. Therefore, it is recommended that high-performing caulks be used for all sound insulation programs. Even though modern caulking products are formulated for better durability, the materials still age and crack eventually. Plans should incorporate procedures to obtain an owner's acknowledgment of the responsibility to refinish or replace the caulking as needed. AAMA 800-10 (Voluntary Specifications and Test Methods for Sealants) includes a compilation of standards and test methods for determining the performance of compounds, sealants, and tapes used either in manufacturing or installation of windows and sliding glass doors.

4.7 Performance and Durability of Green Products

"The performance of green building material, as with conventional building products, depends on durability, appropriate application and proper maintenance" (Froschle, 1999). Since sustainability is growing in popularity within the building and construction industries, in general, and within sound insulation projects, in particular, it is important to spend upfront time and energy researching the new green products, specifying durable material, outlining proper applications, and verifying the information provided by the manufacturer.

The demand for green products has increased the variety of products. Although this variety is simultaneously appealing to designers and specifiers, it creates a challenge in verifying manufacturers' claims. Some manufacturers might exaggerate the environmental qualities of a product whereas others might not specify all characteristics of their products. Specifications may require independent research in assessing manufacturer claims, requiring standardized durability tests when available, and third-party certifications.

Many factors can play a role in the selection of green building material, such as resource efficiency, recycled content, energy efficiency, moisture resistance, minimal chemical emission, life cycle, and durability. Ideally, the architect should determine which of the factors listed above are playing a role in the project and review the applicable standards before selecting a product.

Green product standards can range from government regulations and guidelines (e.g., the EPA Comprehensive Procurement Guidelines for recycled content in products) to industry guidelines (the Carpet and Rug Institute's Green Label program for carpets), to third-party certification standards (e.g., Green Seal standards for paints and Forest Stewardship Council [FSC] standards for wood products). Because of the detailed criteria spelled out in green product standards, these standards can assist in the development of project specifications. Specifiers should also take into consideration that some green products may be subject to limited availability or long lead times.

All of the above factors should be considered in the preparation of technical specifications. Product specifications should describe in detail the product characteristics that make it an environmentally friendly material, such as low toxicity, recycled content, recyclability, moisture resistance, and environmentally conscious installation procedures (Froschle, 1999). The specifications should clearly identify required standards, applicable codes and regulations, required third-party testing, installation procedures, and expected warranties.

4.8 Product Longevity and Warranties

Unfortunately, there are few metrics available to architects and the construction industry to measure durability (Mathis, 2007). Product warranties are one of the few items that reliably predict durability because warranty of the product indicates the length of time that the quality of the product will be maintained. Each product should ideally be required to be covered for a minimum specified time period in the specifications. The amount of time is determined through industry standards and requirements of the project.

Fenestration is the most critical item in a building affecting sound insulation and energy performance. Therefore, the warranty provisions should be carefully specified. These provisions include warranties for glass, insulated glass, finishes, material, hardware, transferability, and exclusion. It is recommended that all window parts be covered by a transferable warranty for a period of 10 years or more. Similarly, acoustic storm doors and sliding glass doors ideally should be covered by warranty for 10 years or more.

Exterior wood doors are required to be covered for 5 years or more. Wood by nature is vulnerable to moisture absorption, specifically acoustic wood door construction that is made out of multiple layers of wood, veneer, and sound-absorptive material. Although door manufacturers provide a 5-year warranty, the warranty includes many restrictions that limit a manufacturer's obligation to honor the warranty, as explained in Section 4.2.1. Therefore, it is recommended that a door manufacturer's requirements are followed to the extent possible in order to maintain the warranty. In the event that it is not possible to follow those requirements, different approaches should be considered, such as specification of metal core doors and educating the building owners on this issue.

Window and door hardware play an important role in the opening and closing of the window/door, and any malfunction directly affects the window/door performance as it relates to the overall acoustical goal. Window and door hardware should have a warranty period similar to that of the window/door itself, ensuring the unit's performance for that period of time.

Insulation settles over time and this fact affects the thermal and acoustical performance of the insulation. Therefore, an effective warranty is essential in guaranteeing performance. High-performing insulation ideally should be specified for sound insulation projects, with the standard industry limited-lifetime warranty period.

The performance of **finishes** does not directly affect the performance intended by sound insulation projects, since finishes protect the substrates against moisture, ultraviolet damage, or other climatic factors. Nonetheless, it is worth paying attention to the performance of finishes and specifying high-performing paints, especially since some water-based finishes might not meet the durability requirements of sound insulation projects. In selecting finishes, it is not only important to consider environmental factors, it is also important to pay close attention to the period of time that the finish is covered under warranty so as to provide the best protection possible for newly installed products.

HVAC should ideally be under warranty for 5 years or more.

Summary—Product Specifications

1. Incorporate lessons learned from previous sound insulation projects.
2. Pay close attention to code requirements and new energy requirements.
3. Specify appropriate performance standards and testing during product specifications.
4. Consider requiring third-party certifications for performance and environmental attributes.
5. Review product warranty requirements and restrictions imposed on warranties.
6. Verify that the specified products are submitted during the construction administration period.
7. Consider environmental factors while specifying products.

SECTION 5

Construction Administration

The construction phase of a program is a time when all of the work of participant selection, design activities, and production of the contract documents finally comes to the severe test of actual implementation and the expenditure of significant amounts of FAA and sponsor funds.

Poor workmanship and incorrect installation procedures can lead to big problems that may go unnoticed at the time of installation, only becoming apparent at a later date. Applying treatments to a home to improve the sound insulation properties requires much more careful workmanship than contractors are generally used to providing. Thorough and meticulous construction management during every single step of the construction administration program will result in a high-quality project that will meet and exceed all requirements and expectations.

The construction administration phase generally includes the process shown in Figure 5-1 and described in the following sections.

5.1 Bid Advertisement

To ensure an open and fair competition, government entities are required to follow the competitive bid process. State and local governmental entities must take into account various laws and rules when using public money to fund their projects.

Bid solicitations must be carefully prepared considering all the requirements of the contract. Sponsors will often advertise the solicitation on their own website, in local newspapers, in trade publications, and/or on specific Internet-based notification sites. The notification will identify the nature of the work, provide certain deadlines, identify a method by which to obtain more information or ask questions, identify the point of contact for the solicitation, and indicate whether there is a pre-bid meeting. The notification will also explain how a copy of the full solicitation can be obtained. The terms and conditions for bidding on the project are described in the "Instructions to Bidders" section of the contract documents.

Bid packages may contain a small or large number of units. Contractors like larger bid packages of approximately 50–100 homes at a value of $2–5 million. This allows for lower prices (quantity discounts), lower overhead, and quicker production to increase the pace of construction.[2]

Bids must be received prior to the specified time and date at a designated place. All responses to the solicitation must be received by the deadline or they will not be accepted. There is rarely an exception to this rule. Bids received after the deadline will be returned unopened. Timely receipt of bids/proposals is the sole responsibility of the vendor; therefore, it is in the bidder's best interest to take into account the possibility of unforeseen delays when submitting bids. Any interested party can attend the bid opening. In the case of bids where pricing information is contained in the solicitation response, the vendor's name and total price will be announced and recorded. A bidder may withdraw a bid upon written request and approval.

5.2 Bid Review and Contractor Selection

Bids must be carefully reviewed and a responsive contractor with a solid record of performance selected. The review of bid submittals is very complex and includes issues such as review of all required FAA and sponsor's forms and certificates and contractor license validation. The required FAA forms include the following:

- Bidder Statement of Previous Contracts Subject to Equal Employment Opportunity (EEO) Clause,
- Certification of Non-Segregated Facilities,
- Assurance of Disadvantaged Business Enterprise Participation,

[2] Sound Insulation Program Stakeholders Meeting Summary, March 6, 2013, Los Angeles, CA.

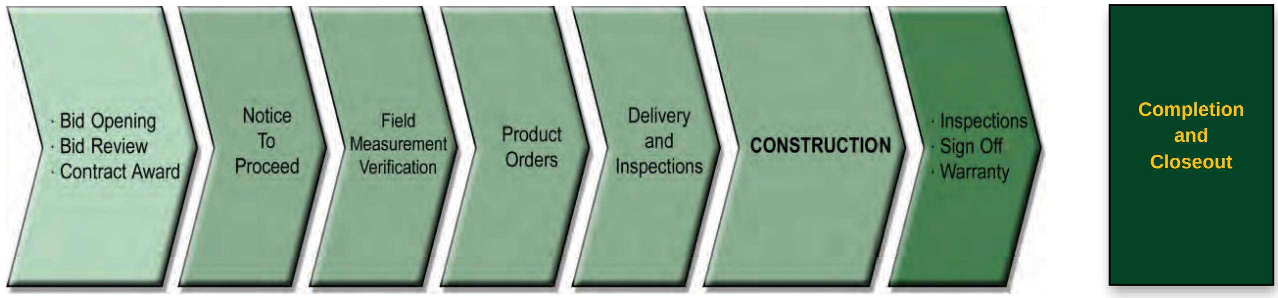


Figure 5-1. Overview of the construction administration process.

- Suspension and Debarment Requirements for All Contracts Over $25,000, and
- Buy American—for steel and manufactured products.

Residential sound insulation projects do not require a large-, or even medium-size, general construction contracting corporation, so smaller firms will attempt to bid. Review of these firms' bids requires particular attention to financial condition and past history in other noise-mitigation or related projects.

A bid is responsive if it provides all of the information requested. This evaluation is usually strict and the consequences often harsh. Failure to sign a form or include a certain document can result in the entire bid being rejected.

Once the evaluation process is concluded and the bidders are ranked, the most highly ranked bidder will be awarded the contract. The winning bidder will normally be notified of the award by telephone, email, or letter. Sometimes awards are announced at a public meeting. Once the contract is awarded, the winning bidder must either enter into a contract with the government entity or negotiate a contract. Often times, the contract is included in the solicitation document so the bidder knows the terms of the contract in advance.

5.3 Contractor Training

It would be a good practice if the technical specifications of a project required the product manufacturer to be at the project site for the first few days, observe the installations, and provide feedback. This issue was discussed in the Sound Insulation Stakeholders Program Meeting,[3] and the contractors were open to the practice, but the manufacturers stated that they would not be able to absorb the cost if they had not planned in advance for reimbursement.

Aside from requiring the manufacturers to be present at the site, there are other training opportunities available that can be incorporated into technical specifications. Examples of these training opportunities are the AAMA InstallationMasters™ courses available nationwide for new construction and replacement of windows and exterior glass doors in residential and light commercial markets and routine training sessions provided by manufacturers at their site.

5.4 Pre-Bid and Pre-Construction Conferences

A pre-bid meeting involves meeting potential bidders and discussing the project requirements, FAA requirements, and other regulations affecting the project and highlighting the differences between a sound insulation project and other projects in which the contractor may have been involved. The purpose of a pre-bid conference is to promote a dialogue between the contractors and the project staff; to provide bidding instructions; and to ensure that contractors understand how to interpret the contract documents—including the plans, specifications, and details. Contractors will be encouraged to ask questions during the pre-bid conference and prior to bid deadlines.

A pre-bid conference is a useful forum for discussing common problems encountered during bidding and construction. It ensures a competitive bid process and can provide clarification of techniques for installing acoustical windows and unique or complex specifications requirements. Any changes to the plans or schedules can be discussed at this meeting, and the expectations of the program can be underlined. It is a good practice for all programs to host mandatory pre-bid meetings and require potential subcontractors to be represented at the pre-bid and pre-construction meetings.

At the pre-construction meeting, guidelines for construction coordination, directions to contractors, and change order control will be highlighted. Other topics covered will include goals and objectives, working with property owners, payment, sound insulation basics, schedule, submittals, and other policies and procedures.

For additional information, please refer to FAA's *Advisory Circular 150/5300-9B* (AAS-100, 2009).

[3] Sound Insulation Program Stakeholders Meeting Summary, March 6, 2013, Los Angeles, CA.

5.5 Submittal Review

Submittals by the contractor consist of all the proposed product and material information required by the contract documents, including forms to be used by the prime contractor and payment forms and samples of certified payroll, key schedules, warranties, and physical samples. Product submittals review should be comprehensive and check all required performance, required tests, and code compliance factors.

The submittals should include a transmittal letter to list the applicable specifications section number, title, paragraph number, and drawing detail as references for the submittal. This will facilitate the submittals review process. All submittals should be reviewed for conformance with contract documents and approved by the contractor before submission to the architect. AIA Document A201™, General Conditions of the Contract for Construction, (A201) states:

> By approving and submitting Shop Drawings, Product Data, Samples, and similar submittals, the Contractor represents that the Contractor has determined and verified materials, field measurements and field construction criteria related thereto, or will do so, and has checked and coordinated the information within such submittals with the requirements of the Work and of the Contract Documents.

The architect may return the submittals that are not marked as reviewed for conformance with the contract documents and approved by the contractor without any action. A201 states:

> The Contractor shall perform no portion of the Work for which the Contract Documents require submittal and review of Shop Drawings, Product Data, Samples or similar submittals until the respective submittal has been approved by the Architect.

Product submittals should be reviewed to ensure submitted products adhere to the requirements of construction documents and applicable codes by the architect. In general, the architect's role in reviewing the submittals is to make sure the submittals follow the design content and are in conformance with the contract document. According to A201:

> . . . Review of such submittals is not conducted for the purpose of determining the accuracy and completeness of other details such as dimensions and quantities . . . all of which remain the responsibility of the Contractor . . .

The architect marks up the submittals accordingly. The architect also marks up the submittals that are reviewed by subconsultants for their effect on the architectural work, noting that the review is for architectural scope only. After the review, the architect affixes the stamp, specifying whether the submittals are satisfactory or follow-ups are necessary (Atkins & Simpson, 2006). Options may include "approved," "no exceptions taken," "approved as noted," "revise and resubmit," and "rejected."

Deviation from basic materials, manufacturers, models, and sizes should be noted in the review process, and resubmission should be requested if necessary. Minor deviations can be corrected by a simple notation on the submittals. When the contractor intends to submit a product that deviates from the contract document, a substitution request should be submitted in accordance with the requirement of the contract documents, allowing enough time for review and acceptance.

The following are steps to improve the submittal review process:

- Allow adequate review time in the owner-architect agreement for review of the submittals.
- Have the contract documents require a submittal schedule.
- Review the submittal process in the pre-bid meeting and again during the pre-construction meeting.
- Use a checklist. Compiling a checklist of items for review along with products' attributes, such as required tests, is useful and facilitates the submittal review process. This checklist can be distributed to contractors during the preconstruction phase to assist them with the preparation of submittals and ensures a smooth and flawless submittal review phase. Figure 5-2 shows an example of a windows submittal checklist.
- Create a detailed log. A detailed log of submittals, including description, contractor, date of receipt, and note of approval and resubmit or rejection should be prepared and distributed to the project team. At least three copies of each submittal are typically provided. One copy is retained by the architect, one by the city and one is returned to the general contractor.

5.6 Product Inspection

To deal with quality control of delivered products, it is best for programs to incorporate a detailed product inspection. One random window in each style and one random door, sliding glass door, and storm door will be selected and thoroughly inspected. All features will be compared with approved product submittals and construction documents to make sure that the submitted products match the approved products. Special devices can be used for measuring the thickness of glass in acoustic windows, detecting laminated glazing, and measuring the maximum operating force of a sliding glass door or a window to ensure that it meets AAMA specifications.

A material inspection is also an opportunity to verify the accuracy of window and door orders and to ensure that materials are being stored in accordance with the manufacturers' requirements. This is important because warping and or damage that may occur during storage can ultimately delay the construction schedule. Product inspection is a crucial step in verifying the quality of the products. Therefore, it would be a good practice for the consultant familiar with the products or the manufacturer to be present during the inspection and assist the contractor in spotting the potential problem areas.

GROUP #:

Contractor Name:

Spec Section 08 51 13

Review Options	
Approved	
No Exception taken	
Approved with Noted Conditions	
Make Indicated Corrections and Re-submit	
Rejected	

Acoustic Windows - Aluminum

XX Products
Received:

	Model/Type #	Model/DH	Model/FIX	Model/HS	Model/XOX	Model/CAS
Entire Submittal	Not faxed & legible					
Cover Sheet	Manufacturer contact info					
	Contractor and bid group info					
	Contractor stamp/signature for compliance with spec					
Data Sheet	Min. & Max. Sizes					
	Egress Calculation					
	Color & Styles available					
Drawing	Dimensioned and scaled:					
Glass	Type & Thickness					
	Low E					
	Air space amount					
Water test	with pressure of Min. 4.5 psf					
Structural	Max. permanent set < 0.272 inches					
Air infiltration	Max. .15 CFM/sf.					
Forced entry resistance	Pass by AAMA/ANSI					
Operating force	25 lbf for HS 35 lbf for DH					
Thermal	Max SHGC of 0.63					
	Max. U value of 0.66					
NVLAP	STC 40					
Handle	Adjustable for HS					
	Low profile Crank in addition to standard					
Statement	Time required to deliver materials to the project, and a statement assuring that the materials will be delivered					
	That the design of the window not changed since tested.					
Operation	XX for DH & HS					
	Installation Instruction & maintenance					
Warranty	10 years					

STC 30 Window submittals??

Notes:

Figure 5-2. Sample checklist for submittal review.

5.7 Homeowner Preparation/ Existing Conditions

It is important to keep owners informed on the construction process in their homes. Homeowner preparation starts at first contact for the field measurement verification appointments. Necessary contact information should be given to owners, with assurance that their concerns will be addressed. This has proven to be a significant aid for the construction team when needing to convey or listen to pertinent issues that may arise during this very busy process. Communicating with and preparing the owner for the construction process not only conveys to the owner that the process is being managed professionally, but also makes them feel that they are a part of the process. The following information should be provided:

- Name of general contractor, subcontractors, and their non-working supervisors;
- Emergency contact numbers for general contractor and program staff;
- Checklist for preparing the home for construction;
- Problem resolution procedures; and
- "SAVE" stickers for items that the owner wishes to salvage.

Coordinated measurement verifications/contractor walk-throughs should be scheduled immediately after the pre-construction meeting. The most important part of this walk-through is for the prime contractor, subcontractors (window installers, door installers, mechanical team, electrician, and HAZMAT), and manufacturers' representatives to obtain accurate window and door dimensions as well as verifying all existing conditions impacting construction. It is the responsibility of the contractor to verify measurements and make sure they meet the manufacturers' tolerances. The contractor is also responsible for confirming any noted issues and typical wear and tear that may complicate the installation of the new windows and doors, especially in older homes that have not been maintained properly. The contractor walk-through is the first and best opportunity for those responsible for the actual construction process to interact with the property owner and verify all aspects of the specified work.

In an effort to standardize the quality control efforts, it is best to develop a checklist of items to be followed and require a design team representative to be present at the walk-through to conduct a systematic inspection and order verification process with the contractor and property owner to remove any uncertainty.

5.8 Photographs

Experience has proved that photographically recording all aspects of the construction process, both before and after construction, is immensely helpful for all parties involved.

Figure 5-3. Retrofit installation.

Each dwelling has its own unique characteristics that must be photographed before, during, and after construction. Photographs during construction are often useful as a record of materials and techniques that may not be apparent after completion of the work. Figure 5-3 shows before, during, and after photographs of a window replaced as part of a sound insulation program.

5.9 Labor Compliance Monitoring and Inspection

Certified payroll forms should be submitted and monitored in accordance with Federal Contracts-Working Conditions and applicable state provisions. The U.S. Department of Labor states, in regard to the Davis-Bacon Act and related acts:

> The Davis-Bacon Act requires that all contractors and subcontractors performing on federal contracts (and contractors or subcontractors performing on federally assisted contracts under the related Acts) in excess of $2,000 pay their laborers and mechanics not less than the prevailing wage rates and fringe benefits listed in the contract's Davis-Bacon wage determination for corresponding classes of laborers and mechanics employed on similar projects in the area. Davis-Bacon labor standards clauses must be included in covered contracts.
>
> Apprentices may be employed at less than predetermined rates if they are in an apprenticeship program registered with the Department of Labor or with a state apprenticeship agency recognized by the Department. Trainees may be employed at less than predetermined rates if they are in a training program certified by the Department.

Programs must make sure that the prevailing wages in construction contracts are paid and reported according to guidelines. Each contractor and subcontractor must, on a weekly basis, provide the program a copy of all payrolls indicating the required information for the preceding weekly payroll period. Each payroll submitted must be accompanied by a "Statement of Compliance." For more information, visit www.dol.gov/compliance/guide/dbra.htm.

Interviews should be conducted with workers in order to record the wages being paid and document the type of work being performed at the time of the interview. These items are then compared to the wages and the trade reported on the certified payroll to ensure the accuracy of certified payrolls. Public works programs require that either the state or the federal Davis-Bacon wage rates be paid to all construction personnel (whichever is higher). A table of the required rates is typically included in the bid documents. During the preconstruction period, the prime contractor can be notified regarding these requirements and steps can be taken to make sure the contractor understands the tables correctly.

5.10 Proper Installation

Knowing that the success of a program relies on the ability of contractors to complete the intended scope of work in the time allotted, it is important to take a proactive approach in the construction observation and punch inspection process. It is important for the construction project and activities to be observed and documented on a daily basis by a seasoned construction manager to make sure the contractors are adhering to plans as intended by the architect. For example, given their heavy weight, if acoustical windows are not securely connected to the structural members, it is inevitable that they will sag or lose their ability to perform as intended soon after construction is completed. If the window sill does not receive the necessary support, the window will sag, and fail to perform.

5.11 Punch List and Final Inspection

It is the contractor's responsibility to prepare the punch list request form, but if the contractor does not prepare a punch list request form, an "Auto Punch" inspection prior to the scheduled completion date should be prepared. This procedure expedites inspection of the work and allows the contractor to mitigate the remaining items prior to the end date and avoid any potential penalties. The construction manager or the architect should assist during punch list inspections and document any outstanding items for the contractor's attention. The contractor then has a number of days, based on the contract documents, to correct any deficiencies. During the punch inspection, any issues the property owner may have should be discussed, and the property owner must be informed of how to operate and maintain all of the newly received products and materials.

5.12 In-Situ Testing Procedures

Field testing is an important part of quality control procedures. Such testing can detect any deviation of products from what is promised through approved product submittals and can uncover potential problem areas. This procedure is explained in more detail in Section 6.6.

5.13 Closeout

The purpose of the closeout phase is to detail the ending of a project, its formal acceptance, and the hand over to the customer. A successful project closeout will benefit all parties—owner, architect, and contractor. To have a successful project closeout phase, it has to be planned ahead of time. The closeout phase consists of but is not limited to the following:

- **Performing punch list inspections.** It is recommended that the A/E firm identified at the beginning of the project work alongside the construction team or take full responsibility for development of the project closeout punch list.
- **Preparing and issuing a certificate of substantial completion and or notices of final completion with attached punch lists.** AIA Document G704-2000, "Architect's Certificate of Substantial Completion," defines this stage as: "the stage in the progress of the Work where the Work or designated portion is sufficiently complete in accordance with the Contract Documents so that the Owner can occupy or utilize the Work for its intended use." It is crucial that these documents are prepared, signed, and dated as they represent the point in time when the owner takes responsibility for maintenance and the warranty period commences.

- **Completing final change orders.** If the cost of the project is different from the specified allowances on the project, the architect should prepare the final change order.
- **Conducting maintenance training.** Maintenance, as stated in subsequent sections, is crucial in maintaining the performance of the products and should be conducted accordingly.
- **Delivering project records.** Complete and accurate project record drawings should be maintained by the general contractor or construction manager from the beginning of the project.
- **Delivering operation and warranty manuals.** The contractor should create a booklet containing all product warranties and operation manuals for submittal to the owner at the end of the project.
- **Collecting liens.** The contractor shall compile lien waivers from subcontractors and suppliers. These documents should be reviewed carefully by the architect before certifying the final and retention pay application.
- **Reviewing closeout materials.** The closeout material should be reviewed by the architect in order to determine contract compliance for submittals. It is very important to ensure that documentation is complete.
- **Processing the progress and final pay applications.** All payment applications should be submitted by the contractor and then reviewed and certified by the architect for payments. Before certifying the final payment, the architect must ensure that completed certified payrolls are in place; that all vendors, suppliers, and subconsultants have been paid; and that the final project meets the requirements of the contract documents and satisfies the owner.
- **Submitting the final reports.** Preparing the final report and documenting that the project goals set by the FAA and other involved parties are met is one of the most critical parts of the closeout procedure. This involves performing the acoustical measurements outlined in the 1992 guidelines for both pre-construction and post-construction. In addition to the acoustical tests, the final report provides a history of the project, a summary of the plans, the schedule, and the financial data. This report can be used during grant application to FAA for reimbursement.

The requirement of closeout procedures can be included in the "general requirements" section of the specifications. It is important to determine closeout responsibilities before signing the contract, and it is a best practice to integrate closeout into construction administration. For a successful closeout, the owner, the architect, and the contractor should be satisfied, and their goals should be met (AIA, 2007).

Summary—Construction Administration

1. During the contractor selection process, pay close attention to contractors' performance history in other projects.
2. Provide opportunities for contractor training.
3. Perform detailed product inspection to verify that delivered products are in accordance with approved product submittals and contract documents. It recommended that the manufacturer and/or the consultant familiar with the products participate in the inspection.
4. Create checklists for submittal reviews, product inspections, field measurement verifications, and punch inspections as part of the quality control plan.
5. Employ a seasoned construction manager to observe and document the construction process on a daily basis to make sure that the contractors are adhering to plans as intended by the architect.

SECTION 6

Quality Control

Quality control is one of the most important items in promoting durability and longevity. Effective quality control depends on a multiphased approach to excellence in technical implementation and management. The most efficient quality control action is to minimize the occurrence of errors. Quality assurance methods differ from firm to firm. One effective method of quality assurance is Total Quality Management (TQM). TQM is a management approach aimed at delivery of quality service based on participation of all team members from management to design personnel to suppliers and customers, with the goal of long-term customer satisfaction. TQM involves maintaining a quality standard, a set of procedures that cover all key processes in the business. The procedures typically include the following:

- Monitoring the process to ensure its effectiveness;
- Incorporating a disciplined methodology for monitoring conformance with standards, tracking non-conformance, and ultimately resolving any non-conformance;
- Identifying, assessing, and mitigating performance, schedule, costs, and risks early in the task management process;
- Checking outputs for defects and promoting corrective actions when necessary;
- Keeping adequate records; and
- Promoting continual improvement.

The following material describes the steps necessary at each stage of the sound insulation project.

6.1 Design

Steps that can be taken to ensure a quality job during design include the following:

- In-house team meetings;
- Meeting with the entire project team;
- Use of checklists (standard quality control forms and checklists can be used during initial design and final design phases such as the International Conference of Building Officials [ICBO] and the CSI quality assurance reviewing guides and tools);
- Code compliance review;
- Obtaining clients' approval at the end of each phase;
- Documentation and approval of key decisions;
- Development and use of library of standard details;
- Third-party peer review or review by a senior staff member not involved in the project;
- Procedures for coordination with consultants;
- Maintaining awareness of product changes; and
- Assigning senior quality assurance staff in the project team to perform final review.

6.2 Shop Drawing Reviews

Shop drawings are a set of drawings prepared by the manufacturers or the contractor with emphasis on particular products or installations and excluding additional notes or information concerning other products. This can include job site dimensions verified through job walks to special fabrication notes. Since fabricators rely solely on shop drawings (and not the construction documents), these drawings must be clear, concise, and free of error.

Preparing and reviewing shop drawings is a necessary part of the construction process. If these tasks are not taken seriously, there is a risk of error in installation and delays. Arthur O'Leary referred to shop drawings as a "necessary evil": "To the construction industry, shop drawings seem to be a necessary evil. Contractors find them expensive to produce and architects find them unappealing to review. Both find them time-consuming and costly to administer"(O'Leary, 2003). Therefore, the architect/designer should incorporate a highly thorough, organized, and timely review process.

Including references to the construction documents, drawings, and specifications assists the architect and engineer in their review of the shop drawings. The shop drawings should also incorporate notes concerning changes or differences from the original documents for approval by the architect and engineer. The purpose of reviewing the shop drawings is checking for conformance with the information given and the design concept expressed in the contract documents.

6.3 Manufacturing

Quality Assurance/Quality Control (QA/QC) plays an important role in durability long after the manufacturing process is completed. Manufacturers over time have developed QA/QC procedures, and they have invested in this phase. The quality control process can be lengthy and complex. Incorporating procedures as outlined below has proved to be successful:

- Developing quality control plans and standard work instructions;
- Developing control charts;
- Incorporating regular calibration of equipment;
- Incorporating product inspection processes for material, equipment, and procedures;
- Performing audits and random in-process inspections;
- Testing products to uncover defects;
- Hiring quality control engineers;
- Incorporating additional training and corrective actions as uncovered through testing and auditing;
- Emphasizing competence, such as knowledge, skills, experience, and qualifications;
- Obtaining recognized certifications in the QA/QC process such as ISO 9001, international standard for design and manufacturing excellence, or incorporating ASTM or AAMA requirements for manufacturing; and
- Reviewing shop drawings thoroughly to make sure they match project specifications.

In a discussion at the 2013 Sound Insulation Stakeholders meeting,[4] contractors expressed their frustration with the lack of manufacturer quality control and inaccurate inventories. Improving quality control in manufacturing and having accurate inventory numbers streamlines the product order process and reduces the amount of hardship for owners, contractors, and manufacturers and ultimately contributes to a well-functioning program.

[4]Sound Insulation Program Stakeholders Meeting Summary, March 6, 2013, Los Angeles, CA.

6.4 Product Inspection

Inspecting products for defects and non-conformance at delivery helps control quality by identifying problems before product installation. Both delivered products and conformance with manufacturers' storing requirements should be checked during this phase. In some cases, the inspection will require specialized skills and expertise in examining products and equipment to verify the technical specifications of the products. Inspection of the products before installation adds another layer of quality control and provides an opportunity for the manufacturer/contractor to alleviate the problem and offer solutions before a property is opened for construction. For more information regarding product inspection, refer to Section 5.6.

6.5 Installation and Workmanship

The best products can be specified and purchased, but they are only as effective as the method of installation. Through experience from the early sound insulation programs, installation methods have improved by introducing more rigorous training for contractors and more detailed inspection procedures throughout construction. Whereas in early programs, contractors tended to regard sound insulation jobs as just the same as any other house upgrade, they now realize that sound insulation construction requires much more attention to details.

Poor contractor performance contributes to problems during and after construction. Specifically, when the contractor or a subcontractor does not follow the plans, there is increased risk of products not performing as intended. Examples of poorly executed work that can cause problems are as follows:

- **Not supporting the windows completely at the sill.** Technical specifications or design documents include requirements for fully supported sills, and the construction managers should pay close attention to this item.
- **Inadequate attachment of the window to the building structure at jamb locations.** Design documents and details include requirements to address this issue, such as following the manufacturer's written installation instructions, mandatory trainings by the manufacturer, and specifying adequate installation experience for window installers.
- **Rushing through the job in a short time or cutting corners.** A very fast paced construction schedule can force the trade to work very quickly, making it difficult to maintain the quality of the work at an acceptable level without constant supervision. A requirement needs to be put in place to avoid this situation, and acceptable supervision by the program and experienced construction managers/building inspectors is necessary to keep contractors accountable for

the quality of their installations and adherence to plans and details.

- **Improper finishing of the wood doors.** Some programs include finishing/sealing instructions in their technical specifications, outlining requirements for finishing and sealing all six edges of the doors and any cut holes. Some other programs have made it mandatory for doors to receive the primer and the first coat in the warehouse in a dry, controlled environment. In addition, manufacturers of wood doors list finishing requirements in the warranty language so that the programs and contractors pay close attention to this item.

Additionally, the following tools and procedures utilized in sound insulation programs can minimize problems associated with installations:

- Utilizing request for information (RFI)/request for change order (RFCO) forms and procedures;
- Employing experienced construction managers to ensure contractor performance (oversight of the construction process and contractor performance are crucial for appropriate installation and finishing of acoustical products because these enhance the products' performance);
- Conducting detailed pre-bid and pre-construction meetings to communicate the specific acoustical goals of the program with the contractors;
- Specifying liquidated damages if the contractor does not finish the project on schedule; and
- Specifying the prevailing wage, which means that contractors will pay higher rates to their employees, but thereby also makes it possible to hire the best in the trade, which should minimize potential worker performance problems associated with less-experienced workers and ensure a smooth construction phase.

6.6 Quality Control Testing Procedures

Field testing is an effective tool for verifying that the installed products live up to the promise of product submittals and manufacturer manuals. Although specifying field testing includes additional cost, the quality control benefit it offers outweighs the cost. Common field tests include installed window testing for air infiltration, water penetration, and acoustical performance and balancing tests for installed mechanical systems. Other field tests are thermal evaluation, glass evaluation (bow/warp and frost point), blower door, and thermal imaging.

There are ASTM and AAMA standards for field testing such as the following:

- ASTM E 783 and E 1186 testing to determine and evaluate air leakage in building envelopes and fenestration;
- ASTM E 1105, Standard Test Method for Field Determination of Water Penetration of Exterior Windows, Skylights, Doors, and Curtain Walls;
- AAMA 502, Voluntary Specification for Field Testing of Newly Installed Fenestration Products;
- AAMA 501.2, Quality Assurance and Diagnostic Water Leakage Field Check of Installed Storefronts, Curtain Walls, and Sloped Glazing Systems;
- AAMA 511, Voluntary Guideline for Forensic Water Penetration Testing of Fenestration Products; and
- The measurement of sound transmission through building facades and facade elements (ASTM Guide E 966).

ASTM E 783, Field Measurement of Air Leakage through Installed Exterior Windows and Doors, is conducted at 1.57 psf (25 mph). According to AAMA 502-12, the allowable air leakage is 1.5 times the laboratory requirements. AAMA 502-12 also allows water pressure to be ⅔ of the laboratory-specified value during field testing (ATI, n.d.).

These standards can be incorporated into technical specifications for identifying and evaluating design and/or construction defects. Usually templates are used for specifying field testing such as MasterSpec or AAMA short forms.

It is also advisable for specifications to require selection of one random window and door from delivered products to be sent for independent laboratory testing prior to the start of construction. While not many programs utilize field testing of uninstalled products due to the associated cost, these tests have been very effective in identifying manufacturing problems before and during construction.

6.7 Energy Testing

Given the necessity of incorporating energy-efficiency measures into sound insulation programs, it might be necessary for future programs to perform energy evaluation, analysis, and modeling, and to assist owners in making an informed decision. The level of effort can vary from a simple walk-through to more comprehensive energy audits, analysis, and modeling depending on the needs of the program in general or for dealing with special cases.

Currently, some programs perform energy auditing as part of standard design services on 10% of the homes before and after construction. The audit involves the blower door test to provide the program with information regarding energy savings. This effort can be expanded to perform a comprehensive performance evaluation and modeling. Energy audits and modeling can accompany acoustical designs when necessary for either conforming to codes or dealing with special cases, such as assisting owners in selecting the most energy-efficient acoustical treatment available.

The different levels of energy auditing are described below—energy accounting, blower door test, thermographic inspection, and energy modeling tools. Sound insulation programs, depending on the need, can incorporate one or a combination of these tests to evaluate the efficiency of the building components or systems and suggest the best treatment options.

6.7.1 Energy Accounting

Energy accounting is a process of collecting, organizing, and analyzing energy data including electricity, water, and fuel. For electricity accounts, usage data normally are tracked and should include metered kilowatt-hour consumption, metered peak demand, billed demand, and rate schedules. Similar information will be collected for water and fuel usage. These data can be obtained through analysis of utility data and energy bills (New Jersey Department of Environmental Protection, 2006).

Home performance evaluation includes items such as the following:

- Check envelope for tight fit,
- Inspect attic for leaks around barrier,
- Determine how well the insulation insulates,
- Inspect holes that electrical lines pass through,
- Inspect performance of the furnace and water heater, and
- Locate insulated ductwork or any duct leakage.

The energy assessment reveals areas where energy is wasted and provides a comprehensive home energy report.

6.7.2 Blower Door Test

A blower door test incorporates a special fan called a blower door to depressurize the home. First, the inspector closes all doors, windows, and anything else that lets in outside air. With doors and windows closed and fan running, it is easy to capture the leaks with an infrared camera. Often, energy-efficiency incentive programs, such as the DOE/EPA Energy Star program, require a blower test to confirm the "tightness" of the house. This test can be performed in less than an hour (DOE, 2012a). Figure 6-1 illustrates a fan used for a blower door test.

There are two types of blower doors: uncalibrated and calibrated. Uncalibrated blower doors can only detect leaks. Calibrated blower doors have several gauges to measure leakage and allow the auditor to quantify the amount of air leakage and the effectiveness of any air-sealing job. This is the test recommended by DOE (DOE, 2012a).

Source: Holtkamp Heating & A/C, Inc.

Figure 6-1. Blower door test.

6.7.3 Thermographic Inspection

A thermographic inspection is either an interior or exterior survey. It measures the surface temperature with infrared videos and cameras. Depending on the weather conditions, the auditor selects either an interior or exterior survey for the best results. Interior scans are used more often since they are generally more accurate, and they benefit from fewer wind effects (DOE, 2012b).

6.7.4 Energy Modeling

Energy modeling tools can be utilized for more complicated projects to accurately model the building components, analyze how certain modifications impact energy usage, and predict associated costs. This approach involves more extensive data collection to allow for performing a detailed comparative analysis of building designs. The software considers the effect of external factors such as weather data. Common tools for energy modeling are EnergyPlus, DOE-2, and eQuest.

Summary—Quality Control

1. Employ a TQM approach.
2. Provide more rigorous training for contractors and perform detailed inspection procedures throughout construction.
3. Incorporate field testing requirements into the construction documents and plan for laboratory testing of one random window/door.

SECTION 7

Maintenance

A survey of early sound insulation programs indicated that maintenance was the main issue in the homes showing deterioration in performance of the sound insulation products. This section discusses the proper maintenance procedures, commissioning, replacements, and warranties for sound insulation projects.

7.1 Maintenance Procedures

Proper maintenance and care for the installed products are key factors affecting the durability of acoustical performance in sound insulation products. Building owners play an important role in maintaining the products. Wood products and sealants are the most vulnerable materials in installed products, and lack of proper maintenance will contribute to failure. Wood products require repainting or refinishing regularly to prevent moisture or ultraviolet damage and wear.

As discussed in previous sections, durability based on the interdependence of systems may become apparent long after the construction is completed. For example, programs can specify and install the most expensive acoustically rated windows, but the homeowner's neglect in fixing or replacing cracked sealants and caulk can result in moisture penetrating and becoming trapped around the window. This can, in turn, result in damage to window framing and eventually create a path for noise to penetrate the building. It is essential to inform owners of the importance of maintenance and care for their new products and include a dedicated acknowledgement section in the plans for the owner to read and sign. At the same time, most product manufacturers provide owners with a maintenance manual to inform them of how to care for their new product and maintain the warranty. Certain types of maintenance are required for the warranty to be honored. The specifications should require a maintenance manual to be submitted during the product submittal phase and as a condition of product approval.

7.2 Commissioning

Commissioning is the process of verifying that building systems are operating as planned/designed and plays an important role in making sure that installed products and systems perform to their potential and therefore result in a durable outcome (LEEDuser, n.d.; WBDG Project Management Committee, 2012). ASHRAE defines commissioning as "the process of ensuring that systems are designed, installed, functionally tested, and capable of being operated and maintained to perform in conformity with the design intent." In addition, commissioning will improve building performance to some degree, depending on building type and complexity. Commissioning is becoming an increasingly important step in architecture as energy-efficient designs and sustainability demand are growing. Table 7-1 summarizes the key commissioning steps involved in each phase of the project.

Commissioning is a quality-assurance-based process that formalizes review and integration of all project expectations during planning, design, construction, and occupancy phases through inspections, tests, oversight, and record documentation (WBDG Project Management Committee, 2012). Commissioning can be performed either by the design/construction team or can be contracted to a third party. Sound insulation design and construction teams currently employ some of the steps listed in Table 7-1 in their programs. However, implementing a full process will improve the performance of a building. Building commissioning has emerged as the preferred method of ensuring that building systems are installed and operated properly to provide the performance envisioned by the designer (Energy Systems Laboratory, Texas A&M University System, and University of Nebraska, October 2002).

In order to start commissioning in a project, sound insulation programs should undertake a series of activities: determine the available utility and government resource, hire a lead, specify the project scope and objectives, identify the team's capabilities, assess the need for hiring consultants, and include

Table 7-1. Commissioning process by project phase.

Project Phase	Commissioning Process Steps
Planning	Establish goals Establish budget Select commissioning lead Establish schedule Establish testing needs and requirements Select a commission lead Create initial commissioning plans
Design	Update commissioning plan Perform commissioning-focused design review Develop commissioning specifications Develop checklists for verifications Develop training requirements
Construction	Review submittals and shop drawings Perform construction monitoring Perform diagnostic testing Verify training Develop reports
Occupancy	Verify systems are performing as designed Perform necessary testing Perform near warranty–end review

Sources: ASHRAE 0-2005, 2005; Portland Energy Conservation, Inc., 2006.

commissioning requirements in the specifications to ensure that contractors are required to participate in the commissioning (Portland Energy Conservation, Inc., 2006).

The main guidelines for the commissioning process are the following:

- *ASHRAE Guideline: The Commissioning Process* (ASHRAE 0-2005, 2005), the industry-accepted commissioning guideline;
- *NIBS Guideline 3-2012, Building Enclosure Commissioning Process BECx*, National Institute of Building Sciences, 2012;
- *NIBS Guideline 3-2006, Exterior Enclosure Technical Requirements for the Commissioning Process*, National Institute of Building Sciences, 2006; and
- *The Building Commissioning Guide*, U.S. General Services Administration, 2005 (WBDG Project Management Committee, 2012).

7.3 Replacement

According to industry surveys summarized in *Durability by Design* (NAHB Research Center, Inc., 2002), windows and doors are among the most commonly reported products with durability issues in a new construction project. This is shown in the frequency and cost of homeowner warranty claims and overall expenditures for repairs, maintenance, and replacement. Air and water leakage, glass fogs, and frosts are the main performance problems with windows and skylights, while poor weather stripping, checking and splitting of panels, and swelling are widespread problems for exterior doors.

Window durability problems depend to a large degree on the window framing material and its assembly details (Vigener & Brown, 2012). Wood, vinyl, and fiberglass are currently the most widely used window frame materials in residential construction. Steel frames are less common.

Wood frames are prone to separation of frame joints from moisture and thermal, structural, and transportation movements. Wood frames are also more likely to decay from prolonged contact with moisture unless they are pressure treated and properly coated. Many new wood windows are protected by a durable exterior finish or cladding that prevents moisture from forming underneath (EWCG, 2011).

As mentioned in Section 4.5.1, aluminum frames are strong and inherently corrosion resistant in most environments if anodized and properly sealed or painted; however, they readily conduct heat. Condensation and even frost can be an issue with aluminum windows as well. Thermal breaks reduce conduction and improve condensation resistance; however, the durability of thermal breaks varies by type and quality (EWCG, 2011). Another metal alternative would be steel frames, which depend on an applied coating for corrosion resistance (Vigener & Brown, 2012).

Vinyl window frames provide better energy performance than aluminum frames due to lower thermal conductivity, and vinyl frames offer welded components that seal the joinery. Vinyl window frames provide good moisture resistance and are low maintenance, but they tend to expand or contract with changes in temperature. Recent designs have improved dimensional stability and resistance to ultraviolet radiation and temperature extremes (EWCG, 2011).

New wood/polymer composite and fiberglass window frames are strong and dimensionally stable. They provide better moisture and decay resistance than conventional wood (EWCG, 2011).

With regard to products used in sound insulation projects, ACRP Project 02-31 has shown that retrofit treatment of buildings for sound insulation projects will provide a long-term sound insulation goal without much need for actual replacement of the windows or door units.

As noted in Section 7.1, maintenance has a direct effect on longevity of products. Lack of maintenance will result in depreciation of products or their components. The list that follows includes major sound insulation products or components that are prone to deterioration, which may cause sound leaks, usually through or around windows and doors:

- **Weather stripping.** Aging, as well as wear and tear due to product use, causes weather stripping to shrink and/or lose its resilience until it is no longer able to seal air and sound gaps.
- **Hardware.** Building structures tend to settle racking door and window jambs out of square. This makes it difficult for the window sash or door panel to contact the sill or threshold evenly enough to achieve an airtight seal. This also causes

Figure 7-1. Crack in sealant.

the locks, balances, and hinges not to work as intended, leaving cracks for sound leaks.

- **Sealants and caulks.** Due to structure settlement or aging, the caulking surrounding building components may crack or deteriorate (see Figure 7-1). This may result in air and sound gaps or water intrusion and deterioration of frames and other construction, creating other sound transmission paths.
- **Wall insulation.** Some early programs installed cellulose insulation blown into the wall cavity. Over time, cellulose can settle, compromising the acoustic performance of the upper portion of the wall.
- **Insulated glass unit (IGU)**. The life of an IGU varies depending on the quality of materials used, workmanship, and installation location in terms of sun exposure and geography. Lack of proper maintenance also affects the longevity of IGUs. If IGUs are altered, such as by installing a solar control film, the durability of the unit is limited, and the warranty may be voided by the manufacturer.
- **Aluminum frames.** Aluminum frames installed in an area near the ocean may corrode due to the salt-laden air.
- **Door bottom seals.** These seals experience loss of effective noise reduction due to the effects of deterioration and aging. Some programs have utilized automatic door bottoms that drop down when the door is closed to provide a positive seal. These automatic door bottoms have a tendency to require adjustment to ensure a good seal. Also, the gasket sealing against the floor can be pulled out during operation, and this creates a major air gap providing a path for noise penetration; therefore, further occasional adjustments may be necessary.
- **Wood doors.** There have been instances of the delamination of exterior doors due to incorrect installation of glazing elements or untested manufacturing processes. This delamination causes the doors to fail, yielding air and sound leaks.

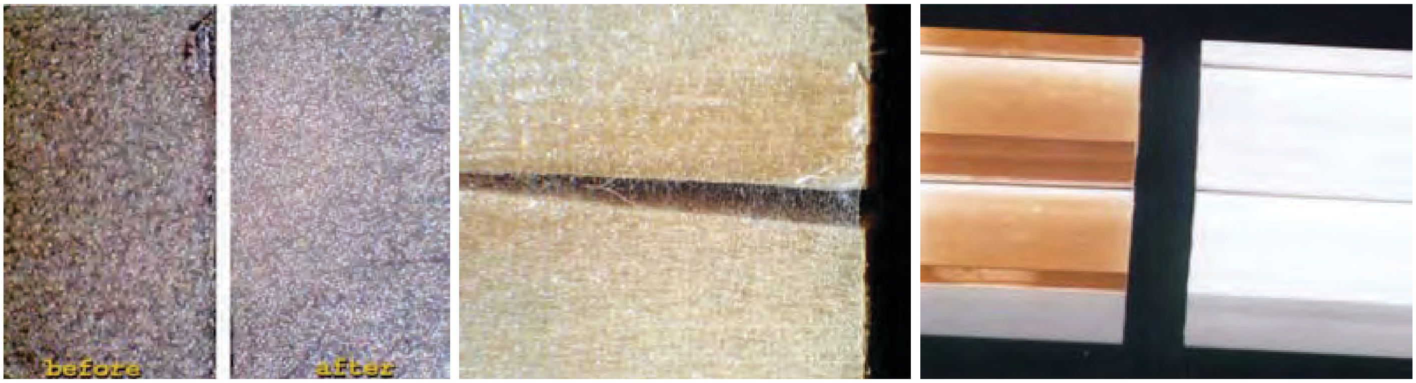
Although the research for ACRP Project 02-31 did not indicate widespread deterioration, the study team encountered instances of low performance due to lack of maintenance. For instance, it is advisable to replace exterior caulks every 7 to 10 years or maintain the exterior envelope by refinishing the wood sidings and fixing cracks. This maintenance will minimize the possibility of water penetrating the cracks, which is one of the factors contributing to failure of a door or window.

There are situations when not just window and door parts should be replaced, but entire window or door units should be replaced. Frame materials deteriorate to some degree through environmental factors. A study performed on the life cycle of window frame material shows that window frame material—polyvinyl chloride (PVC), wood, and aluminum—can be affected by environmental factors. PVC is sensitive to heat and ultraviolet radiation, aluminum will corrode near industrial and coastal areas, and wood is sensitive to moisture (Asif, Davidson, & Muneer, 2002). Figure 7-2 illustrates deterioration of window frame materials. Figure 7-2a shows an uncoated aluminum sample before (left) and after (right) an immersion test. Figure 7-2b shows a crevice opening in a timber sample after a cyclic test. Figure 7-2c shows a PVC sample before (right) and after (left) an ultraviolet test.

Factors that contribute to replacement of windows and doors include failure of thermal breaks in aluminum windows, breaks of other components, difficulty in operation of windows, delamination of doors, deformation of vinyl frames, and unpleasing aesthetics.

The findings regarding the life expectancy of sound insulation projects in ACRP Project 02-31 are somewhat consistent with the life expectancy of building components reported in numerous publications (Morrison Hershfield Limited, 2002; NAHB Research Center, Inc., 2002; Kesik, 2002; SHSC, 2004; The Old House Web, n.d.; InterNACHI, 2010; Mayer, 2005). This information is summarized in Table 7-2.

FAA-funded sound insulation programs will provide modifications to each dwelling only once. The owners are



(a) (b) (c)

Source: Asif, Davidson, & Muneer, 2002.

Figure 7-2. Before and after test results on aluminum, wood, and PVC.

responsible for any replacements needed due to aging and regular wear and tear. If replacement is due to a defective product or poor workmanship, the owners have the option to work with program sponsors, contractors, and the manufacturers depending on when the problem was detected. This procedure is further explained in Section 7-4.

7.4 Warranty

As an additional layer of quality assurance and homeowner protection, sound insulation programs require warranties on installation (contractor's warranty) and installed products (manufacturer's warranty). If issues arise after the completion of the program treatment, the warranties ensure that they can be resolved without additional cost to the program.

7.4.1 Contractor Warranty

The contractor's warranty requires the general contractor to provide a full warranty covering all labor and materials necessary to address problems or failures of installed modifications. The contractor's warranty runs concurrently with any manufacturer's warranty in place. The contractor's warranty excludes maintenance and damage to the products after final inspection.

Upon final acceptance by the program manager, the contractor must provide a warranty package for each dwelling and an additional copy (digital or hard) for program records. It is recommended that homeowners sign an acknowledgement of receipt upon issuance of the warranty packet.

The warranty package should include the following:

- A list of sponsors, consultants, and contractors and their respective contact information;
- A statement outlining the terms of the 1-year contractor's warranty, including the start and/or expiration dates of said warranty;
- A list of installed products, warranty periods, and the manufacturers' contact information;
- Copies of all manufacturers' warranties; and
- Copies of maintenance, instruction, and/or installation manuals for individual products.

Homeowners should be provided with instructions on how to make a warranty claim during the warranty period and after the expiration of the contractor's warranty. While the contractor's warranty is in effect, it is common for programs to require the homeowners to contact the contractor directly for warranty issues. The benefit of this method is that it minimizes the involvement of program management and costs. The disadvantages are that there will be a lack of program oversight and thereby an inability to ensure timely contractor response, the quality of any repair, and/or to track reoccurring issues. Due to these disadvantages, some programs have opted to manage the contractor's warranty. In this scenario, homeowners submit their claims directly to program staff. Program staff members have the ability to determine the validity of the claim, ensure notification and response from the contractor,

Table 7-2. Building materials life expectancy.

Building Material	Replacement Cycle (Years)
Window glazing	10
Vinyl windows	20
Aluminum windows	25
Aluminum doors	25
Wood windows	15–20
Acoustical wood doors	15–20
Insulated glass	10
Caulk	7–10
Hardware	10
Sealant	7–10
Insulation	30
Repaint	1–10
HVAC	20

and track the types of warranty claims submitted. The tracking process can be useful for identifying potentially substandard products or installation issues, which may need to be addressed by program staff on a larger scale. Upon completion of the contractor's warranty, the manufacturer's warranties for some products will still be in effect.

7.4.2 Manufacturer Warranty

Each product should be required to be covered for a minimum time period as listed in the specifications. The amount of time is determined through industry standards and the specific requirements of sound insulation projects. Refer to Section 4.8 for details.

7.4.3 Warranty Issues

Most manufacturers of building products provide some length of warranty for their products. However, most warranties are honored only if the products were installed in accordance with the manufacturer's installation instructions. In this case, as discussed in Section 5, the construction administration plays an extremely important role in making sure the manufacturer's installation instructions are followed and documented by the contractors.

In addition, the warranties have other restricting clauses such as climate factors, proximity to the ocean, and transferability.

Sound insulation projects have been significantly impacted by the tight restrictions that wood door manufacturers have imposed on door warranties. These restrictions include requiring oil-based paint finishes, requiring a 4-ft overhang in each direction to protect the door, or requiring the addition of storm doors. Sometimes it is difficult to design for a door replacement and meet all the requirements listed in warranty certificates. There are other times in which following these requirements is not possible without creating code violations. For example, adding a 4-ft overhang to an outswing door located at a side yard with only 3 ft of setback will encroach on the neighbor's property. To date, programs have not been successful in requiring wood door manufacturers to revise these requirements. To address this issue, some programs require the contractor to provide the necessary warranty, to add storm doors or overhang whenever possible, use metal core doors, or obtain an owner's acknowledgement regarding the shortcoming of the wood door warranties.

Climate and ocean proximity mostly affect aluminum products. Fortunately, the newer finishes perform much better. This has enabled aluminum window manufacturers to provide more durable products that are more resistant to the climate factor and presence of salt in the air.

Another equally important issue relating to warranties is the period of workmanship warranty, which for most sound insulation projects is 1 year. Any issues related to contractor performance will not be covered under this warranty beyond 1 year. In general, construction project contracts require a 1- to 2-year warranty period for workmanship. Sound insulation projects usually require a 1-year period of warranty. However, some defects related to workmanship might take longer than a year to become apparent. Increasing the workmanship warranty beyond 2 years might not be practical, and it may be cost prohibitive. Therefore, it is recommended that the workmanship warranty be increased from 1 to 2 years.

Another important issue to keep in mind is that when program staff members accept a product or constructed item, it is deemed final. Programs generally do not have "implied" warranty rights except if specified in the contract or in any warranties furnished by the contractor. In construction projects, some defects caused by failure in design, workmanship, and products may not become apparent during the warranty period. Under most state laws, contractors have legal obligations for their work. For federal projects, if a latent defect[5] exists, the government is entitled to revoke its earlier acceptance of the contract (Chu & Briglia, 2002). Therefore, the end of the warranty period does not mean that the contractor or manufacturer is released from all liability. The statute of limitations for patent (obvious) defects is usually limited and defined by the contract documents. For latent defects, the liability period varies in different jurisdictions from 2 to 12 years. To pursue claims related to latent defects, several proofs are required. One key requirement is that a reasonable inspection by the program staff before acceptance would not have revealed the defect. Therefore, it is critical to keep records of daily inspections, punch list inspections, and final inspection.

Summary—Maintenance

1. Inform owners of the importance of maintenance and care for their new products.
2. Incorporate a full commission process into the programs.
3. Carefully select and specify required provisions for manufacturers' and contractors' warranties and provide instructions to owners on how to make claims on the warranties.

[5] Defect that cannot be discovered by observation or an inspection made with ordinary care.

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Glossary

Absorption (or Sound Absorption): The ability of sound-absorbing materials to trap sound and convert it to heat. Materials such as carpeting and upholstered furniture absorb sound, providing a quieter space regardless of the source of the sound.

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 a building (as is the case with "structure-borne sound").

American Architectural Manufacturers Association (AAMA): AAMA is a national trade association that establishes voluntary standards for the window, door, storefront, curtain wall, and skylight industries. Website: www.aamanet.org

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

ASTM International (ASTM): ASTM International, formerly known as the American Society for Testing and Materials (ASTM), is an organization that develops and publishes recommended practices and standards for a broad range of testing and material properties issues. Website: www.astm.org

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 1,000 and 6,000 Hz and the relatively reduced sensitivity to sound below 1,000 Hz or above 6,000 Hz. The A-weighted sound level is used to predict the relative "noisiness" or "annoyance" of many common sounds.

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.

Community Noise Equivalent Level (CNEL): CNEL is a measure of the average daily noise exposure with a 5 dB additional weighting given to noise occurring during evening hours (7 p.m. to 10 p.m.) and a 10 dB additional weighting given to noise occurring during nighttime hours (10 p.m. to 7 a.m.). This measure has been formally adopted by the State of California for assessment of community noise levels. It is used by airports in California to assess aircraft noise exposures over a year averaged 24-hour period and is approved for such use by the state and the FAA. CNEL noise contours are usually portrayed on maps at the 65 dB, 70 dB, and 75 dB levels.

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.

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 noise between 10:00 p.m. and 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.*

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 the Standard Building Code (SBC) (as well as IBC). Also, states typically have their own building codes that may incorporate all or part of these codes.

National Fenestration Rating Council (NFRC): NFRC is an American National Standard Institute (ANSI) Accredited Standards Developer (ASD) and develops and administers comparative energy and related rating programs for fenestration products.

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.

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-insulating 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.

South Coast Air Quality Management District (SCAQMD): The SCAQMD is the air pollution control agency for all of Orange County and the urban portions of Los Angeles, Riverside and San Bernardino counties in California.

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.

Abbreviations and acronyms used without definitions in TRB publications:

A4A	Airlines for America
AAAE	American Association of Airport Executives
AASHO	American Association of State Highway Officials
AASHTO	American Association of State Highway and Transportation Officials
ACI–NA	Airports Council International–North America
ACRP	Airport Cooperative Research Program
ADA	Americans with Disabilities Act
APTA	American Public Transportation Association
ASCE	American Society of Civil Engineers
ASME	American Society of Mechanical Engineers
ASTM	American Society for Testing and Materials
ATA	American Trucking Associations
CTAA	Community Transportation Association of America
CTBSSP	Commercial Truck and Bus Safety Synthesis Program
DHS	Department of Homeland Security
DOE	Department of Energy
EPA	Environmental Protection Agency
FAA	Federal Aviation Administration
FHWA	Federal Highway Administration
FMCSA	Federal Motor Carrier Safety Administration
FRA	Federal Railroad Administration
FTA	Federal Transit Administration
HMCRP	Hazardous Materials Cooperative Research Program
IEEE	Institute of Electrical and Electronics Engineers
ISTEA	Intermodal Surface Transportation Efficiency Act of 1991
ITE	Institute of Transportation Engineers
MAP-21	Moving Ahead for Progress in the 21st Century Act (2012)
NASA	National Aeronautics and Space Administration
NASAO	National Association of State Aviation Officials
NCFRP	National Cooperative Freight Research Program
NCHRP	National Cooperative Highway Research Program
NHTSA	National Highway Traffic Safety Administration
NTSB	National Transportation Safety Board
PHMSA	Pipeline and Hazardous Materials Safety Administration
RITA	Research and Innovative Technology Administration
SAE	Society of Automotive Engineers
SAFETEA-LU	Safe, Accountable, Flexible, Efficient Transportation Equity Act: A Legacy for Users (2005)
TCRP	Transit Cooperative Research Program
TEA-21	Transportation Equity Act for the 21st Century (1998)
TRB	Transportation Research Board
TSA	Transportation Security Administration
U.S.DOT	United States Department of Transportation