A house doctor seals off thermal bypasses by applying foam sealant between wood framing and a masonry party wall.

Finding Hidden Heat Leaks

by Thomas Blandy

Knowing where to look for leaks can help you build tighter, more comfortable houses

Remember the energy conservation industry? In the '80s I was part of it. I was a house doctor. My partner and I would arrive at a house, set up our blower door, peek through our infrared scanner, test the furnace, and use other house-doctor equipment.

But more important than these gadgets was the knowledge, gained from ten years of research at Princeton University, of where and how most buildings lose energy. Studying hundreds of buildings under real-life conditions, the researchers found many ways that heat escapes by *bypassing* the usual weatherization measures of weatherstripping and caulking. These thermal bypasses can greatly compromise a home's comfort, contribute to moisture problems, and add significantly to energy bills (see "Plugging the Gap: A Case Study").

The benefits of fixing these bypasses vary greatly from building to building; Princeton researchers found a 15% to 20% average annual energy savings. In some buildings the problem areas are inaccessible or just too difficult to identify. However, many problems can be found and corrected with simple measures, reaping significant energy savings, clearing up moisture problems, and — perhaps the biggest benefit to consumers — increasing comfort.

In existing houses, these gaps are usually hidden behind walls and can be hard to see and get to — thus the fancy diagnostic equipment. In new construction, however, they are easy to see and fix. Either way, they are easier to find and fix if you know where to look, which is where a knowledge of common problem spots comes into play.

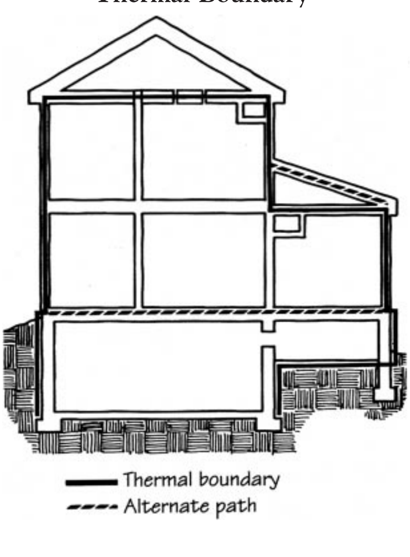
A Few Fundamentals

Knowledge of a few crucial concepts can help builders and remodelers diagnose or prevent most thermal leaks.

The thermal boundary. This is the boundary between the cold and windy outside and the inside, which we want to keep warm and draft-free. This seems obvious. However, many buildings have compromised thermal boundaries where cold air gets in the spaces and hollows behind finishes and in floors, walls, and ceilings. If buildings were made of solid concrete, the only problems would be cracks and imperfect joints. But as we know, most buildings in North America are assembled out of thousands of little sticks and layers of sheet material laced with holes for pipes, wires, and mechanicals.

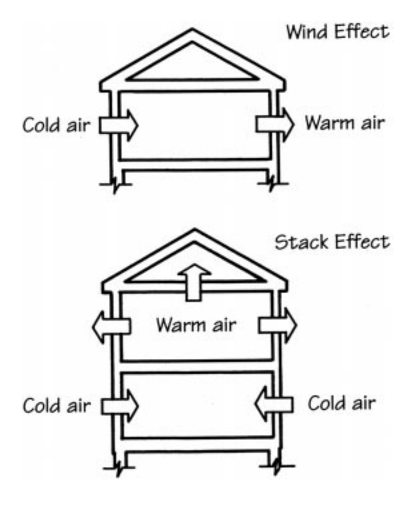
Fundamentals of Heat Loss in Houses

Thermal Boundary



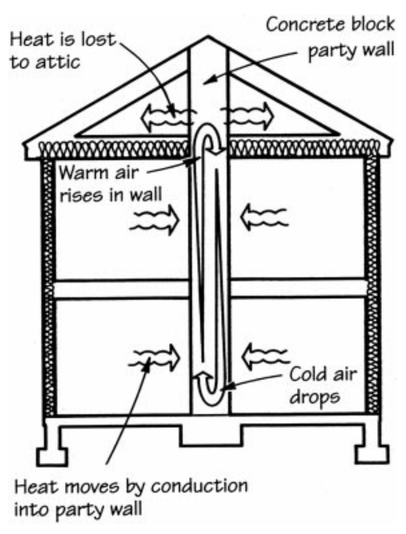
The thermal boundary *divides conditioned indoor space from unconditioned space. The boundary needs to be continuous and should follow the shortest, most compact route. Heating equipment and other utilities should lie inside the thermal boundary.*

Infiltration



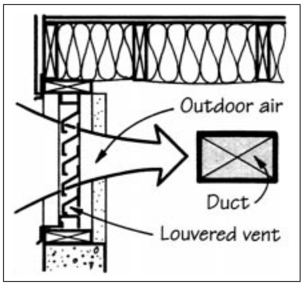
Infiltration *occurs when outside air enters the building through an opening in the thermal boundary. An equal amount of inside air will always exit elsewhere. Infiltration occurs because of wind (top) and the stack effect (bottom).*

Convective Loops

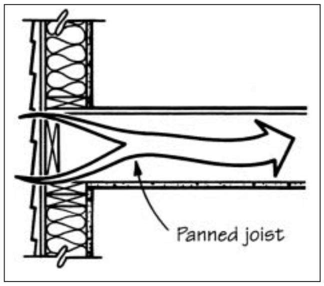


Convective loops *occur when warm inside air loses heat to a cold surface, such as a party wall that bleeds heat into an unheated attic. No air exchange takes place; only the heat leaves the building.*

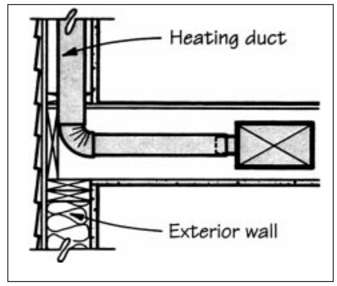
Mechanical System Problems and Solutions



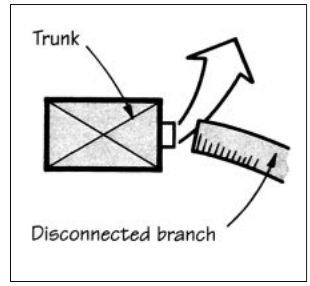
Pipes and ducts in unheated spaces. *Either insulate them or include them in the thermal boundary by insulating the basement or crawlspace.*



Return air plenum pulls outside air. *This occurs when a joist bay is used as a return air plenum. Block and caulk at the inside of the band joist.*



Ducts in outside walls lose heat*, both by radiant loss and by leaks through untaped seams. This is a tough one to solve; the options include using insulated duct, moving the duct, or adding exterior rigid foam.*



Are ducts connected? *If the hot-air furnace isn't blowing well or warmly enough, perhaps the ducts aren't well-connected. Check all connections and tape any seams.*

Infiltration. Infiltration occurs when outside air enters the building envelope; an equal amount exits elsewhere. This often occurs at doors and windows, but other places are often more important to examine for leaks.

Convective loops. A convective loop begins when warm interior air loses heat to a cold surface, such as a cold attic hatch or an open-block party wall (see illustration, previous page). As the air loses heat, it drops, making room for more warm air to move into place, thus setting up a circular pattern of movement. With a convective loop, the home's interior air temperature drops, even though air isn't penetrating the thermal boundary — only heat is passing through.

Gaps between insulation and air seal. Insulation suppresses heat flow not with the insulation material, but with the air it traps. If air is moving through the material, it doesn't insulate. (Fiberglass, for instance, is often used as a filter material.) So unless the insulation is up against the air seal — typically the poly vapor barrier — it doesn't do its job well. Rigid board insulations do, of course, form their own air seal when properly sealed at the edges.

Air seals on the inside. Buildings should be sealed at the inside finish surface (that is, on the warm side of the insulation), and there should be no gaps between the insulation and the air seal. The more snugly the insulation fits against this barrier the better, because air movement is discouraged. On the outside of the insulation layer there needs to be an escape for any moisture that does penetrate the finish. Thus it is useless, and can even be detrimental, to deal with infiltration through a frame wall by caulking the exterior, which should be done only for the purpose of keeping rain out.

Stopping the Gaps

The illustrations on the next page show common (and a few not-so-common) examples of thermal bypasses. In a building under construction, you can watch out for these bypasses and fix them while it's easy, before the drywall goes up.

Search for the symptoms. In an existing building, however, you'll most often find thermal bypasses by identifying their symptoms. A cold corner at a partition wall or wall-ceiling intersection, for instance, may reveal itself through mildew that has formed on its cold surface. A draft from an outlet might suggest that the wall is serving as a conduit for cold air coming all the way down from the attic. Cold floorboards on the second floor of a garrison might suggest air is leaking in through unblocked cantilevered framing. And a blast of cold air from the cabinet under the sink might suggest that cold air from the soffit is entering the stud space.

Without a knowledge of where bypasses occur, these symptoms are just mysteries. But if you know enough to make an educated guess as to where the cold air is coming from, you can often track down the cause.

In all cases, it is a matter of thinking about how air moves. Air, being a gas, obeys the laws of physics, moving in response to differences in pressure and temperature; humidity plays a role, too. But I find it helps to think of cold air as smart and resourceful — assume it will find a house's weak spots and get in. The stack effect — cold air entering the basement, moving up through the house, and out the attic — spurs much of the leakage. This makes the attic the most important place to look for leaks. The basement is second in importance, but don't tighten the basement so much that the heating unit can't draw enough combustion air.

House doctoring on a budget. If you want to get into professional house doctoring, you can spend quite a bit of money. A late-model Agema hand-held infrared scanner that can detect even slight temperature differences behind walls can cost about $25,000. A blower door with accessories is a bit more reasonable at around $2,000, but that's still more than most builder/remodelers want to pay for use on the occasional house-doctoring day. But you can diagnose many of the problems illustrated here by digging around and spotting the signs of infiltration already mentioned, such as moisture. This is something akin to the family doctor diagnosing ills by poking, prodding, and asking questions, rather than by putting the patient through a battery of high-tech tests. In most cases, it will work.

Actually fixing the thermal

Plugging the Gap: A Case Study

Imagine an apartment conversion of a 1920s three-story brick school building, with a corridor down the middle and high-ceilinged classrooms on each side. The contractor blew insulation into the exterior walls and installed new windows and mechanical systems; it was a quality project. All in all, everyone did their jobs competently, but the thermal boundary got lost because no one was in charge of thinking about it. This scenario often happens.

In this case, each apartment had two zones. Zone 1 was living room and bedrooms, which had the existing high ceilings. Zone 2 had dropped ceilings over entry, kitchen, bath, and mechanical rooms — several different ceiling heights, some made of drywall, some of dropped-in tile. Open-backed walls framed with steel studs joined the staggered ceilings. Through these and other chases ran the wires, plumbing lines and vents, AC ducts, refrigerant lines, and kitchen and bath exhausts, with lots of fiberglass laid over the ceilings and tucked down along the adjoining walls for insulation.

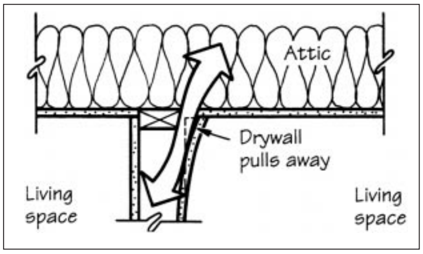
Now try to imagine the thermal boundary in this building. It's difficult, right? That's because there wasn't any. A three-dimensional maze of air passages had been created from the building's top to bottom. In places, it would have been possible to raise a ceiling tile and release a bird that could then find its way to the open attic without encountering any barrier.

Plenty of cold air could travel the same path downward. This would have caused a disaster from burst water lines alone, but fortunately it was October and not January when the owner, on a hunch, called the house doctors. It took two crews (six of us) about three weeks to set things right.

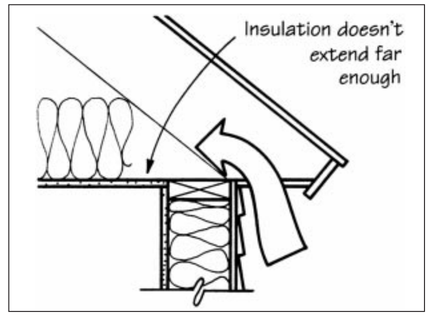
Zone 1 was fine because the insulation had been laid over the existing plaster, as in any house attic. In Zone 2, we didn't even try to follow and fix every zig and zag. Instead, we established a new boundary by putting a simple cap over the whole thing. We removed all the batts, constructed an auxiliary 2x6 frame at a higher level, laid polyethylene over this, carefully stapling seams and edges, and then laid the insulation on top of that. The only other item was the stairs to the attic, which we covered with an insulated flap.

— T. B.

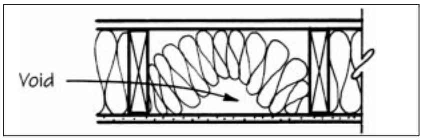
Common Thermal Bypasses



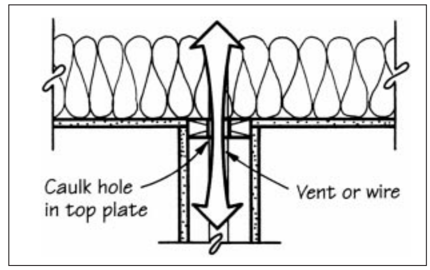
◄ ***Leaks at wall-ceiling intersection.*** *If the top plate shrinks and pulls away from the drywall, cold air will enter the partition and then the living space through openings such as electrical boxes. Prevent this by caulking the top plate or laying poly beneath the insulation batts in the ceiling. The same problem can also occur where a partition wall joins an*



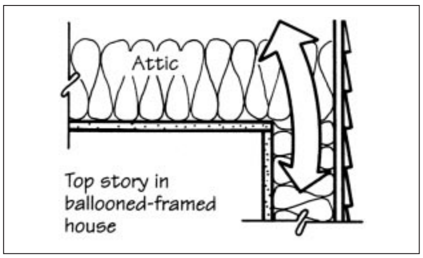
Cold wall-ceiling intersection at eaves; may have mildew from condensation. *This occurs when insulation doesn't extend deeply enough into the eaves. Fix by extending batt far enough t o completely cover the living space, but make sure* ►



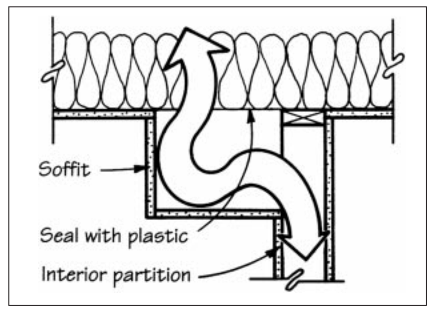
◄ ***Insulation installed with voids*** *allows small convective loops to form, lowering the insulation's R-value. Prevent or fix by cutting and installing insulation accurately.*



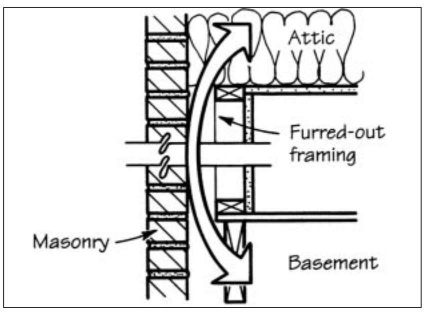
Leaks around plumbing vents and wiring. *This is one of the most frequent problems. Fix by caulking or foaming around openings in the top plate or using rubber boots that slip around pipes or chases.* ►



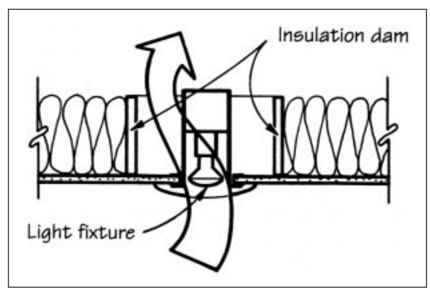
◄ ***Unblocked stud bay in balloon framing.*** *Whether in partitions or outside walls, the stud bay needs a cap at attic level even if the wall is insulated. Use rigid foam and caulk.*



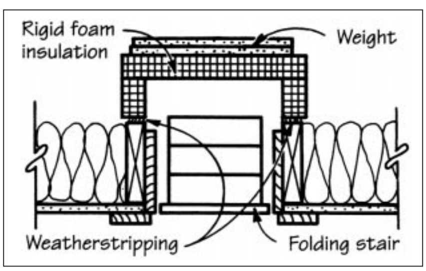
Unsealed kitchen or bath soffit. *This happens all the time! A soffit is hung from the framing with no wallboard at ceiling level to seal the insulation. Cold air filters down through the insulation and into the partition wall. Seal with plastic under the ceiling insulation. This may be hard to retrofit, but it's a major problem.* ►



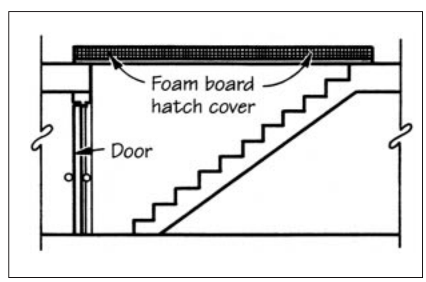
◄ ***Furred-out masonry.*** *Cold air winds its way between masonry wall and stud wall, resulting in both convective loss and infiltration. Seal the top of the space with caulked rigid foam.*



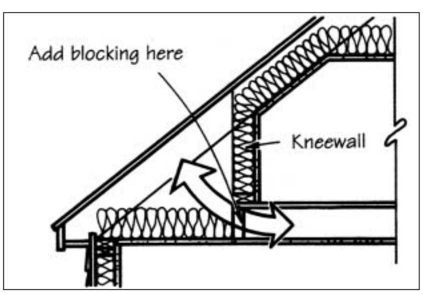
Recessed ceiling lights. *These are tough to deal with, though some models now offer good air sealing. Reduce use of recessed cans as much as possible.* ►



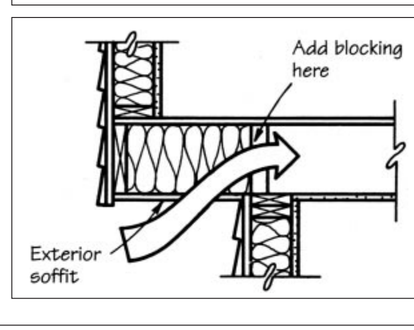
◄ ***No seal or insulation over folding attic stair.*** *The best solution is a box made of rigid foam with a little weight on top (wallboard works well), with weatherstripping to seal it.*



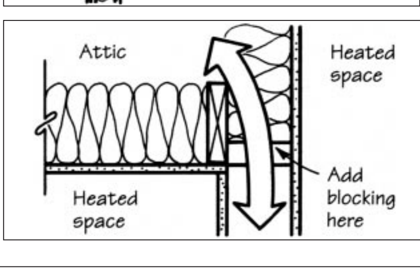
Cold air entering through attic stair. *It's easier to put an insulated hatch over the top than to try to insulate both the existing door and the stair itself. The hatch can simply be a door made of rigid foam.* ►



◄ ***Gap below kneewall in Cape Cod second story.*** *Unless the joist space is blocked below the kneewall, cold air enters the joist space. Block with rigid foam sealed with caulk.*



Unblocked joist space behind overhang. *In garrison and other cantilevered designs, soffits are almost never well sealed. To fix, block the joist space just over the plate with rigid foam sealed with caulk.* ►



◄ ***Unblocked stud bay to attic in split-levels.*** *Similar to the problem in balloon framing, this happens where stud bays continue past ceiling joists to the attic. Block with rigid foam.*

breaks once you find them requires relatively inexpensive materials and tools — mostly insulation scraps, poly, and caulk and sealants. Blockers and hatch covers can be made from 3/4- or 1-inch foil-faced rigid insulation. The type of foil-faced duct board used to fabricate insulated ducts works, too. By joining the duct board into a box with foil-faced tape, you can make a nice hatch over folding stair units; flat doors over stairs need an insulated door made of hardboard, rigid foam, and 1x framing.

For blocking stud cavities, use waxed cardboard (such as that used for eaves ventilation chutes), duct board, or scraps of rigid foam cut to fit. Seal cracks with acrylic-latex or siliconized acrylic caulk. (Use acrylic-latex for any surfaces to be painted, as siliconized caulks won't take paint.)

Another good material for cracks is the foam backer rod used to back caulk joints in masonry. Backer rod comes in various diameters. Another option for such cracks, or for the spaces around window or door frames, is the foam insulation that comes in pressurized cans; the cans come in various sizes with hoses and nozzles. Get the nonexpanding kind if possible, as the expanding type can get out of control and sometimes bulge window or door frames. It takes some practice to be able to dispense neatly — be careful what you get it on, as it never comes off. (Gloves and coveralls are definitely required; I've ruined lots of clothes with that stuff.)

Despite the low cost of these materials, fixing thermal gaps can be expensive in existing homes if you have to tear away and replace existing finishes — walls and ceilings, most commonly — to get to the trouble spots. But often enough there is a way. In new homes, it's simply a matter of sealing the area in question before the wallboard goes up.

Don't Forget the Basics

When combing a house for cracks, crevices, unblocked stud and joist spaces, and other thermal bypasses, don't neglect the more fundamental issues of temperature and air control. Doors and windows should close well and have good weatherstripping. Hvac systems should be well-tuned and in good working condition, with any ductwork sealed and checked. The house should have high-quality, properly vented bathroom and kitchen exhaust fans to expel moisture. Eaves and ridge vents should be properly sized and clear of obstruction. Any dirt crawlspaces or basement floors should be covered with 6-mil poly to prevent moisture infiltration. ■

Thomas Blandy, an architect in Troy, N.Y., operated a house doctoring company in the early 1980s and currently specializes in the adaptive reuse of older buildings. His book All Through the House *(McGraw-Hill, 1980) is a guide to home weatherization.*