Finding and Fixing Hidden Air Leaks

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Most publications about weatherization still recommend caulking exterior siding and weatherstripping doors and windows to prevent drafts. In some cases, these measures may increase your comfort slightly by reducing drafts coming through exterior walls, but they may not save as much energy as most energy audits estimate. This is because in many homes a great deal of air escapes through hidden air leak passageways on the interior of the home which are not affected by typical exterior caulking and weatherstripping efforts.

Because there are numerous paths for an air leak to follow once it is inside the wall or ceiling of a home, sealing the source of the air leak from the inside the home is more effective than trying to seal it from the outside. Also, it’s easier to find and fix hidden air leaks working from the inside, because cracks and holes are accessible. And because the work can be done indoors, you can do the work in the middle of winter when the heat loss from the greatest. To understand why the standard exterior caulking and weatherstripping recommendations are likely to be ineffective, you need to understand what causes air leakage in homes.

What causes air leaks?

Air will not move through a hole in a wall or floor without a driving force. One of the most powerful driving forces in winter is the stack effect—convection currents of hot air rising. Rising warm air will "exfiltrate" or pass out of the house through any crack or hole in the ceiling. Then cooler outside air "infiltrates" into the house around cracks and holes near the foundation. Plumbing and electrical wiring holes and shafts, interior partition walls that open into the attic, floor joists, and foundation areas all provide unintended and hidden air leakage passageways in homes (Figures 1 and 2). Older, "balloon-framed" houses with framing running the full height of the structure have many more air leak possibilities than do newer, platform-framed houses whose walls extend up only one story.

The greater the difference in temperature between warm indoor air and cooler outdoor air, the more air that is moved by the stack effect. When the outside temperature is 0°F and inside is 68 to 70°F, the stack effect may move as much air as a kitchen range hood left running continuously. This results in areas of higher pressurization near the top of the house and depressurization near the bottom of the structure.

Around the mid-level of a house, the so-called "neutral pressure zone," comparatively little stack effect-driven air leakage in or out of the house occurs. In this area of the home, another driving force of air leakage is sometimes noticeable: drafts resulting from windy or door weather. Typical caulking and weatherstripping measures, such as door and window weatherstripping, significantly reduce this wind-driven air leakage.

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Figure 1.—Common interior air leaks.
In a few situations, hot air rising in homes is desirable. Chimney flues of fireplaces, furnaces, and gas water heaters, for example, depend on the stack effect to remove the hot exhaust gases from combustion from the house.

In all but the newest combustion heating systems, house air is used for combustion, creating a negative pressure in the furnace zone, which further increases the infiltration of cold air.

Mechanical devices such as exhaust fans or clothes dryers also increase air leakage in homes. Furnace blowers, although not exhausting to the outside, can affect air leakage in homes significantly. While the furnace blower is operating, the negative pressure typical around the furnace may temporarily increase the air infiltration in the basement, while the positive pressure created upstairs increases the rate of exfiltration in other parts of the house.

Some people try to solve the problem of cold floors by using ceiling fans to circulate hot air from the ceiling. Although these fans do help distribute heat, the amount actually saved is minimal since the stratification mostly masks the continuing air leakage problem. Reducing hidden air leaks is the most effective way to solve warm ceiling-cold floor problems. In a well-sealed, two-story house, temperature difference between floors should be less than 3°F.

Can my house be too air tight?

You may worry that by air tightening your home you could trap moisture and other pollutants that previously were carried outside by the escaping air. Over the course of a year, the rate of air leaks in a home varies considerably. Depending on the season, local weather conditions, use of exhaust fans, and heating system operation, the air leak rate of a home can vary by a factor of 10 during a single day.

During winter, when doors and windows are closed, the air exchange resulting from stack-driven air leaks probably exceeds the ventilation requirements of most homes. But in spring and fall, when houses are still closed and indoor/outdoor temperatures don't differ enough to create a strong stack effect, the indoor air quality in many homes, particularly those with fireplaces and woodstoves, may already be temporarily affected. In certain circumstances, the power of the interior stack effect can actually overpower the chimney draft and pull exhaust gases into the home. Occupants sometimes unwittingly contribute to the problem of chimney backdrafting by opening an upstairs window to provide some additional fresh air, thus increasing the pull of the interior air leakage against the draft of the chimney.

Professional "house doctors" use a blower door to pressurize the house to accurately find hidden air leaks. Even professional weatherization contractors rarely seal homes tighter than one-third air change per hour, a limit believed to provide adequate fresh air without a mechanical ventilation system for most homes. Using the air sealing techniques presented here, it's highly unlikely that you could tighten your house up sufficiently to affect air quality unless the house already has pollution problems. For this reason, it's essential to identify and correct any existing pollution and moisture problems before tightening your house.

Look for signs of indoor air pollution such as mold and mildew on walls, window frames, and ceilings caused by high winter humidity levels. Corrosion or rust and flue pipes above oil or gas furnaces and water heaters indicates furnace backdrafting. You can verify radon levels using inexpensive testing kits available in department and building supply stores. Correct these problems before undertaking the air tightening measures suggested here.

Other weatherization measures you may install can affect the overall air leakage rate of a house; for example, cellulose insulation in walls typically reduces cold wind-driven drafts, and storm windows reduce air leakage around window openings. None of these, however, affects the hidden air leaks in a home.

Where to find air leaks

The Wisconsin Energy Conservation Corporation’s weatherization program developed a very effective air sealing priority list as part of their Energy Audit System. Techniques for safely sealing each area are detailed below.

1. Seal the big holes, especially the ones that are cheap to fix, such as replacing broken glass and gypsum board, and caulking electrical and plumbing holes.

2. Seal leaks in areas of greatest pressure difference. Usually these are
leaks into the attic, through the upper story ceiling, and basement or foundation holes (Figure 3). The most common locations include:

- Attic bypasses, including plumbing vent stacks and chimneys passing into the attic.
- Attic access panels or doors. Weatherstrip these and add a latch to hold them tightly closed.
- Sillplate (mudsill) and other foundation leaks, such as poorly fitting basement windows. The sillplate is on top of the foundation walls (it's what the floor joists rest on).
- Open floor joist ends in kneewall attics. (See below for detailed description.)
- All joints in forced air heating ductwork, both heat supply and return air ducts.

Remember, the purpose is to close off the top and bottom of the hidden passageways through which warm air is escaping and cold air is entering. Since air leaks can easily move inside walls and find other ways of escaping, sealing these leaks from the inside surfaces of the home is most effective.

After the above areas are sealed, undertake the standard caulking and weatherstripping projects. The Wisconsin guidelines suggest the following jobs be addressed next:

- Weatherstrip exterior doors, if necessary. A door to an unheated garage or basement should be considered an exterior door.
- Weatherstrip windows, if necessary. Adjusting sash locks and stops is often more effective than installing weatherstripping in windows.
- Replace cracked glass.
- Caulk other interior locations if you have access to a attic door.

Sealing materials

To get started, first survey your home from the inside to find where the air leak pathways might be located. Check in the attic for plumbing pipes, interior partition in room below, in the basement for plumbing and ductwork leaks, and around built-in cabinets and drop ceilings. Then decide what materials you need to seal them. Try to buy all the materials you’ll need on hand so you won’t have to stop and buy more supplies. Store your receipts so you can return unused materials when you’re done.

You probably will need caulk, spray foam, high-temperature duct tape, and some small plastic bags and fiberglass insulation for other holes. To seal around chimneys and metal flues, use metal flashing or rockwool and special high-temperature caulk. For the majority of your interior sealing, use inexpensive acrylic latex caulk, which costs about $2 per tube and is quite long lasting. Use it for sealing narrow cracks and holes in the living areas of your house and any other holes smaller than about ½ inch. Caulk is simple to use, gives a finished look, sets up quickly for painting, and is easy to clean up.

Begin caulking in out-of-the-way areas of your house while you learn to control the caulk gun to get an even “bead” of caulk. For sealing cracks and holes up to about 1 inch wide in basements and around windows and door rough openings, some people use expanding urethane foam, sometimes called “spray foam” or “single component” urethane foam. It costs about $5 per can. Some foam will continue to come out the nozzle after you stop pressing the trigger, so begin in an area where some foam dripping won’t matter. Keep a rag handy to catch drips. The foam takes from 6 to 12 hours to harden, depending on indoor humidity levels. After it’s dry, you can trim the excess foam with a pocket knife. Wear old clothes and rubber gloves when working with spray foam, as it’s very difficult to clean up, even using paint thinner as a solvent.

Tubular polyethylene backer rod or fiberglass stuffed into plastic vegetable bags from the supermarket also are effective for sealing larger openings. Other materials you may need include high-temperature foil duct tape or mastic for sealing forced-air heating ducts (available from heating contractors or wholesalers), and about 2 square feet of rock wool or class I fire-rated fiberglass insulation, for stuffing tightly around chimney or woodstove flue pipes. If you have an attic that is converted into a living space, see the section on kneewall attic spaces for special materials to seal the floor joist area.

Figure 3.—Important places to stop air leaks into attics.
Sealing special areas

Attics

Check for holes where plumbing vent pipes and electrical wiring enter the attic space. In some homes, pipes and wiring are framed in a small shaft or "chase" that runs from the basement or ground floor to the attic. Lift up the insulation and look for holes where wires drop down into the rooms below. Where the interior partition walls are, look for air leak passageways. fiberglass insulation over these holes often is gray rather than pink or yellow because it filters out the dust from the escaping air. On cold days, you may be able to feel the hot air coming up through the pathways.

Wear a face mask or respirator when working in the attic, since you'll disturb lots of dust that has settled over the years. Use caulk to seal small wiring and plumbing holes. For larger spaces, pack them with rolled pieces of unfaced insulation stuffed into a plastic vegetable bag. Seal very large gaps by tapping a piece of polyethylene sheeting around pipes and sealing the other end to the attic and basement framing.

For fire safety, use only non-combustible material to seal air leaks around the fire clearance area of chimneys and heating system flue pipes. Around narrow gaps, you can tightly stuff rock wool or other Class II fire-rated fiberglass insulation into the gap between the chimney and attic framing. For wider gaps, use a sheetmetal collar fabricated and caulked to the chimney and attic framing with specially rated high-temperature caulk.

Some types of connectors, called thimbles, used for passing stovepipe through floors or walls, need an air space around them for cooling. Don't stuff anything into these holes. If you don't know whether your woodstove has this type of thimble, don't seal this area.

The attic access panel or door is an often-overlooked but very effective place to seal. Because the access often is located in a closet, it's easily forgotten and not weatherstripped. Depending on how the panel or door is framed, use V-type weatherstripping mounted on the jamb, or self-adhesive foam tape mounted on the flange that supports the panel. Install a latch to keep the panel or door tightly closed.

Since the fit between sheetrock and most electrical junction boxes and bathroom fans in ceilings can result in large gaps hidden by trim plates, check and caulk these areas from above whenever possible. However, don't seal or allow insulation to be placed over recessed lighting fixtures, unless they are designed for it, since most recessed lighting fixtures need the additional air flow to dissipate excess heat for safety (a label should state "IC rated").

Don't seal the attic vents to the outside along the eaves and gable ends. These are designed to allow any moisture that does get into the attic to escape outside.

Vaulted ceilings

Cathedral or vaulted ceilings often allow significant air leaks. The edges of exposed beams can provide a direct passageway outside for warm air. You may need to caulk the edges of the boards in a tongue-and-groove ceiling if there is no polyethylene air-vapor
barrier behind them (Figure 4). Sometimes the best solution is to remove the boards and install polyethylene rather than trying to caulk everything. Even if polyethylene has been installed, it may not be properly caulked to the beam and framing members, and will permit leaks.

**Kneewall attic spaces**

In attics converted into living spaces, short walls (kneewalls) are added to separate the area where the roof meets the floor from the heated area of the house. Weatherstrip and insulate any access doors into the kneewall area. Build enclosures behind any built-in cabinets, or weatherstrip the drawers to prevent air leaks into the unheated area behind the storage space.

Large amounts of air can escape up into the walls from below and into the attic through the floor joists of this attic space (Figure 4). To stop this heat loss, professional weatherizers often cut pieces of cardboard, metal flashing, or rigid insulation stuffed into plastic bags and packed into the holes. Reduce air leaks in the fire clearance area around chimneys and flue pipes with the non-combustible materials described in the section on attics.

**Basements and foundations**

The basement or foundation usually is the source of cold air entering the house. Where to air seal in basements and foundations depends on whether the area is heated, such as in a daylight basement. If the house has a crawl space, sealing through the floor is critical because the crawl space is vented to the outside. If the basement area is heated or semi-heated, or contains the furnace and other appliances, then you need to seal both the foundation walls and air leaks through the floor. Foundation air leaks in homes built on slab foundations must be sealed along interior floor-wall baseboards or from the outside.

Pipe and electrical penetrations to the floor above are the most important areas to seal. Use expanding foam or, for gaps several inches wide, fiberglass insulation stuffed into plastic bags and packed into the holes. Reduce air leaks in the fire clearance area around chimneys and flue pipes with the non-combustible materials described in the section on attics.

There are many ways for air to enter the house where the floor rests on the foundation. Caulk along the edge of the board that supports the floor joists resting on the foundation wall, called the sillplate or mudsill. In areas where the
crack is larger than the tip of the caulk gun, use expanding foam. Caulk the entire length of the board, because air may move a great distance along the mudsill until it finds an opening into the house.

The boards covering the ends of the floor joists, called the band joists, also should be caulked. This is critical in Oregon since the subfloors in many homes are constructed with 2 x 6 tongue-in-groove boards, commonly known as “car decking.” Cold air can easily travel into the center of the house along the cracks between each board unless the ends are sealed.

Be sure to fill the holes around pipes for outside water faucets, electrical service entry, and telephone or cable television wiring. Make sure windows are latched tightly and rough openings of the frames are sealed. Replace any missing panes of glass in basement windows. Be sure the dryer vent flapper closes when the dryer is not in use. Replace the outside weather hood if necessary.

**Furnaces and ductwork**

The joints in metal ductwork sections often are not sealed or may have come loose over the years. Since the furnace blower creates a great deal of pressure while distributing heat, it is important to seal the joints of all accessible ductwork—heating supply ducts as well as cold air returns. Don’t solve this problem, because they are designed to fit loosely so that heat will not crack the glass. Clean out any material resting on the ledge that might prevent the damper from closing completely. Sometimes a misfitting damper can be adjusted for a better fit. If a new damper is needed, a chimney top damper for masonry chimneys, is easy to retrofit. This damper has a long chain that hangs down the chimney for easy opening and closing.

**Built-in cabinets, closets, and drop ceilings**

Sometimes the area behind cabinets, closets, or built-in bookcases and service entry, and telephone or cable television wiring. Make sure windows are latched tightly and rough openings of the frames are sealed. Replace any missing panes of glass in basement windows. Be sure the dryer vent flapper closes when the dryer is not in use. Replace the outside weather hood if necessary.

**Flue and damper work**

Fireplaces with poorly fitting dampers provide a continuous stack for air to escape. Most fireplace glass doors don’t solve this problem, because they are designed to fit loosely so that heat will not crack the glass. Clean out any material resting on the ledge that might prevent the damper from closing completely. Sometimes a misfitting damper can be adjusted for a better fit. If a new damper is needed, a chimney top damper for masonry chimneys, is easy to retrofit. This damper has a long chain that hangs down the chimney for easy opening and closing.

Figure 6.—Repair broken plaster and caulk all trim plates.
effectively block warm air from getting into hidden pathways, you need to install these gaskets on outlets and switch plates on both interior walls as well. In some cases, you’ll need to use “childproof” caps to stop air flowing through the receptacle itself.

The holes where sink drain pipes and supply pipes pass into floors and walls are another source of air leaks because they invariably are cut larger than necessary (Figure 6). Complaints of a cold bathtub or frozen dishwashing soap in the winter usually are a result of air leakage underneath the kitchen sink. Use expanding foam or stuff fiberglass in a plastic bag tightly into the opening to seal these holes. Getting access to the holes for bathtub or shower pipes and drains can be difficult, but sealing them is very effective. Be sure to locate and seal openings in the basement and attic where this plumbing extends.

One of the few places you may have to seal air leaks from the outside is underneath sections of the house that extend past the foundation walls. These cantilevered areas allow air into the floor joists, which might connect with interior air leak pathways, such as plumbing chases. If these areas are uninsulated, remove the bottom board and fully insulate before replacing and caulking tightly.

**Windows and doors**

Much has been written about weatherstripping doors and windows to keep winter drafts out of the house. As indicated above, such efforts may be very effective at reducing wind-driven air leakage, but they may not have a significant effect on overall air leakage unless they are located in areas strongly influenced by stack effect.

One area around windows and doors that can contribute to hidden air leakage is around the frame. The most effective way to seal these “rough openings” between the wall and the frame is to remove the trim molding and add a layer of expanding foam into the space. Filling the opening with foam can easily expand and warp the frame, preventing the door or window from operating smoothly. One layer of foam is all that is needed to stop the air leak. Simply stuffing fiberglass scraps into the opening may not stop much of the air passing through. A new product of tubular polyethylene foam, called “backer rod,” also can be stuffed into the rough opening for effective air sealing. An alternative to removing the trim around the window or door is to caulk both edges of the trim to seal it.

**Ghost drafts**

Sometimes you can feel drafts for which there are no corresponding holes. These “ghost drafts” often are caused by air convection currents coming off single-pane windows or doors in insulation. Another case of ghost drafts is a floor or interior wall that’s open to the outside. If one end of stack losses occur but cold surfaces next to the cavity may cause convection currents in the room. These ghost drafts will be especially noticeable on windy days.

**Fix the big leaks first**

Finding and fixing the hidden air leaks in a home usually is the least expensive and most effective energy improvement a homeowner can make. These efforts will improve your comfort or reducing drafts and minimizing temperature differences between floors and ceilings, probably allowing you to lower your thermostat setting while remaining comfortable. Do-it-yourself air sealing shouldn't take more than an afternoon and probably will cost less than $50 in materials.

In some areas of the country, companies offer blower-door air sealing services to effectively identify and seal air leaks. Experienced contractors know where to look for the hidden air leaks and have developed many effective techniques for sealing them. These firms charge between $100 and $300 for their services and will provide a printout of the before-and-after air leakage characteristics of your home. Although the price may seem high, the resulting energy savings can easily pay back your investment in a year or two.

Remember that fixing the air leaks from the inside of the house in the areas of greatest pressure difference—leaks near foundation and upstairs ceiling areas—is the top priority. Sealing those leaks and ducts before undertaking the standard weatherstripping and caulking measures for your home will result in the greatest energy and cost savings and comfort.
For further reading

**Popular references**

*Advanced Air Sealing*, Iris Communications, 1993, 40 pp. (Order from Iris Communications, 258 East 10th Ave. #E, Eugene OR 97401-3284. Enclose a check for $15.)

*Attic Bypasses*, Energy Division, Minnesota Department of Public Service, 1988. (To order a copy, send a self-addressed stamped, business-size envelope to Minnesota Department of Public Service, Attention: Energy Information Center, 121 7th Place East, St. Paul, MN 55101-2145.)


**Technical references**

*Air Sealing Homes for Energy Conservation*, second draft, Building Energy Technology Transfer Program, Energy, Mines and Resources, Canada, Ottawa, Ontario, 1984. (Available at most energy offices and some utilities.)


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