Air Leakage Control: The Devil's in the Details

Avoid dread customer callbacks—due to drafty new houses, moisture problems, and high energy bills—by air sealing properly.

by Bill Van der Meer

Uncontrolled air loss from a building can have a significant impact on occupant comfort, and on what it costs to operate and maintain a building. Typically, air infiltration can account for 25% or more of a home's heat loss. In fact, many callbacks related to comfort, moisture problems, or high fuel bills can be directly traced to air leakage into and out of the conditioned space. While builders routinely provide controlled openings for ventilation and for exhausting the byproducts of combustion, *unintended* air leakage is undesirable. Proper air sealing can often make the difference between a comfortable house and a cold, drafty house.

The occupants of the home, whose initial concerns are likely to focus on color schemes and finished appearances, may never see many of the leakage sites. Direct penetrations, such as leaky baseboards, windows, receptacles, and band joists, can account for a lot of builder callbacks simply because occupants feel these leaks and are disturbed by them. If it is allowed to penetrate building cavities, moisture-laden interior air may condense on cold surfaces, leading to mold and rot. It's generally bad for business to make your customers uncomfortable, however unintentionally, or to create the perception that you are somehow responsible for their having to shell out much more than they anticipated in energy bills.

For years, a number of conscientious builders here in Pennsylvania, seeking to limit their exposure to the dread customer callback, and driven by various utility company and government incentives, have been incorporating air sealing protocols into their construction processes. However—based on the hundreds of customer-complaint-driven inspections referred to my colleagues and me at the Pennsylvania Housing Resource Center (PHRC) at Penn College by the Department of Community and Economic Development's Housing Standards Division—we may safely conclude that there are many builders who have not.

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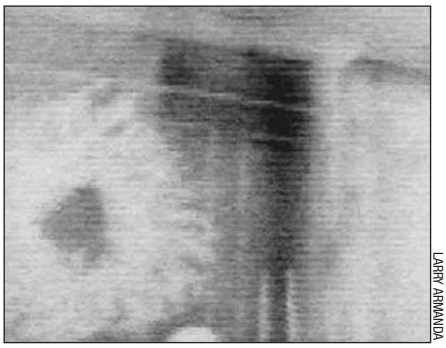

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Infrared imaging reveals a common thermal problem that is associated with a lack of attention to detailed air sealing where the fireplace framing intersects an outside wall.

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Recessed lighting is here to stay. If left unsealed from the living space, they may contribute greatly to air leakage.

Fixing Air Leakage Sites

Due to the segmented nature of residential construction, many builders often see truly effective air leakage control work as a challenge. Although they routinely do the more visible types of weatherstripping and caulking, truly comprehensive and integrated air sealing protocols are not considered state of the practice among mainstream builders. One of the difficulties that come into play is the rapid-fire succession of jobs that are done by the various subcontracting trades on the job site. For instance, as soon as the drywall is finished, the carpet is laid and the baseboard is installed, leaving a potentially large (and uncomfortable) perimeter air leak around the exterior wall.

However challenging it may be to get the details of air sealing done properly, it is of critical importance to do so. This article describes some of the most common air leakage problems and explains how to prevent them during construction. They are not necessarily


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(left) A dropped soffit in a kitchen can funnel huge volumes of air if left unsealed from the wall and ceiling framing. *(right)* Here, the builder has provided a continuous air barrier on the outside walls before installing the tub.

listed in their order of importance but are all fairly significant nonetheless.

Baseboard Blues

Drafts are most commonly felt where the carpet meets the baseboard molding along an exterior wall. The actual penetration occurs at the intersection of the subfloor and the bottom plate. The solution is relatively simple and cheap, as long as it's well timed. Caulk the inside face of the bottom plate to the subfloor before the baseboard and carpet are installed. (This can also be done using spray foam; see "Spray Foams and the Code.") Another option would be to caulk all the sill plates to the subfloor during rough framing.

Recessed Can Lights

According to tests conducted in 1992 by the Mechanical Engineering Department at Penn State University in conjunction with Juno Lighting Corporation, the air leakage path associated with a single recessed can light fixture may account for $5–$30 worth of energy loss per year. The same study went on to conclude that a single unsealed can light may serve as a conduit for the movement of about one-third of a gallon of water daily into a cold attic. Today's upscale tract homes may contain anywhere from 20 to 40 or more recessed can lights. Insulation Contact (IC) -rated Washington State Compliant airtight fixtures are now required by chapter 11 of the International Residential Code (IRC) 2003. These so-called airtight fixtures must restrict measured air leakage to less than 2 CFM of air flow at 75 Pa pressure difference (ASTM E-283 test method). Unfortunately, the cost of an airtight fixture and trim package is generally more than twice that of a conventional fixture. There is an alternative allowed by the code. A builder may opt to fabricate a sealed box of $^1/_2$-inch gypsum board to completely encapsulate the fixture and seal it to the back side of the ceiling wallboard, while maintaining a required clearance of 3 inches from the fixture (IRC 2003 Section N1102.1.11). This may not necessarily be a less expensive alternative to the airtight fixture, considering the labor cost of constructing and installing the boxes. Quality control issues must also be addressed on-site. (For more on recessed can lights, see "A Recessed Can of Worms," *HE* Jan/Feb '01, p. 42.)


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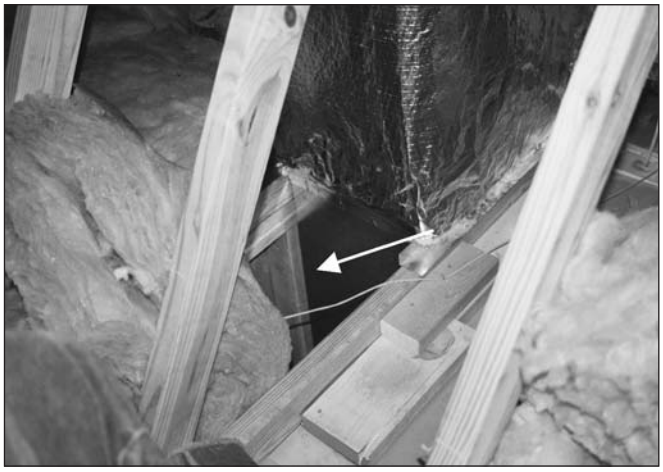
Note the opportunities for massive amounts of air leakage to the attic from within the fireplace framework.

Dropped Soffits

Dropped soffits form large voids that are usually associated with kitchen cabinet bulkheads or vaulted ceiling details in master bedrooms. These large voids communicate with the wall, floor, or attic framing. At the PHRC, we've viewed numerous thermal defects associated with dropped soffits using infrared imaging. If left unsealed from the house framing, they may serve as huge conduits for air leakage. At the very least, they may provide a large surface on which moisture can condense. Although homeowners may never feel the air leaks associated with dropped soffits, they will notice the mold if enough moisture is present to condense on these potentially cold surfaces, as often occurs in winter. Wherever dropped soffits are incorporated, the builder's goal should be to provide a continuous air barrier between the wall and ceiling framing and the soffit subassembly. In practical terms, that means installing the drywall on the wall and ceiling before attaching the soffit framing. (For more on sealing dropped soffits, see "Chasing Interior Ducts," *HE* May/June '02, p. 24.)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(left) A large chase way adjacent to a return duct was left unsealed by a builder. The roof sheathing directly above this hole showed signs of moisture degradation within one year of completion. The builder's initial stab at a solution was to provide a turbine vent, which only served to draw more moisture-laden house air onto the sheathing and resulted in another angry customer callback. In this case both the problem and the cure were hidden underneath a fiberglass batt. *(right)* Here's an innovative solution to a second story cantilever and band joist detail. The builder has employed the use of house wrap. Note how the sheathing above overlaps the air barrier and that the seams of the sheathing are taped.

Tub Enclosures

Tubs and showers are often installed directly against unfinished wall framing intersecting an outside wall. Our observations have shown us that it is also common practice to leave plumbing penetrations that communicate with the floor cavity unsealed. Attach a continuous air barrier, such as polyethylene sheet plastic, to the wall framing extending from the floor to the ceiling before setting the tub. Seal all plumbing penetrations at the floor and ceiling with materials such as caulk, closed-cell foam backer rod, or spray foam.

Fireplace Enclosures

Many of today's fireplace options are nonmasonry inserts served by metal chimneys. They are generally encased by a variety of exterior and interior finishes supported by wood frame assemblies. The construction of these features often leaves large air pathways that communicate directly with open wall and ceiling assemblies. Before Sheetrock is applied, short-circuit these large air pathways with a combination of rigid or flexible materials such as drywall and polyethylene plastic while maintaining required clearance to combustibles as per manufacturer specs. Be sure to caulk or apply spray foam along all seams. This need not be expensive—it can be done with scrap

Spray Foams and the Code

Both expanding and nonexpanding polyurethane spray foams are very effective for sealing large holes within the building framework. Before the interior finish is applied, they are best suited for sealing plumbing or wiring penetrations as well as the seams of rigid air sealing materials. They are easy to apply, are available in bulk containers, and are much more forgiving than caulk in the sense that they will fill fairly large openings without the use of backer rods.

By code definition these products fall into the category of foam plastics, the majority of which meet flame spread and smoke-developed rating parameters as per ASTM E-814. As such, they are classified as a UL Class 1 material, which qualifies them as fire blocks. Fire blocks are generic materials installed in concealed spaces to resist or block the migration of fire and hot gases for an undetermined period of time. It is important to note that the 2000 International Building Code (IBC) and IRC 2000 codes (section 602.8) have both eliminated the noncombustible requirements pertaining to fire blocks and are revised to read "approved material to resist the free passage of flame and the products of combustion." It wasn't always this way. As one Building Officials and Code Administrators International, Incorporated, engineer recently put it, "Why seal a hole in a combustible stud with a noncombustible material, just to make it better than the stud?"

By way of clarification, fire blocking should not be confused with fire-stopping. Today, a "Through-Penetration Firestop System" is described in three model codes (including the 2000 IBC) as being comprised of materials used to seal penetrations in fire-rated assemblies and stop the migration of fire and hot gases for a prescribed period of time. Generally speaking, there are no fire-rated assemblies in a single-family home—only the party wall in a multifamily dwelling.

sheet material, sealant, and usually less than an hour of labor.

The Trouble with Ducts

HVAC ducts running through conditioned spaces, such as basements, are seldom a problem. Even if the ducts do leak slightly, the house recovers most of the conditioned air from the duct leak. But where they traverse unconditioned spaces, such as crawlspaces and attics, it is especially critical that ducts be tightly sealed and insulated. If hard ducts pass through framed chases, these chaises must be sealed where they enter an unconditioned space. Sealing attic penetrations of this type is easily accomplished with a variety of air sealing materials prior to insulating the attic. Simply covering a bypass with a fiberglass batt just won't do it. During A/C operation, return leakage may create sufficient negative pressure within a building cavity to draw hot, humid outside air across an A/C coil. This will reduce efficiency and waste energy. Worse yet, the builder will definitely hear about it when an otherwise properly sized system will not cool a customer's house because of an excessive temperature rise across the A/C coil. (For examples of well- and not-so-well constructed duct systems and bypass sealing in California, see "New Construction Report Card," *HE* Jan/Feb '03, p.18, and "New Construction Report Card, Part II," *HE* Mar/Apr '03, p. 35.)

Band Joists

We found that builders generally do a pretty good job of sealing the mudsill to the foundation through the use of closed-cell foam roll gaskets. However, they often fall short in paying attention to the rest of the perimeter floor framing. The band joist at all stories should be sealed with caulk or foam where it intersects the subfloor, top plate, and bottom plate. When properly overlapped and taped at the seams,

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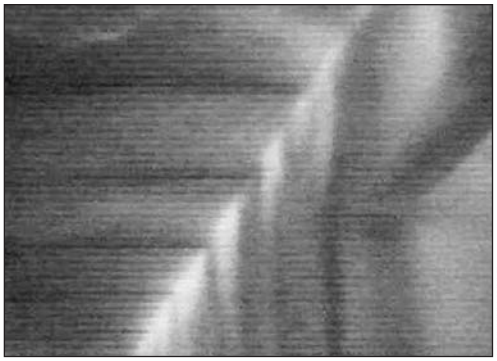
Exterior OSB sheathing is allowed to float across framing of a bay wall. If this nearly one-inch, floor-to-ceiling gap is left unsealed, the builder should expect a comfort-related callback.



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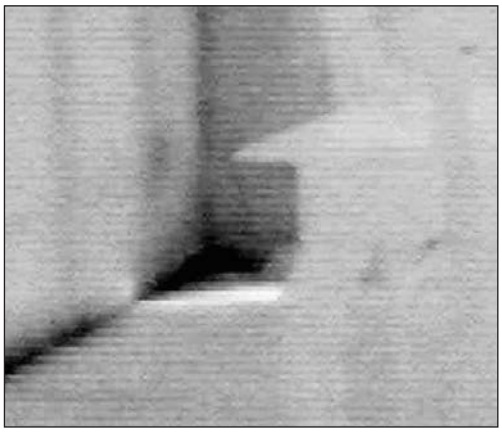
An infrared scan taken during the summer reveals air leakage at the top plate of an interior second-story partition. Much of this leakage could have been prevented by the application of a continuous fat bead of caulk along the inside edge of the double top plate as part of the drywall hanging process.



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Infrared scanning performed in conjunction with a blower door test exposes air leakage at the baseboard trim.

commercially available house wrap applied to the exterior of the sheathing may provide a practical and quick alternative.

Windows, Doors, and Some More

The gap between window and door units and the rough framing is an important conduit for air leakage. Before installing the drywall, seal these gaps with foam backer rod or spray foam. Use nonexpanding foams to prevent the expansion of jambs. The final bead of caulk applied around the trim will take care of the rest. When using house wrap, seal it to the inside of the window framing. Dupont manufactures a moldable flashing material called FlexWrap that is designed to be used in conjunction with their Tyvec house wrap to seal from the face to the inside of rough window and door frame openings.

A note about corners: If you "float" exterior sheathing over unframed inside corners and bay details—which is common practice in some areas—be sure to install gaskets or use spray foam to seal the gap between the framing members. Above all, do not use fiberglass batt insulation as an air sealer. This material is designed to retard conductive losses, but it is really nothing more than a glorified air filter when installed in an unsealed building cavity.

Top Plates

Leakage at the top plates adjacent to attics along exterior walls and interior partitions has been very common in new homes we've inspected. The top of the structure is where air sealing will have the greatest benefit, because these are high-velocity leaks. Leakage paths at the top of a structure tend to funnel much more air than leakage paths at the middle of the structure, due to the natural stack effect. Think of a two-story house as a short, fat chimney. Seal the chimney at the top and reduce one of the major opportunities for convective air loss.

Builders should caulk or apply spray foam to all top plate attic wiring

and plumbing penetrations, as well as to the joint between the drywall and framing exposed in the attic. If you can spec out the application of a continuous bead of caulk along the inside of all exterior and interior double top plates (and bottom plates) as part of the drywall installation process, so much the better. Once again, the timing of these air sealing processes during construction is important, since it's usually too late once attic insulation is in place.

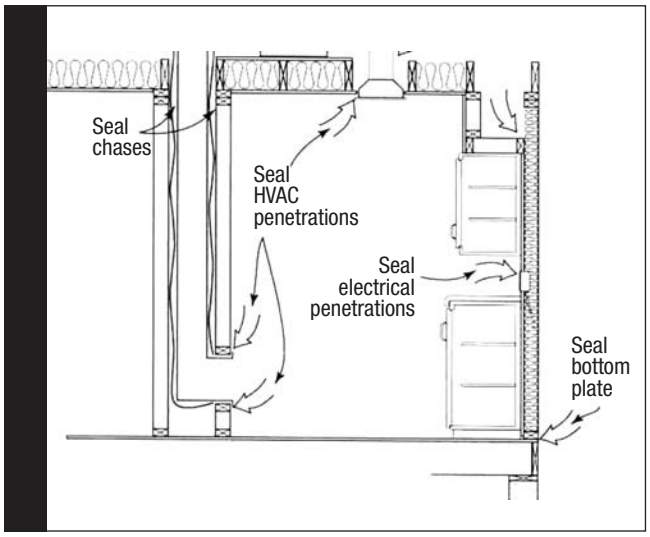

Figure 1. The illustration shows a few selected air sealing locations. (Source: Fact Sheet, DOE's Office of Building Technology and Community Programs.)

Other Penetrations

The myriad of other leaks, such as those associated with hatch covers, receptacles, ceiling fans, exhaust fans, central vacuum systems, and so on, can translate into a lot of air loss. The cumulative effect might be comparable to leaving a window open in the family room on Super Bowl Sunday. Most of these leaks may be sealed after drywall is finished. Here are a few examples:

- Seal switch and outlet boxes to the drywall with caulk and install gaskets underneath the cover plates. However, this will probably not be totally effective, since electrical boxes have holes through which wiring must pass. Consider using spray foam to seal the wiring knockouts and other gaps on the inside of the boxes after the rough wiring has been installed. This would be especially beneficial for electrical boxes located on exterior walls.
- Weatherstrip attic hatches.
- Place gaskets around lighting and ceiling fan trims.
- Use exhaust fans equipped with dampers that close when the fan is not operating.

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The IRC 2003 (R-502.12) requires that "draftstops" be installed to separate floor/ceiling assemblies into "approximately equal areas" not exceeding 1,000 square feet. Dropped ceilings and open web truss floor systems are specifically mentioned as the primary target areas for draft stopping.

Closing Up

There are many other potential problem areas—too many to mention within the scope of this article (see Figure 1). Here we have discussed only some of the usual suspects and how to treat them. The sheer variety of home design options may lead to many complex framing configurations. Architectural features such as floor systems associated with knee walls, cantilevers, and bonus rooms over tuck-under garages will require creative solutions.

The primary goal of the designer and builder is first to define, and then to seal and insulate, the thermal envelope. By definition, the thermal envelope consists of those building components and surfaces that separate conditioned from unconditioned space. Once the builder understands this concept, and understands all the possible causes of air loss, the rest will fall into place.

The major challenge to the builder is not the expense of air sealing. It is how to adjust site management practices to accommodate air sealing operations at various phases of construction. In most cases, the expense of material and labor is minimal. The benefits, on the other hand, will certainly be worthwhile in terms of customer satisfaction and reduced builder callbacks. HE

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Special credit goes to Ed Minch, partner of Energy Services Group in Wilmington, Delaware, who shared his opinions as well as important supporting documents regarding the allowable uses of spray foams in building assemblies.

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