Exterior Soundproofing THAT WORKS

In 1986, the FAA initiated the Regulation "Part 150" Airport Noise and Land Use Compatibility Planning Program for homes, schools, health-care facilities, and other "sensitive noise

by Michael Payne

receptors" located in the thunderous shadows of the nation's ever-growing airports. Many of these airports have received funding to implement the largest part of that effort, The Residential Sound Insulation Program. The architectural and program management firm I work for has participated in over 20 sound-insulation programs across the country over the course of 15 years, including the local program for Boston's Logan Airport.

The effectiveness of the sound insulation programs is tested by acoustical engineers in representative participant houses, both before and after treatment. The acoustical engineers set up a loudspeaker in front of the subject house and broadcast a soundtrack that simulates the noise event and frequency spectrum of a jet taking off. Microphones placed 3 feet away from both sides of the door or window being tested capture the difference between the inside and outside noise

Airtight components, acoustical sealants, and sound-absorbing surfaces provide a quieter living space

Typical Noise Levels

Audible sound threshold	3 dB
Normal conversation	30 to 50 dB
Sound begins to be painful	90 dB
Gas-powered lawn mower	90 dB
Working table saw	100 dB
Jet engine at take-off	140 dB

Figure 1. Recreating a "noise event" and measuring the sound levels on either side of a residence's window provides a before-and-after evaluation of the effectiveness of the sound-insulation treatment.

Figure 2. Without special glazing, frame, and sash properties, a window isn't much more than a hole in the wall where noise will enter freely. An acoustical window, capped by a high-performance triple-track storm window, can reduce sound transmission by 50% compared to conventional windows.

levels (see Figure 1). The recorded difference, expressed in decibels (dB), is the total amount of noise reduction that is provided by the door or window (see "Sound Terminology"). If we've done our job, the same test repeated after the sound-insulation treatment will show noise levels reduced by a minimum of 5 dB (25%).

At an average treatment cost of $25,000 per home, and with tens of thousands of homes potentially affected, environmental-noise abatement has become a real niche industry. Several large construction firms currently specialize in this type of work, bidding on sound-insulation contracts for up to 100 or more residences at a time in municipalities across the country. In this article, we'll look at some of the techniques we apply to create a quieter indoor environment.

Underlying Principles

In concert with manufacturers and acoustical engineers over the past 15 years, my firm has developed sound-insulation techniques for homes that need to meet the FAA-mandated average noise reduction (NR) of 5 dB. The subjective experience of decibel values is due to the unique ability of the human ear to reduce its sensitivity as sound pressure increases. Therefore, although a 10-decibel increase in sound represents a threefold increase in pressure, it only doubles the appreciable sound level.

The principles involved in these sound-insulation techniques are straightforward:

- The more airtight the product or installation, the more resistant it will be to airborne noise.
- The denser the material, or the more mass it has, the more resistant it will be to airborne noise.
- Decoupling, or the physical isolation of interior and exterior surfaces, reduces the transmission of noise.
- Insulation, in certain cases, will help reduce noise energy by absorption.

These four principles form the basis for our acoustical treatment recommendations. Because noise acts like water — if it finds a hole, it will leak through — the primary focus of most programs is on treating noise paths through exterior openings, like doors, windows, and vents.

Window Treatment

Windows are a prime source of noise transmission. Most of the homes that we treat are older, with single-glazed sash and retrofitted combination storm/screen windows applied to the exterior. In terms of noise-resistance, these windows amount to little more than a hole in the wall (Figure 2).

Window remediation commonly requires complete replacement of the old units. Although not the intent of the program, reduced heat-loss through the replacement windows also benefits the homeowner.

Ordinary windows, whether single-glazed or insulated, provide little barrier to noise. When field tested, ordinary wood windows without a storm panel yield an average noise reduction (NR) performance of 22 dB. The same type of window with a secondary storm unit applied yields an average NR performance of 25 dB. By contrast, the acoustical window combinations typically used in sound-insulation programs result in an average NR performance of 35 dB.

Airtightness. The additional noise reduction achieved by the acoustical window is due to its airtight construction (air infiltration typically less than .10 cfm at 25 mph) and the wide air space (2 inch minimum) between the prime and storm windows. To effectively address the windows as a noise path, we replace all the existing windows with high-performance acoustical units.

Vinyl acoustical windows are popular with many homeowners, given their easy maintenance, tilt-in operation, and the range of colors and grille patterns available. The window we use most commonly, from Harvey Industries (see “Sources of Supply,” page 8), is a vinyl unit with a sound transmission class rating (STC-rating) of 29. By adding a high-performance

Sound Terminology

The decibel (dB). Scientifically speaking, sound is nothing more than a change in air pressure. Air pressure is measured in Pascals (Pa), a unit so small that the ratio of the softest sound to the loudest is 10,000,000:1. To represent the same scale using smaller numbers, Bell Labs came up with the Bel. A Bel expresses the logarithm of the ratio between two pressures, or powers. To express sound measurements in single Bels would be similar to representing mileage in feet, so these measurements are called out in $^1/_{10}$-Bel chunks, or decibels (dB). A 10 dB increase in sound pressure increases the noise level by 100%; a 10 dB decrease cuts the noise by 50%.

A decibel reading represents a comparative number; when we say that the sound pressure level of a jet take-off is 140 dB loud, it really means that the sound pressure is 140 dB greater than the softest sound pressure we can perceive with our ears.

Decoupling is the physical separation of elements, which decreases noise transmission. It requires a 2-inch gap at the minimum.

Sound transmission class ratings (STC-ratings) are derived from sound transmission loss values, measured in decibels in a prescribed manner. STC-ratings provide a simple reference for determining sound-transmission properties and express the **noise reduction (NR)** that may be expected of a given building assembly or component. The higher the STC-rating, the better the sound-insulation performance.

— Dave Holbrook

Figure 3. Sliding storm panels provide extra sound insulation at sliding door locations. In every instance of a secondary door or window, there should be a minimum 2-inch gap between primary and storm units.

triple-track storm window on the exterior, STC-ratings of between 39 and 45 can be achieved.

Laminated glass is typically required in order to achieve the higher range of these STC-ratings. Laminated glass consists of two or more layers of glass bonded together by a transparent plastic interlayer. The increased mass of the glass and the dampening effect of the plastic interlayer both contribute to its superior sound-insulation characteristics.

Wood windows. Acoustical window treatment options are not limited to vinyl windows; wood and aluminum units are available as well. Wood windows are the preferred acoustical window treatment for homes where the aesthetic of the home requires it, or for homes where there are historic considerations.

With wood windows, STC-ratings of up to 40 can be achieved by installing a high-performance wood replacement sash and high-performance storm window or secondary glazing panel separated from the primary unit by a 2-inch airspace. "High performance" is defined here as having an air infiltration rate of less than .25 cfm at 25 mph for a primary window and less than .33 cfm air infiltration at 25 mph for a storm window.

Homes that are on historic registers may be compelled to use a secondary glazing panel on the interior of the prime sash rather than an exterior storm. Such interior panels are acoustically equivalent to an exterior storm as long as they are well gasketed, tight fitting, and maintain a 2-inch air space between the secondary and primary windows. Glazing in the wood replacement sash is typically 1/2-inch insulating glass.

Aluminum acoustical windows are preferred for most commercial, institutional, and high-rise installations, but they're also available for residential use. They are typically a dual window configuration; that is, two sets of parallel sashes separated by a minimum 2-inch air space in a single master frame. By varying the type and thickness of glazing in the sash and the width of the air space between the two sets, the window can easily be configured to create much higher STC-ratings than those available in vinyl or wood windows.

There are a couple of drawbacks to using aluminum acoustical windows. First, the frame depth of the aluminum units used in residential construction is 5 1/2 inches, which can create tricky detailing in a typical wood-frame wall. Also, their sash are typically single-glazed and are "side-loading" — the double-hung sash must be slid sideways within the jamb and physically lifted out to clean it. These two features make them less popular with many homeowners who have come to expect insulated glass and convenient maintenance. However, the windows do come in a variety of colors and offer various grille configurations.

Aluminum acoustical windows work well where higher STC-ratings are required, wind loading is a design issue, and wall depth is not a controlling factor.

VISCO

Figure 4. An automatic door sweep ensures a good seal against air and noise infiltration at the threshold.

Shutting the Door on Noise

Doors that lead directly from the exterior to the interior without an intervening air space or vestibule are major noise paths. As it happens, solid-core wood doors are highly effective at reducing noise energy by virtue of their mass. We typically install 1 3/4-inch wood raised-panel doors with a panel thickness of no less than 1 1/8 inches. The maximum area of any glazing in

Figure 5. Custom-made insulated plywood covers seal attic hatches (left) and through-wall AC units. Cam-type latches and compressible gaskets ensure a tight seal.

the door can be no more than 50% of the total door area and should be 1/2- or 5/8-inch insulating glass. The expected STC-rating of the prime door is 34.

Secondary door. The noise-reduction properties of the prime door are significantly enhanced by adding a high-performance storm door outside. "High performance" for leaf-type storm doors is defined as having an air infiltration rate of less than 1 cfm per square foot at 25 mph. There should be a minimum 2-inch air gap between doors, which may require a special build-out of the existing door's casing. The storm door helps reduce noise by virtue of its mass, with the core consisting of 3/4-inch-thick flakeboard or laminated fiberboard. The door has an aluminum or vinyl skin with various color and applied trim styles. As with the primary door, the maximum size of any glazing should be no more than 50% of the total door area. The expected STC-rating for the storm door is 28.

Sliding patio doors. In the case of a sliding glass door, conditions occasionally dictate installing the sliding storm panel on the interior side of the prime door to provide adequate sill support (Figure 3, page 3). Since sliding-door handles project out from the face of the door and may interfere with one another, the space between the doors may have to be greater than 2 inches.

Gasketing. It is acoustically important that both prime and storm doors are well-gasketed with continuous weatherstripping to minimize air leakage. The weatherstripping should create a flexible, shape-conforming, airtight seal between door and frame. We use polyprene or polypropylene bulb weatherstripping because they maintain flexibility longer than other types of weatherstripping without stiffening or cracking.

With the correct airtight seal, you can feel a vacuum-type resistance when you open the primary door with the storm-door closed, and a compressive pressure when you close it again. Weatherstripping at the threshold, preferably with a flip-down sweep, is equally important (Figure 4).

Sound Baffle at Gable Vent

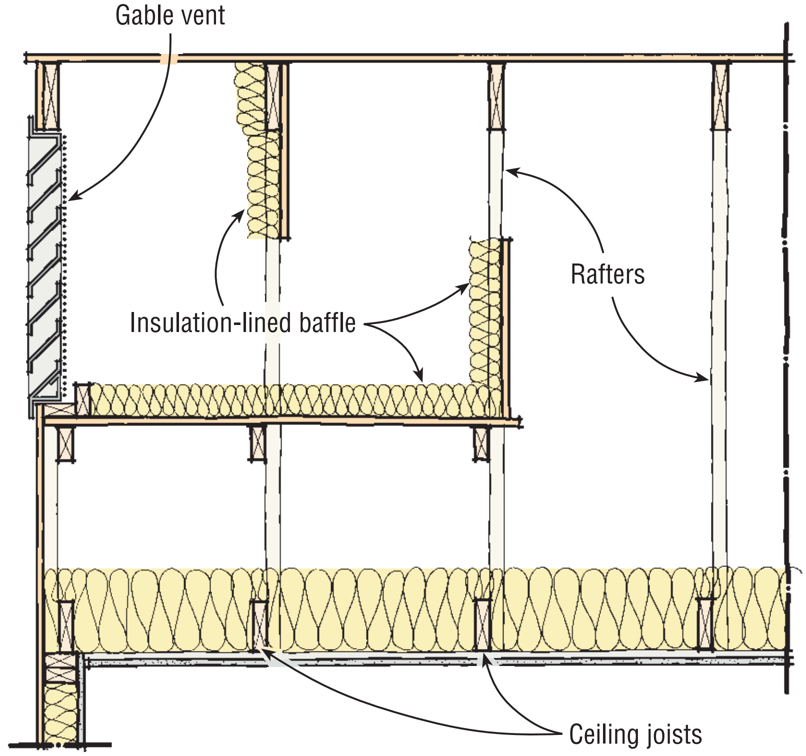

Figure 6. Roof vents provide a potential path for noise entry. A custom insulation-lined baffle disrupts and muffles sound entering the structure.

Figure 7. Applying the principle that surface mass absorbs noise energy, adding an extra 5/8-inch-thick layer of gypsum blueboard with a plaster skim coat helps to reduce the noise transmitted through flat-roof and cathedral-style ceilings.

Air Quality

In the process of replacing all of the windows and doors and sealing other points of airflow, a home's exterior envelope becomes considerably tighter than it was before. As a consequence, indoor air quality may suffer and combustion devices may become oxygen-starved. Older homes without vapor barriers and modern insulation usually continue to breathe sufficiently; with newer homes, however, we specify additional ventilation to provide make-up air for the health of the occupants and normal operation of the home's mechanical systems.

Installation Guidelines

Whatever type of windows or doors are used, proper installation is critical to acoustical performance. The principle of tightness is the controlling guideline to ensure that the acoustical performance is not degraded by flanking path leaks around the perimeter of the installation. We insert fiberglass insulation in the shim space between the window frame and rough opening at head and jambs. Sash-weight cavities are always abandoned in the window replacement process; we insulate these as well, being careful not to overfill or compact the insulation. Again, since noise can leak through any air gap, caulking and sealing are important. We set and seal windows and doors in the rough opening with a non-skinning, non-hardening polyurethane or silicone sealant.

Other openings in the building envelope also need attention, such as through-the-wall air-conditioning units, ceiling-mounted attic hatches, and vents. We've developed some simple gasketed covers, made of cabinet-grade plywood, that encapsulate and seal the

Quiet Room Details

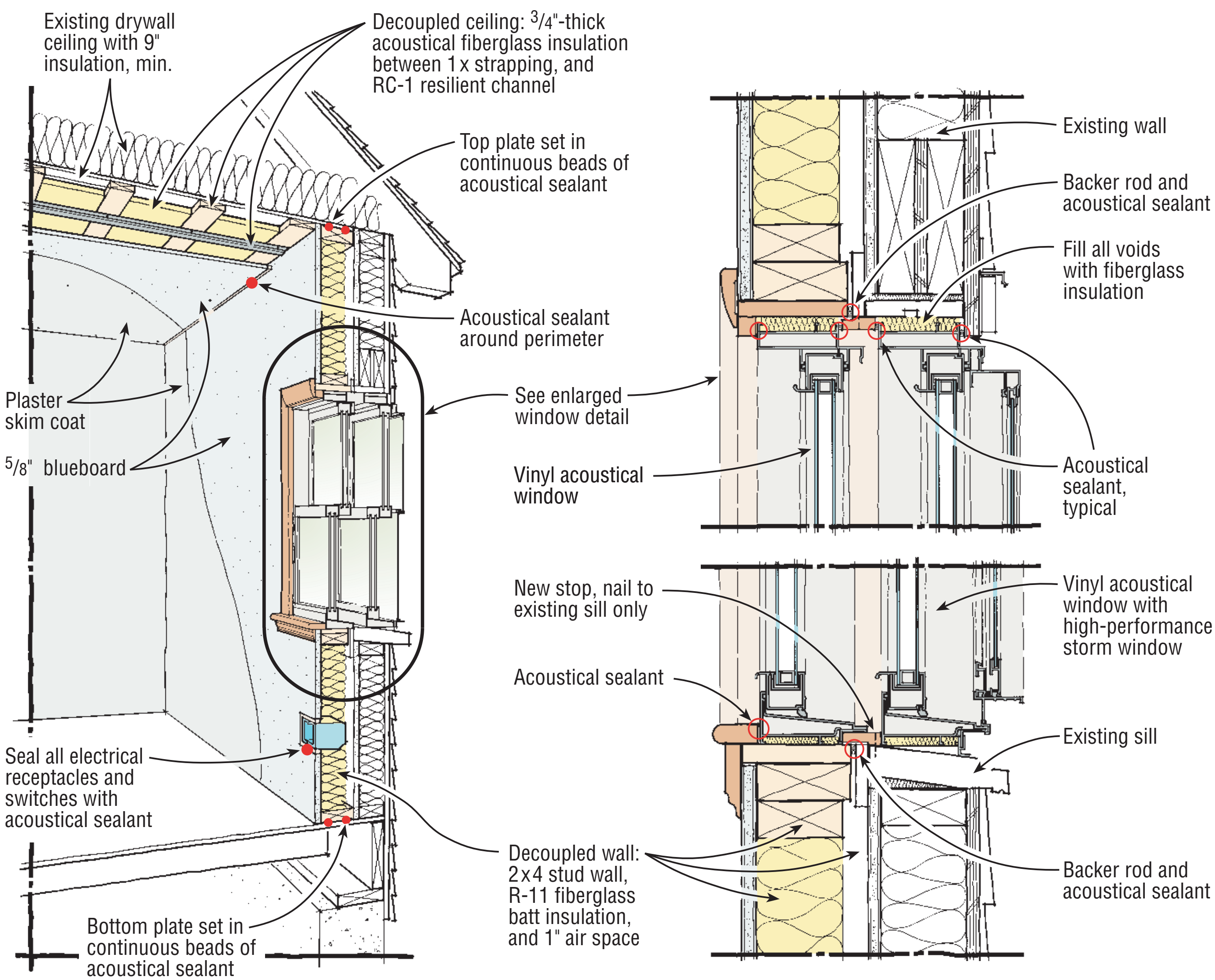

Figure 8. Double wall and ceiling construction decouples, or isolates, the interior space from the exterior building envelope. Although the existing room size is slightly reduced, the thunder of a passing jet is lowered to background noise.

AC unit and the attic hatch when they're not in use (Figure 5, page 4).

We review vent openings on a case-by-case basis to determine if they constitute a significant noise path that must be treated. We use some simple rules of thumb: First of all, ridge vents, gable vents, and roof louvers must be baffled if their aggregate clear opening area exceeds 1% of the attic floor area. Secondly, bathroom and kitchen vents and range hoods must be baffled or reducted if there is an existing line-of-sight path between inside and outside.

Baffles usually need to be custom designed for each particular situation, but the design principles are the same — the baffle should allow free air movement along a circuitous path across absorbent material (Figure 6, page 5).

Adding Mass

Normal wood-frame construction — 1/2-inch drywall, 3 1/2-inch studs and insulated cavity, and 5/8-inch sheathing with siding — does not create a noise path that requires treatment. However, uninsulated wall and ceiling framing may require treatment. A ceiling that is part of the roof assembly is exposed to more outside noise energy than a flat ceiling under an attic space. To absorb some of this energy, we increase the surface mass by applying an additional layer of 5/8-inch blueboard with a plaster skim coat, going directly over the existing layer of gypsum (Figure 7, page 5). Where attics exist above ceilings, no acoustical treatments are generally required as long as the ceiling has at least one layer of 1/2-inch gypsum board, and there is at least 9 inches of insulation in the joist bays.

Quiet room. Boston's Logan Airport program offers participating homeowners an extra measure of sound insulation beyond the typical door and window treatments. Homeowners may choose one room in their home to receive a "quiet room" treatment that effectively creates a room within the existing room. Any wall or ceiling in the designated room that has exterior noise exposure will have a second wall or ceiling constructed 1 inch inside of the existing surfaces (Figure 8, page 6). This, of course, results in some downsizing of the room's dimensions.

Surface isolation. Decoupling these rooms works very well — the thunder of a jet departing is reduced to background noise. The average tested noise rating of a quiet room is 45 dB — a 10 dB, or 50%, noise reduction beyond that achieved by our normal door and window treatments.

For these rooms to be optimally efficient, careful attention to detail is a must. We make sure that no elements bridge the gap between the new and existing walls and/or ceilings, and that seams and holes are tightly sealed. These are the steps:

- Set the new wall plate in acoustical sealant where it is in contact with the floor.
- Seal all electrical wall switches and receptacles with the same sealant.
- Use the standard elements of a normal 2x4 wood-framed wall in the double-wall construction, and include R-11 insulation (Figure 9).

Figure 9. Double-wall 2x4 framing set in acoustical sealant caps the top and bottom of an existing boxed-out lower wall section. Fiberglass batt insulation absorbs sound energy. Resilient channel crosses 1x3 strapping over the existing ceiling, which is covered with semi-rigid acoustical fiberglass insulation, followed by a layer of 5/8-inch-thick blueboard with a plaster skim coat.

Figure 10. Even the windows get doubled in a sound-insulated room. Thermopane glass, minimum 2-inch air spaces between units, and a high-performance storm window present an effective barrier to external noise.

- Replace any windows in the existing wall with a new acoustical window.
- The double wall also receives an acoustical window, creating a double window construction (Figure 10).
- To decouple the ceiling, install 3/4-inch-thick acoustical fiberglass insulation between wood strapping, directly over the existing ceiling.
- To reduce the transmission of vibration, cross the wood strapping with RC-1 resilient channel, and fasten a layer of 5/8-inch blueboard to it.
- A layer of skim-coat plaster and a prime coat of paint finish the job.

The only thing left for the homeowner to do is the final painting and decorating.

One of the main goals of the residential insulation programs is homeowner satisfaction and community goodwill toward the airports. As a testament to the adaptability of people, not to mention their savvy in not passing up a good deal, one program participant, when asked if she noticed the difference after her home was sound-insulated, responded, "I've lived here for 32 years, so I don't even think about the noise anymore, but I'm happy with the job — it looks very nice."

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Sources of Supply

ChemRex
889 Valley Park Dr.
Shakopee, MN 55379
800/433-9517
www.chemrex.com
Sonneborn's Sonoclastic NP1
Sonneborn's Sonolastic Omniseal

Graham Architectural Products
1551 Mount Rose Ave.
York, PA 17403
800/755-6274
www.grahamarch.com
Aluminum acoustical windows

Harvey Industries
1400 Main St.
Waltham, MA 02451
800/942-7839
www.harveyind.com
Vinyl acoustical windows
Storm doors

Hess Manufacturing
P.O. Box 127
Quincy, PA 17247
800/541-6666
www.armaclad.com
Armaclad storm doors

J.B. Sash and Door Company
280 Second St.
Chelsea, MA 02150
800/648-9339
www.jbsash.com
Wood replacement windows
Primary solid-core wood doors

Kolbe & Kolbe
1323 S. 11th Ave.
Wausau, WI 54401
800/477-8656
www.kolbe-kolbe.com
Wood replacement windows

M-D Building Products/ Maclanburg-Duncan
4041 N. Santa Fe
Oklahoma City, OK 73118
800/654-0008
www.mdteam.com
Flex-O-Matic door sweep

Marvin Windows
P.O. Box 100
Warroad, MN 56768
888/537-8266
www.marvin.com
Wood replacement windows

Mohawk Flush Doors
P.O. Box 112
Northumberland, PA 17857
714/473-3557
www.mohawkdoors.com
Primary solid-core wood doors

Mon-Ray
801 Boon Ave. North
Minneapolis, MN 55427
800/544-3646
www.monray.com
Aluminum acoustical windows
Patio storm doors

Morgan Manufacturing
228 W. 6th Ave.
Oshkosh, WI 54902
920/235-7170
www.doors-windows.com
Primary solid-core wood doors

Pecora
165 Wambold Rd.
Harleysville, PA 19438
800/523-6688
www.pecora.com
Dynatrol I, 864, and 863 sealant

Peerless Products
P.O. Box 2469
Shawnee Mission, KS 66201
800/279-9999
www.peerlessproducts.com
Aluminum acoustical windows
Sliding storm doors

Premier Sealants
P.O. Box 484
Elmer, NJ 08318
856/256-1111
www.premiersealants.com
Tremco's Dymonic sealant

Republic Windows
930 W. Evergreen Ave.
Chicago, IL 60622
800/248-1775
www.republicwdws.com
Vinyl acoustical windows

Visco Weather Seal Products
166 Valley St., Bldg. 7
Providence, RI 02909
401/831-1665
Uni-Check door sweep

Weather Shield Mfg.
One Weather Shield Plaza
Medford, WI 54451
800/222-2995
www.weathershield.com
Wood replacement windows