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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 probably won't 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 is 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 do the work in the middle of winter when the heat loss is 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 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 (figure 1). 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 only extend up 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 outdoor weather. Typical caulking and weatherstripping measures, such as door and window weatherstripping, effectively reduce this wind-driven air leakage.

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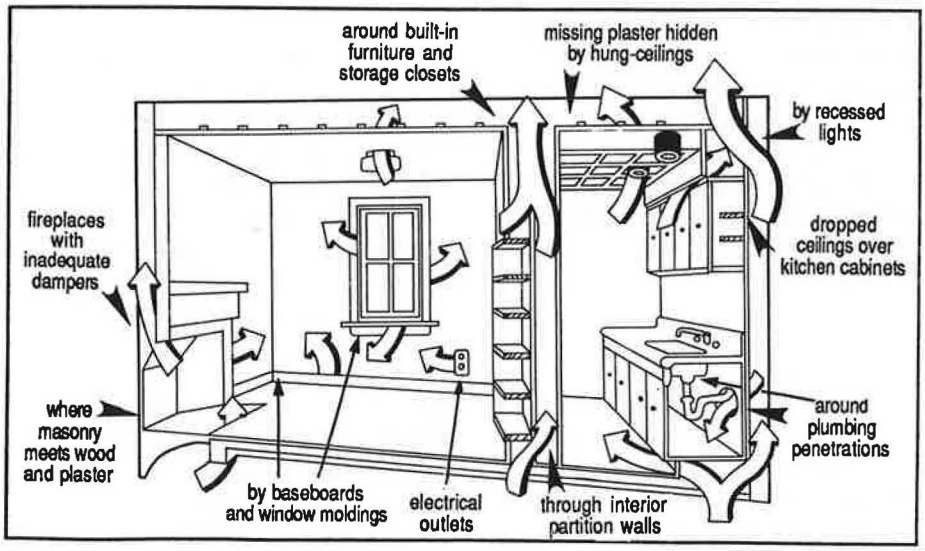

Figure 1. Common interior air leaks.

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In a few instances 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 units, house air is used for combustion, creating a negative pressure around the burner, further increasing the infiltration of cold air if the appliance is located in the basement or ground floor.

Mechanical devices, such as exhaust fans or clothes driers, 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.

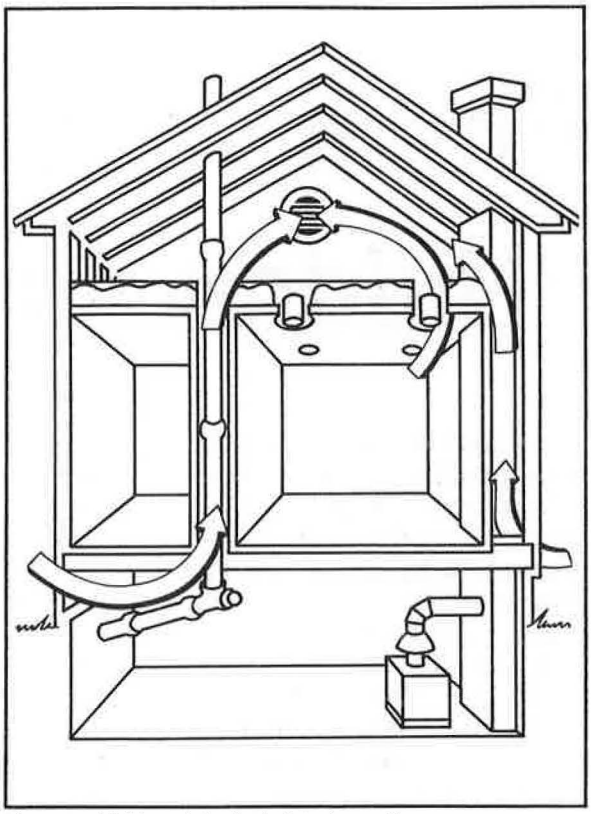

Figure 2. Hidden air leaks in interior walls can cause furnace gases to"backdraft" into the house.

Some people try to solve the problem of cold floors by using ceiling fans to circulate hot air from ceiling. Although these fans do help distribute heat, the amount of energy saved is minimal since the destratification mostly masks the continuing air leakage problem. Sealing 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 (figure 2). In certain circumstances, the power of the interior stack effect can actually overpower the chimney draft and pull exhaust gases into the home. Unwittingly, occupants sometime 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.

Even professional weatherization contractors using blower doors rarely seal homes tighter than one-third air change per hour, a limit presently believed to provide adequate fresh air without a mechanical ventilation system for most homes. Using the air sealing techniques presented here it is highly unlikely that you could tighten your house up sufficiently to affect air quality unless the house already has serious pollution problems. For this reason it is 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 around 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: cellulose insulation in walls typically reduces cold wind-driven drafts and storm windows reduce air leakage around window openings. None of these, however, affect 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.

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

❷ Seal leaks in areas of greatest pressure difference. Usually these are leaks into the attic, through the upper floor 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 and what the floor joists rests 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, seal these leaks from the inside surfaces of the home is most effective.

❸ 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.

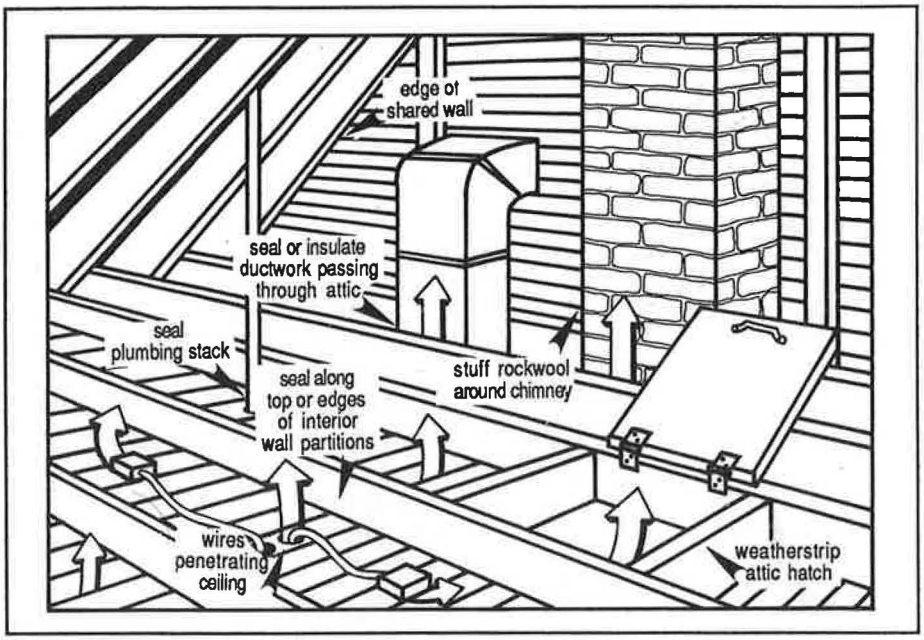

Figure 3. Important places to stop air leaks into attics.

• Other interior caulking locations if you have access to a blower 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. Remember that the most effective way is to stop this undesirable air movement is from the inside the house. Then decide what materials you need to seal them. Try to have all the materials you'll need on hand so you won't need to stop and buy more supplies. Save your receipts and return unused materials when you're done.

You will probably need latex caulk, spray foam, high temperature duct tape and some plastic bags and fiberglass insulation for other holes. To seal around chimneys and metal flues use rockwool and special high temperature caulk. For the majority of your interior sealing use inexpensive latex or "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 3/8 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 opeings, 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 is dry, you can trim the excess with a pocket knife. Wear old clothes and rubber gloves when working with spray foam as it is 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 are also effective for sealing larger openings.

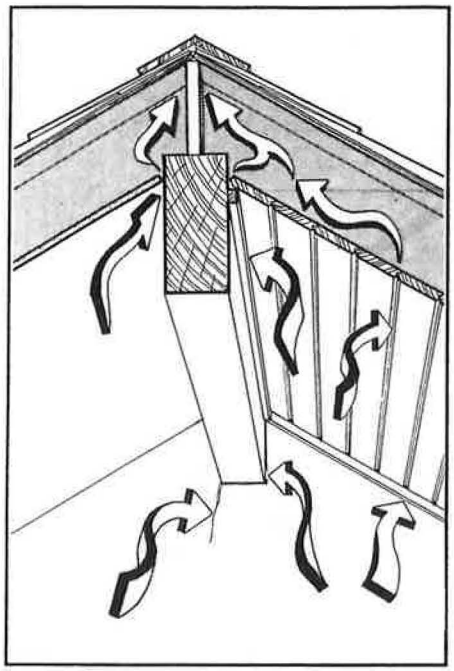

Figure 4. Caulk along all edges and cracks of vaulted ceilings.

Other materials you may need include high-temperature foil duct tape for sealing forced-air heating ducts (available from heating contractors or wholesalers) and about 2 square feet of rock wool or class II fire-rated fiberglass insulation for stuffing tightly around chimney or woodstove flue pipes. If you have an attic that is converted into living space, see the section on kneewall attic spaces for special materials to seal the floor joist area.

Sealing Special Areas

Attics

Check for holes where plumbing vent pipes and electrical wiring enters 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 wiring drops down into the rooms below. Find where the interior partition walls are and 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 which has settled over the years. Use caulk to seal small wiring and plumbing holes. Fill larger spaces by packing them with rolled pieces of unfaced insulation stuffed into a plastic vegetable bag. Seal very large gaps by taping a piece of polyethylene sheeting around pipes and sealing the other end to the attic and basement framing.

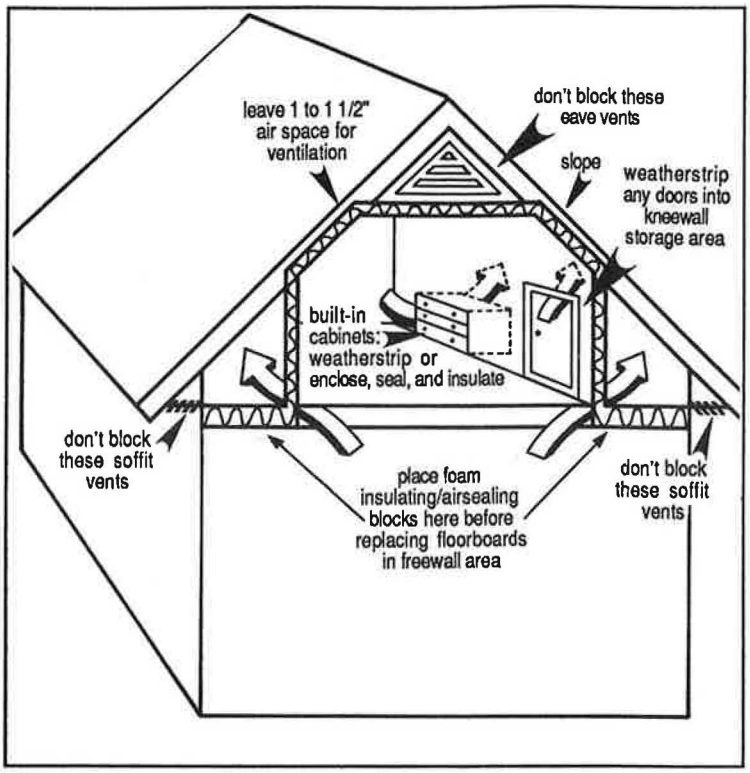

Figure 5. Kneewall attics have many air leak points.

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 sheet metal 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 one of the most effective places to seal. Because the access is often located in a closet, it are 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 (they should state "IC rated"), since most recessed lighting fixtures need the additional air flow to dissipate excess heat for safety.

Don't seal the attic vents to the outside along the eaves and gable ends. These are designed to provide ventilation allowing 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

Air Leaks in Building Components

	Area in square inches
Ceiling	
1. General (per 100 square feet)	0.05
2. Dropped ceiling (per 100 sq. ft.)	
no plastic vapor barrier	78
plastic vapor barrier	8
3. Chimney framing: open	12
insulated	1
4. Whole house fan	
louvers closed	8
covered with tight box	0.6
5. Lighting fixtures	
recessed	4
surface	0.3
6. Pipe or duct penetration:	
uncaulked	1
caulked at ceiling	0.2
Interior Walls	
7. Pocket door	5
8. Pipe or duct in wall	2
9. Recessed cabinet	0.8
10. Electric junction box:	
ungasketed	0.2
gasketed	0.03
Exterior Walls	
11.General per 100 square feet	0.8
12. Sill on masonry: uncaulked	65
caulked	13
13. Band joist (box sill): uncaulked	65
caulked	13
14. Floor-wall joint	27
baseboard caulked	7
15. Duct in wall	9
16. Pipe in wall	2
17. Electric junction box:	
ungasketed	0.2
gasketed	0.05
18. Polyethylene vapor barrier (deduct)	-30
19. Foam sheathing (deduct)	-15
Doors	
20. Attic fold-down stairs	17
weatherstripped	8
insulated cover	2
21. Attic hatch	8
weatherstripped	3
22. Sliding patio glass door	16
22. Entrance door (plain)	8
weatherstripped	6
magnetic weatherstrip	4
24. Air lock entryway (deduct)	-4
25. Storm door (deduct)	-3
Windows (weatherstripped)	
26. Double hung	0.8
27. Horizontal slider	0.6
28. Awning	0.2
29. Casement	0.2
30. Fixed (picture windows)	0.2
(For new windows, see manufacturers' catalogs for air leakage data for different style windows.)	
Door and Window Frames	
31. Mounted in masonry wall:	
uncaulked	2
caulked	0.4
32. Mounted in wood wall:	
uncaulked	0.6
caulked	0.1
Vents	
33. Kitchen range hood:	
damper open or missing	9
damper closed	2
34. Clothes dryer:	
damper open or missing	4
damper closed	1
35. Bathroom fan:	
damper open or missing	3
damper closed	1
36. Fireplace:	
damper open or missing	54
average fitting damper	9
tight damper	2
37. Fireplace insert	2
Heating System	
38. Ducts in unheated space:	
not taped or caulked	58
taped or caulked	28
39. Oil furnace:	
flame retention burner	12
with vent damper	12
with both above	9
40. Gas water heater	8

Adapted from D. T. Jarrje and G. J. Born, Cataloging Air Leakage Components in Houses, *Princeton University Center for Energy and Environmental Studies, 1984.*

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 every joint. Even if polyethylene has been installed, it may not be 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. The area behind the kneewall often is used as a storage space and sometimes have built-in cabinets behind them. This area should be isolated 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.

If the floor joists of this attic space open into the kneewall area, large amounts of air can escape up interior walls from below and into the attic (figure 5). To stop this heat loss, professional weatherizers often cut squares of rigid insulation, such as polystyrene or polyurethane foam board, and fit these plugs into the open joist ends below the kneewall. If this area is used for storage, put down floor board to avoid compressing the insulation here.

Basements and foundations

The basement or foundation is usually 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 design. 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.

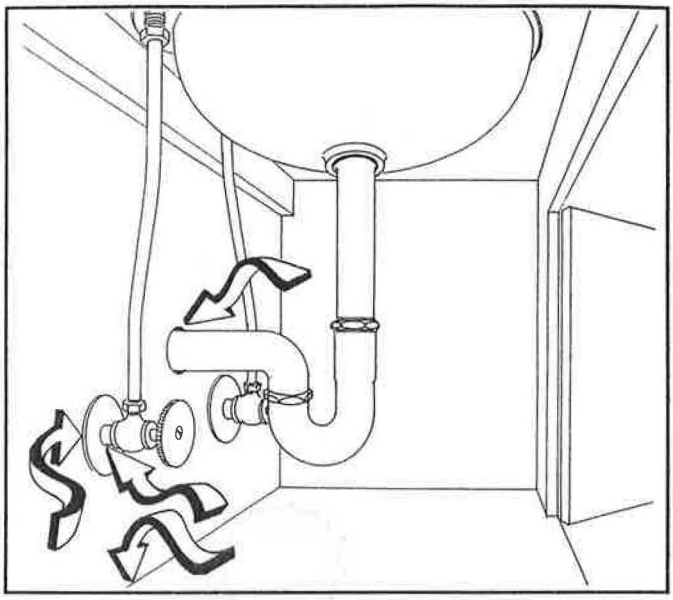

Figure 6. Repair broken plaster and caulk all trim plates.

board that supports the floor joists resting on the foundation wall, called the sillplate or mudsill. In areas where the 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 joist, should also 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 are often not sealed or may have come loose over the years. Since the furnace blower creates a great deal of pressure while distributing its heat, it is important to seal the joints of all accessible ductwork, both heating supply ducts as well as cold air returns. Don't forget the joints on the cold air return ductwork as well as the large air chamber or "plenum" attached to the furnace as well. Except in homes with heated basements, all ductwork and furnace plenums should be insulated after sealing.

While inspecting the ductwork look for loose or disconnected sections. Use sheet metal screws to fasten duct sections before taping. When the furnace blower is on, use burning incense to locate air leaks in ductwork joints. Some homes use an enclosed floor joist space to form a return air duct. Be sure all edges of this cavity are effectively sealed especially the ends. Any holes for wiring or pipes passing through this cavity should be sealed. Check the opening in the floor or wall where the ductwork terminates, called the "register boot." After removing the grilles and register covers in each room, caulk the edge where the sheet metal meets the floor.

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 which might prevent the damper from closing completely. Sometime an existing damper is can be adjusted for a better fit. If a new damper is needed consider a chimney top damper for masonry chimneys. 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 window seats is not plastered or sheetrocked. This allows heat to escape directly into the wall or ceiling and to the outside. The solution is to install sheetrock, or at least polyethylene with taped seams, in the closet or behind built-ins and cabinets. You may not have access to the area behind built-in cabinets but you can weatherstrip each drawer and carefully caulk all joints in the cabinets to minimize air leaks.

Sometimes kitchen remodelers install a suspended ceiling if the original ceiling is in poor condition. However the holes in the original ceiling from removal of electrical boxes or installation of new pipes are rarely patched allowing warm air to find its way out of the house. Use expanding foam to seal smaller holes or install sheetrock with taped joints if large areas are exposed.

Baseboards, outlets, and the kitchen sink

Since the sheetrock or plaster may not extend all the way to the floor, baseboards on both interior and exterior walls are another important area to seal. Removing the baseboard and sealing the gap between the wallboard and floor with caulk or expanding foam is usually the best solution although care must be taken not to break it when removing. You also can seal both the top and bottom edges of the baseboard but you must seal the entire length. Experience with blower doors demonstrates that if only the visible cracks along the baseboard are sealed, air leaks simply find another pathway to the inside of the house and have to be "chased" along the baseboard with a caulk gun.

Installing foam gaskets behind outlet and switch plate covers on exterior walls has long been recommended. But to 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 will need to use "childproofer" 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 frozen dishwashing soap in the winter are usually the result of air leakage underneath the kitchen sink. Use expanding foam or stuff fiberglass tightly in the opening to seal these holes. Getting access to the holes for bathtub or shower pipes and drains can be difficult, but sealing them usually 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 very significant effect on overall air leakage of homes 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 frames. 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. Don't fill the opening with foam as it can easily expand and warp the frame preventing the door or window from operating smoothly. Simply stuffing fiberglass scraps into the opening won't stop much of the air passing through very effectively. A new product of tubular polyethylene foam, called "backer rod," can also 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" are often caused by air convection currents coming off single-pane windows or breaks in insulation. Another cause of ghost drafts is a floor or interior wall that is open to the outside on only one end. No stack effect occurs 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 is usually the least expensive and most effective energy improvement a homeowner can make. These efforts will improve your comfort by reducing drafts and minimizing temperature differences between floors and ceilings, probably allowing you to lower your thermostat setting while remaining comfortable. Do-it-youself air sealing shouldn't take more than an afternoon and will probably 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 before undertaking the standard weatherstripping and caulking measures for your home will result in the greatest energy and cost savings and comfort.

Prioritizing Air Sealing Efforts

- ❑ Heating duct repairs (supply and return ductwork in unheated space)
- ❑ Ceiling penetrations
- ❑ Furnace flue and fireplace damper work
- ❑ Floor air leakage sites
- ❑ Exterior door and window frames (rough openings)
- ❑ Interior door frames (rough openings)
- ❑ Ceiling cracks
- ❑ Plumbing and electrical penetrations
- ❑ Wall air leakage sites
- ❑ Wall cracks

From *House Tightening Manual for Homeowners and Weatherization Contractors,* Bonneville Power Administration, U. S. Department of Energy, 1986.

For Further Reading

Popular references

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Contractor's Guide to Finding and Sealing Hidden Air Leaks, Alex Wilson and Steve Nadel. Massachussetts Audubon Society, Lincoln, Massachusetts, 1986. (Order from Educational Resource Office, Massachussetts Audubon Society, Lincoln, Mass. 01773. Enclose check for $3.50. *How to Weatherize Your Home or Apartment,* listed below, contains similar information and other energy-saving ideas.)

Find and Fix the Leaks: A Guide to Air Infiltration Reduction and Indoor Air Quality Control (DOE/CE-006), U.S. Department of Energy, May 1981 ($2.50, available from U.S. Government Bookstore, 1305 SW First Ave., Portland, OR 97201. Phone orders with Visa or Mastercard (503) 221-6217.)

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Home Weatherization and Indoor Air Pollutants (DOE/BP-310), Bonneville Power Administration, Portland, Oregon. (Free. Order from Public Involvement Section, Bonneville Power Administration, Post Office Box 12999, Portland, Oregon 97212; 1-800-452-8429, toll-free in Oregon, or 1-800-547-6048 outside Oregon.)

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