Appendix D
Property Enhancements:
Sound Insulation of Homes and the Use of "Sound Masking"

USE OF "SOUND MASKING" TO REDUCE ANNOYANCE FROM HIGHWAY NOISE

Where highway noise is not severe, more-pleasant sounds can sometimes be used to partially "cover up" the highway noise and thereby reduce its annoyance. The technical term is "sound masking." This small booklet describes what steps you might take to "mask" highway noise, both outside and inside your home.

The use of sound masking does not actually reduce sound levels. In fact, the masking sound combines with the highway noise to increase the total somewhat. In other words, the composite noise—highway plus masking—is louder than highway noise, alone. In spite of this, sound masking is effective because it makes the composite noise more pleasant. In effect, it "covers up" the annoying quality of the highway noise.

Sound masking has its limits, however. It works much like perfume. It does cover up moderate amounts of less-pleasant noise. But it can be repugnant, itself, at large doses. Very loud sound masking is needed to cover up very loud highway noise. And so masking is generally useful only where highway noise is not too severe.

Disclaimer

The guidance in this booklet is approximate. It cannot be guaranteed accurate for your home. For that reason, neither the City of Scottsdale nor its consultants can assume any responsibility for money you spend that seems wasted as a result of this guidance. That is your risk. If you are not willing to risk that, then please hire an acoustical professional to advise you about sound masking.

OUTSIDE YOUR HOME

Outside your home, you could use background music to "mask" highway noise from the freeway. However, your neighbors might object to music, especially if their favorite type of music differs from yours.

You and your neighbors will probably be happier with a water fountain to provide sound masking. The sound of splashing water is certainly more pleasant than highway noise.

Small waterfalls and water flowing over rocks do not provide enough masking sound to be of significant benefit outdoors. Instead of these, you need a relatively substantial fountain of water—one that shoots the water four or five feet in the air and then lets it fall into a pool of water or onto a hard surface. A minimum water flow might be 1000-to-2000 gallons per hour.

Costs for such fountains are not trivial, perhaps as much as $2,000-to-3,000 or more. To save cost, you may want to assemble your own components: a basin, a submersible pump (1/3 horsepower or so), a fountain nozzle, the plumbing to recirculate the water, plus other components recommended by distributors of this equipment.

To get an idea of available outdoor fountains, start by searching the internet (www.google.com). Here are several starting points:

- www.mwdh2o.com/Aqueduct/dec2001/sound.htm
- www.indoor-water-fountains.com/links.htm
- www.i-lookup.com/search.php?que=water+fountains
- www.justliners.com/
- www.fizgigs.com/page.php?page=garden+water+fountain
- http://dir.yahoo.com/Business_and_Economy/Business_to_Business/Landscaping_and_Gardening/Water_Features/

Then find a garden-supply store that sells relatively substantial water fountains. It is important that you listen to the fountain before buying it, to judge its sound character and its loudness relative to the highway noise in your yard. They should be about equally loud. See the last page in this booklet for advice on measuring both with a sound-level meter.

In addition, try to purchase a fountain with variable water flow. Then by increasing or decreasing the water flow, you can control the amount of sound masking. The benefit of the masking will depend upon your distance from the fountain and the amount of highway noise in your yard.

INSIDE YOUR HOME

Smaller water fountains will work well within your home, as well. Even water flowing over rocks can provide some masking of the highway noise that enters your home.

Many garden-supply stores sell small water fountains. To make much sound, the water must actually "fall" and then splash onto something hard or into a pool of water. Sound masking increases as the "fall height" increases. Water dribbling down a surface provides very little sound masking.

It is important that you listen to the fountain before buying it, to judge its sound character and its loudness relative to the highway noise in your home. They should be about equally loud. See the last page in this booklet for advice on measuring both with a sound-level meter.

Try to purchase a fountain with a quiet pump. In addition, try to purchase a fountain with variable water flow. Then by increasing or decreasing the water flow, you can control the amount of sound masking. The benefit of the masking will depend upon the relative loudness of sound masking and the highway noise within your home.

You can also use background music and high-speed fans to mask highway noise inside your home. In addition, small electronic devices are now sold just to mask unpleasant indoor noise. These devices sometimes produce so-called "white noise" and sometimes produce other pleasant, continuous sounds—like ocean surf.

MEASURE WITH A SOUND-LEVEL METER

Sound masking must be about the same loudness as the highway noise you are trying to mask. They must be "balanced" in this sense.

To help reach this balance, first measure your highway noise (outdoors or indoors) with an inexpensive sound-level meter. Either of the two Radio Shack models ($25 and $50) is sufficient. Set the sound-level meter to "A-weighting" and "slow response." With those settings, measure the highway noise's *maximum* value during the loudest time of the day.

Then choose sound masking that is about the same sound level as the highway noise you measured. As before, measure the sound masking with the meter set to "A-weighting" and "slow response," and measure it at an appropriate distance.

Perhaps these sound-level measurements will help you chose a sufficiently loud masking source on the first try—to avoid wasting money. Please re-read the disclaimer on the first page of this booklet.

SOUND INSULATION OF HOMES

Sound insulation of homes can reduce interior sound levels from nearby highways. This information package describes such sound insulation and how you might incorporate it in your home.

Highway noise is generally less expensive to reduce indoors than is aircraft noise. Around airports, typical sound insulation costs $15,000 to $40,000 per home. These high costs include complete replacement of windows and doors with acoustically rated products. Against highway noise, such expensive replacement may not be necessary. This booklet describes lower-cost alternatives that may provide noticeable noise reduction against highway noise in your home.

Please remember that the advice here is very general. It applies to an average home rather than specifically to your home. Only professional noise measurements and computations on homes very similar to yours can accurately advise you about these matters.

YOUR HOME IS LIKE A TOW CHAIN

It is important that you begin by understanding a little about sound-insulation acoustics. Acoustically, your home is like a tow chain—the kind you attach to your rear axle to tow another vehicle.

If you have a weak tow chain and wish to improve it, you must start by replacing its weakest links. Those are the only links that matter. If you replace any strong links, you are completely wasting your money. The chain as a whole will be no stronger. The secret to a stronger tow chain is "fix the weakest links first."

That's true for home sound insulation, as well. You must determine the "weakest links" in your home's current sound insulation, and then fix those items first. Any other approach will waste your money—often lots of money. Luckily, the very weakest links in most homes are relatively cheap to fix.

You might say, "But weakest links are always best to fix first, in any repair job." That's true, of course. But it's especially true for acoustics. If one noise source sounds "twice as loud," it actually emits "ten times as much acoustic energy." So it is essential to attack that source first.

And so.... don't go to a sound-insulation vendor and buy "one of each." That's like repairing your automobile by replacing every part in it, one of each—a waste of money. Instead, follow the advice in this booklet, to reduce your indoor noise one step at a time, starting with the most likely weak links.

First of all, which sides of your home are of concern?

Of no real concern is the side of your house that faces directly away from the highway. In contrast, the other three sides of your house are of concern—even the sides that get just "glancing" sound from the highway, or sound that reflects from your neighbor's house. To test, put your ear against a window or near the cracks around it. If you hear traffic noise, that side of your home is of concern.

Therefore, the remainder of these guidelines pertains only to three sides of your home.

Disclaimer

The general recommendations on the following pages cannot be guaranteed accurate for your home. For that reason, neither the City of Scottsdale nor its consultants can assume any responsibility for money you spend that seems wasted. That is your risk. If you are not willing to risk that, then please hire an acoustical professional to diagnose your home's current sound insulation and recommend improvements to it.

OVERVIEW OF WEAK LINKS

Every part of your home's exterior lets some sound through.

If your home is not centrally air conditioned, your open windows are your weakest links. Nothing can be done about them. Very little can be done with window (or through-the-wall) air conditioners, either. In both situations, you will likely need central air to improve the sound insulation of your home.

Even with central air, sound gets in through air gaps around windows and doors. These may well be your home's weakest links. They are inexpensive to gasket. So gasket before replacing windows or doors. Gasketing may be enough.

Sound also gets through solid surfaces—windows, doors and walls, for example—even though they don't leak air. Tissue paper doesn't leak air, either, but sound certainly passes right through it. Exterior windows and doors may be your home's next-weakest links. Solid-core doors are much better than hollow doors, because they are heavier. Replacement windows or acoustical storm windows have heavier glass and excellent gasketing.

With all this taken into account, many homes fall into the following pattern:

- Weakest link: Obvious, large holes
  Sometimes impossible to fix
- Next-weakest link: Cracks around doors and windows
  Improvement: Install gasketing
- Next-weakest link: Hollow-core doors
  Easiest improvement: Replace with solid-core doors
- Next-weakest link: Thin window panes
  Easiest improvement: Add storm windows
- Next-weakest link: Exterior (solid-core) door
  Improvement: Add storm door

After this, prices increase dramatically:

- Next-weakest link: Combined primary/storm window
  Improvement: Acoustically rated primary/storm window
- Next-weakest link: Combined primary/storm door
  Improvement: Acoustically rated primary/storm door
- Next-weakest link: Wall or roof
  Very difficult and expensive to fix

The remainder of this booklet describes your options more fully. They are arranged from most important to least important (for most homes), so start on the next page and work systematically through the remainder of this booklet.

STEP 1: FIX THE OBVIOUS LARGE HOLES

Almost always, the weakest acoustic links in your home will be holes and air gaps—especially holes through window air conditioners, mail slots in doors, and air gaps around the edges of doors and windows. An amazing amount of sound can get through these holes and gaps.

The following are the worst offenders:

- **Mail slots in doors.** If your exterior doors have mail slots, you will have to replace those doors (see below).
- **Through-the-wall or window air conditioners.** If you have older, through-the-wall or window air conditioners, you may have to replace them with central air for any significant improvement. Replacement with newer, more energy-efficient ones may help somewhat, because these newer models (ENERGY STAR qualified) isolate indoor from outdoor air better—but only when their outside-air vents are closed.
- **Fireplaces**. If you have a fireplace, install a tight-fitting glass fireplace screen over its opening into the room—a screen that covers the full opening.

If you cannot fix large holes like these, then further improvement for those rooms in your home is probably futile.

The remainder of this booklet is less pessimistic.

STEP 2: FIX GAPS AROUND DOORS AND WINDOWS

Air gaps around exterior doors and windows are very common. These generally can be fixed with inexpensive caulking and acoustical gasketing.

Both doors and windows

First, it is important to caulk the joints between your house and all door frames and window frames. In addition, caulk around the edge of any glassed areas in your exterior doors. Always use non-hardening caulk, so it doesn't dry up later and allow air gaps to re-appear.

Exterior doors

Doors almost always leak sound around their edges. Listen to the traffic noise just behind the door, while you pull the door towards you to achieve a tighter fit. If the noise decreases as you pull the door, your door definitely needs acoustically designed gasketing. It also definitely needs such gasketing if you can see any light anywhere around its edge.

And even without these two symptoms, your door *most likely* needs acoustically designed gasketing, especially because it's so cheap. Such gasketing is available from:

- Zero International in New York City
  1-800-635-5335
  1-602-254-5967 in Phoenix
  zero@zerointernational.com for e-mail
  www.zerointernational.com for product information
- National Guard Products in Memphis
  1-800-647-7874
  1-714-544-8003 in Tustin, CA
  robbinm@ngpinc.com for manufacturer e-mail
  brnlassoc@aol.com for e-mail in Tustin, CA
  www.ngpinc.com for product information

Along the bottoms of residential doors, two relatively inexpensive options are adequate: Zero International's Model #119WB and National Guard's B1369N. Along door sides and top, two very inexpensive options are adequate: Zero International's Model #188 and National Guard's 5050 series. Such gasketing costs about $50 per door.

Most likely you can attach all these types by yourself. They either screw onto doorframe edges, or are self-adhesive. Follow the manufacturer's instructions. If you already have storm doors, you should gasket those, as well.

Windows

Windows must be fully gasketed. Acoustically designed window gasketing is available from:

- Zero International in New York City
  1-800-635-5335
  1-602-254-5967 in Phoenix
  zero@zerointernational.com for e-mail
  www.zerointernational.com for product information

For residential windows, their Series 20 (for double-hung windows) and Series 30 (for casement windows) are both adequate. In addition, this company also sells gasketing for other style windows. High-quality window gasketing of this type costs about $100 per window.

Most likely you can install this gasketing by yourself. If you already have storm windows, you should gasket those, as well. Windows are more complex than doors and therefore have more chance for sound gaps. For this reason, it is best to discuss window gasketing with an acoustical-gasketing sales representative.

In addition, inexpensive aluminum storm windows often have various holes and gaps, due to imprecise fit. You must plug these holes with non-hardening caulk. However, be sure not to plug the bottom-most hole that is often designed into these storm windows. That hole drains water out the air space between storms and inside windows, to prevent sill rot.

Finally, if any window rattles within its framing, apply non-hardening caulk around that pane to hold it tight and block the possible air gap there.

STEP 3: REPLACE HOLLOW-CORE DOORS WITH SOLID-CORE ONES

If you now have a hollow-core exterior door, your least expensive option is to replace it with a solid-core exterior one. Solid-core exterior doors are available from typical home supply retailers. Best are doors that come with their own frame (pre-hung doors). If the door comes without its own frame, be sure to gasket it well (see above), to ensure its best performance.

If possible, first remove the existing door frame and then tightly fill in between the frame and your house with wood blocks and thermal insulation. Then caulk the joint between frame and house with non-hardening caulk.

Pre-hung solid-core exterior doors cost about $250 each, plus installation. Make sure the door you chose is rated for exterior use.

STEP 4: ADD STORM WINDOWS

If you currently don't have storm windows, adding them may be less expensive than replacing your primary windows. Likewise, if you now have ordinary (non-acoustical) storm windows, replacing them with acoustical storms may be your least-expensive option.

Acoustically rated storm windows are available from:

- Mon-Ray Inc. in Minneapolis
  1-800-544-3646
  www.monray.com for product information
- Peerless Products, with Phoenix distributor
  1-602-788-1795
  1-480-203-4122 cell phone of George Cobat, local distributor
  jancobat@aol.com for e-mail
  www.peerlessproducts.com for product information
- Republic Windows & Doors in Chicago
  1-800-248-1775
  Contact_Us@Republicwindows.com for e-mail
  www.republicwindows.com for product information
- Sound Control Systems
  1-403-948-6655
  info@soundcontrolsystems.com for e-mail
  www.soundcontrolsystem.com for product information

Acoustically rated storm windows should have a minimum STC (Sound Transmission Class) of 32. Storm windows of this acoustical quality cost about $400 each, plus installation. They may be more expensive for unusually shaped windows, for non-operable hemispherical windows above a regular window, and for possibly windows that flank a door.

Acoustical storm windows should be installed by a construction contractor, using the manufacturer's installation instructions. Proper installation avoids air gaps, which can seriously compromise acoustical performance.

Warning: Some manufacturers warn against acoustical storm windows over vinyl-framed primary windows. They warn that heat buildup between the two may warp the vinyl.

STEP 5: ADD STORM DOORS

If you currently don't have a storm door, adding it may be less expensive than replacing your main door, itself. Likewise, if you now have an ordinary storm door, replacing it with a more substantial one may be your least-expensive option.

The least expensive option is to install a solid-core aluminum storm door with minimum glass thickness of 3/16 inch. These are generally available from local stores. Make sure the door fits tightly and has weather stripping and/or gasketing all around (see above). It should be tight enough so you have to pull it shut, squeezing the weather stripping in the process. You should see absolutely no light around the door perimeter. For assurance, see architectural detail D2 in www.ohare.com/cnrc/ohare/SoundInsYourHome.pdf.

The second option is to install an acoustically rated storm door, available from:

- Hess-Armaclad in Quincy, PA
  1-800-541-6666
  info@armaclad.com for e-mail
  www.armaclad.com for product information
- Mon-Ray Inc. in Minneapolis
  1-800-544-3646
  www.monray.com for product information
- Sound Control Systems
  1-800-334-1328
  1-403-948-6655
  info@soundcontrolsystems.com for e-mail
  www.soundcontrolsystem.com for product information
- Whisper-like Doors in Toledo
  1-800-227-8246
  Lou@Whisper-Like.com for e-mail
  http://whisper-like.com for product information

Acoustically rated storm doors should have a minimum STC (Sound Transmission Class) of 32. Storm doors of this acoustical quality cost around $400 each, plus installation. They may be more expensive for unusually shaped doors.

These acoustical storm doors should be installed by a construction contractor, using the manufacturer's installation instructions. Proper installation avoids air gaps, which can seriously compromise acoustical performance.

STEP 6: REPLACE PRIMARY/STORM WINDOWS WITH ACOUSTICALLY RATED ONES

If you already have storm windows and your windows are still your weakest link, you may have to replace the entire window structure, including the storm window and frame, with an acoustically rated window.

Acoustically rated windows are available from:

- Graham Architectural Products in York, PA
  1-800-755-6274
  info@grahamwindows.com for e-mail
  www.grahamwindows.com for product information
- Krieger Specialty Products in California
  1-866-203-5060
  1-562-695-0645 for Arizona sales manager in Pico River, CA
  shopkins@kriegerproducts.com for e-mail to sales manager
  www.kriegerproducts.com for product information
- Milgard Windows in Tacoma, WA
  1-800-645-4273
  Six distributors in the Phoenix area (see web site)
  www.milgard.com/index.html for product information
- Mon-Ray Inc. in Minneapolis
  1-800-544-3646
  www.monray.com for product information
- Peerless Products, with Phoenix distributor
  1-602-788-1795
  1-480-203-4122 cell phone of George Cobat, local distributor
  jancobat@aol.com for e-mail
  www.peerlessproducts.com for product information
- Republic Windows & Doors in Chicago
  1-800-248-1775
  Contact_Us@Republicwindows.com for e-mail
  www.republicwindows.com for product information
- St. Cloud Window Inc. in Sauk Rapids, MN
  1-800-383-9311
  info@stcloudwindow.com for e-mail
  www.stcloudwindow.com for product information

Acoustically rated windows should have a minimum STC (Sound Transmission Class) of 38 (though only 32 for skylights). Windows of this acoustical quality cost about $1000 each, plus installation. They may be more expensive for unusually shaped windows.

It is crucial that newly installed windows be sealed adequately. The STC values listed in product brochures can only be achieved with near-perfect seals—that is, no air leaks. Windows that do not seal adequately often result in poor acoustical performance. Air can leak not only through visible gaps around window sashes, but also between the window frame and the house structure itself.

In brief, installation is crucial and requires construction professionals, using manufacturer’s installation instructions. It is wise to require your window installer to conform to architectural details W1 and W2 in www.ohare.com/cnrc/ohare/SoundInsYourHome.pdf.

STEP 7: REPLACE PRIMARY/STORM DOORS WITH ACOUSTICALLY RATED ONES

If you already have a storm door and the combination of it and your solid-core door is still your weakest link, you may have to replace the entire door structure, including the storm door and frame, with an acoustically rated door.

Acoustically rated doors are available from:

- Buell Door Company in Dallas
  1-800-556-0155
  1-714-381-2810 for Arizona sales manager in Cypress, CA
  jayerselius@hotmail.com for e-mail to sales manager
  www.buelldoor.com for product information
- Hess-Armaclad in Quincy, PA
  1-800-541-6666
  info@armaclad.com for e-mail
  www.armaclad.com for product information
- Krieger Specialty Products in California
  1-866-203-5060
  1-562-692-0146x207 for Arizona sales manager in Pico River, CA
  shopkins@kriegerproducts.com for e-mail to sales manager
  www.kriegerproducts.com for product information
- Overly Doors
  1-800-979-7300
  1-800-583-7174
  info@silentsource.com for e-mail
  www.silentsource.com/adoors-overly.htm for product information
- Peerless Products, with Phoenix distributor
  1-602-788-1795
  1-480-203-4122 cell phone of George Cobat, local distributor
  jancobat@aol.com for e-mail
  www.peerlessproducts.com for product information
- Republic Windows & Doors in Chicago
  1-800-248-1775
  Contact_Us@Republicwindows.com for e-mail
  www.republicwindows.com for product information

Acoustically rated doors should have a minimum STC (Sound Transmission Class) of 38. Exterior doors of this acoustical quality cost about $2,000 each, plus installation. They may be more expensive for unusually shaped doors.

It is crucial that newly installed doors be sealed adequately. The STC values listed in product brochures can only be achieved with near-perfect seals—that is, no air leaks. Doors that do

not seal adequately often result in poor acoustical performance. Air can leak not only through visible gaps around the door, but also between the door frame and the house structure itself.

In brief, installation is crucial and requires construction professionals, using manufacturer’s installation instructions. It is wise to require your door installer to conform to architectural detail D1 in www.ohare.com/cnrc/ohare/SoundInsYourHome.pdf.

Acoustically rated exterior doors always come with proper acoustical seals to ensure their acoustical performance. Sometimes they come with their own door frames. If not, your door frame will have to be close to standard size.

ADDITIONAL READING MATERIALS

The following web sites provide additional information:

General:

- www.scottsdaleaz.gov/airport/pdf%20files/ModelBuildingCode_SoundInsulationStandards.pdf
  This document describes sound-insulation methods for new home construction in high sound-level areas around airports. Its descriptions of these methods may help you improve the sound insulation of your home.
- www.ohare.com/cnrc/ohare/SoundInsYourHome.pdf
  This document provides sound-insulation guidance to homeowners around O'Hare International Airport in Chicago.
- www.soundproofing.org/sales/EPAmanual.htm
  This document offers further general guidance about sound insulation.
- www.harveyind.com/site/content/homeowner/working_with_contractor.asp
  This document will help you work smoothly with your contractor.

Gasketing:

- www.zerointernational.com/education/acoustics/sb_pdf.pdf
- www.zerointernational.com/whatsnew/publication2.pdf

Acoustical doors and windows:

- http://sweets.construction.com/index/cadlib.htm, then search for "acoustical doors" or similar products.
- www.overly.com/doorCo/Education/Acoustical.cfm

Project descriptions of sound insulation around airports:

- www.hmmh.com/aviation_insulation.html

ADDITIONAL DISCUSSION

Many sound sources contribute to overall outdoor sound—called "noise" when it is not wanted. And outdoor noise penetrates into homes through walls, windows and doors, where it can interfere with TV, music, conversation and sleep.

Mitigation of highway noise commonly includes noise barriers (generally free-standing walls) between the highway and nearby homes. These barriers reduce highway noise both outdoors and indoors. However, sometimes these barriers are not possible to construct, perhaps due to geographical constraints, perhaps for lack of funding. For these situations, indoor noise can be reduced with home sound insulation, thereby improving the acoustical isolation between indoors and outdoors.

Sound-insulation costs depend upon how good current sound isolation is, how much improvement is desired, and the details of the home's construction (including specific materials, quality of construction, and past maintenance).

For example, homes with central air conditioning already have better sound isolation that those without it (even those with window or through-the-wall air conditioners). Therefore, it is harder and more expensive to achieve additional isolation. In addition, homes with acoustically tight windows and doors have initially better isolation, so improvement for these homes is also harder and more expensive that for homes with poorly maintained doors and windows.

On the other hand, homes with thin window glass and without existing storm windows and doors are relatively inexpensive to improve. They are currently louder indoors, and improvement is easier.

Technically, the "noise level reduction" (NLR) is the acoustic measure of the outdoor-to-indoor sound insulation—from outdoors to indoors a particular room. The existing NLR can be measured by acoustics professionals, home-by-home and room-by-room. It can also be computed from construction details of the home, assuming different conditions of home maintenance. In addition, the NLR depends upon the sound characteristics of the outdoor noise, especially the noise's frequency components. So precise measurement and useful computations involve so-called octave bands of sound.

The goal of home sound insulation is to improve the NLR by at least 5 decibels, and preferably by as much as 10 decibels. A 5-decibel improvement is "noticeable" but not greatly beneficial. A 10-decibel improvement is subjectively about "half as loud"—very beneficial. Starting with room windows open, closing them produces a 10-decibel improvement, more or less.

Replacement windows and doors are rated acoustically by their Sound Transmission Class (STC). STC values generally increase with the weight of the door or window glass, with the number of panes of glass through which the sound must pass (storm window, then primary window for example), and especially with the quality of gasketing. The relation between these catalogued STC values and improvement in NLR is complex—a matter for specialized computer programs.