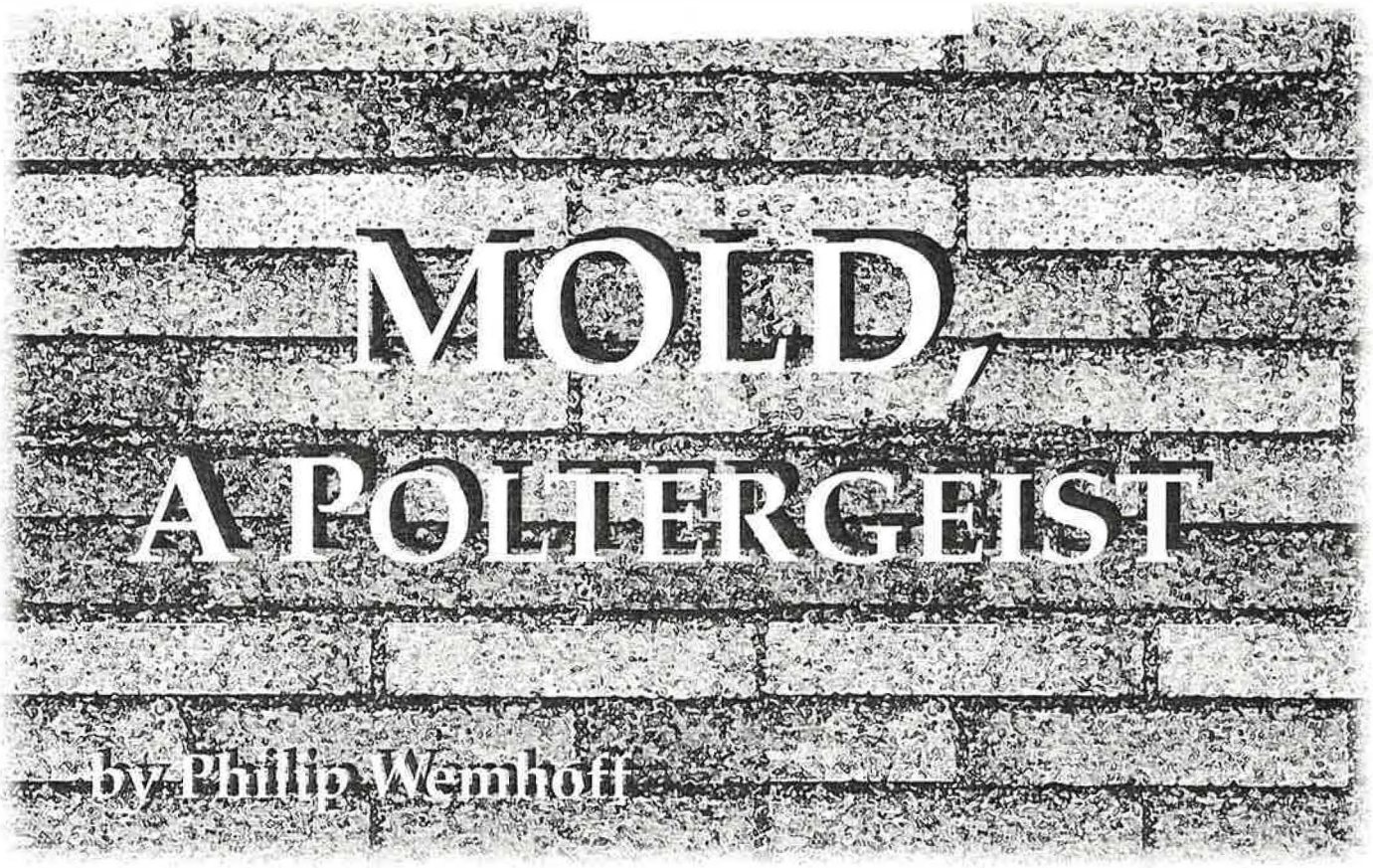


MOLD, A POLTERGEIST

by Philip Wemhoff

SARAH COLLINS

Mold growing within the walls of a brick veneer home can pose special problems for diagnosis and remediation.

For the past three years, ever since her family moved into its new single-story home in Jacksonville, Florida, 15-year-old Megan hasn't been able to sleep in her bedroom—it is haunted by horrible mold odors. Instead, Megan has slept on a portable bed in the hall or in a nearby study, and her bedroom has been sealed shut.

A year and a half ago the builder attempted a fix—removing the moldy drywall and the insulation of the brick veneer wall—without success. Within weeks, the ghostly odor was back. Although disheartened, the family patiently held its anger, relying on the builder's promise to find an answer. When another year passed without builder action, Megan's family pressed again. That's when the builder called in my company, Building Diagnostic Technologies. We investigate unusual moisture, comfort, and energy problems in buildings—and the more mysterious and bizarre, we feel, the better.

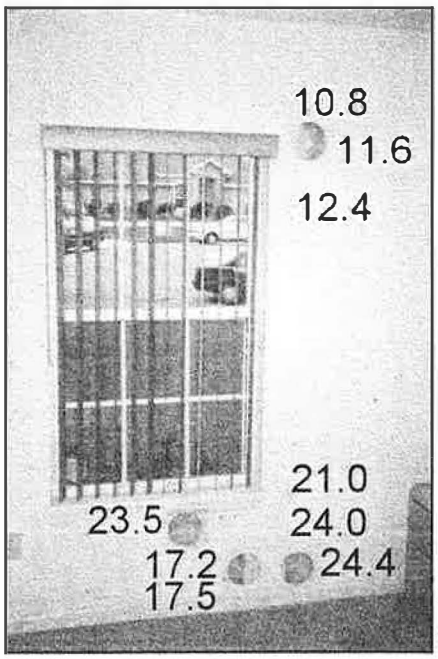
Shortly afterward, my business partner, Robin Peterson, and I arrived with the builder's warranty manager. Megan's father began to remove the tape and towels that had sealed the bedroom door, isolating the room from the rest of the house. "You're not going to like it in there; it's like a poltergeist," he said, as he stood back to let the brunt of the foul air strike us. Within ten minutes, the warranty manager gave a muffled croak and mumbled as he moved for the door, "I've got to get out! My eyes are burning, and I don't feel so good." Peterson and I held out. We love this type of investigation.

Spotting the Demon

The immediate odor source turned out to be the east wall's waferboard sheathing, located between the brick veneer and the wood framing. Our noses targeted the sheathing, and we confirmed its high moisture content (17%–24%) with a highly accurate conductive moisture meter (see "Moisture Meter Selection," p. 21). The moisture was located in a region below waist height. For wood panels, surface mold begins to form at about 17%, and rotting begins at about 27%. The sheathing that was above waist-height had a water content of 11%–12%. Determining the sheathing's water content was easily done with special deep probes designed to penetrate the interior gypsum board with minimal damage and to continue past the wall insulation, without measuring the water content of either.

Once we determined that the sheathing was the odor source, we used a large hole saw to cut 6-inch openings in the gypsum board at strategic locations near the window. This was done to search for liquid water stains, but we found none. Next, we set out to determine whether the moisture source was gaseous water. We carefully removed a 4-inch diameter sample of the wood panel sheathing in order to examine the construction beyond. We found plastic house wrap, an inadequate cavity between the sheathing and the brick veneer, and a poorly constructed drainage

plane. Eventually, we would determine that, for this house, these construction deficiencies did not have to be corrected. However, there are often times when such a wall must be rebuilt (see "Waterproof Brick Veneer Walls," p. 22).



PHILIP WEINHOFF

At 17% moisture content in a wall, mold growth begins; at 27% rotting may begin.

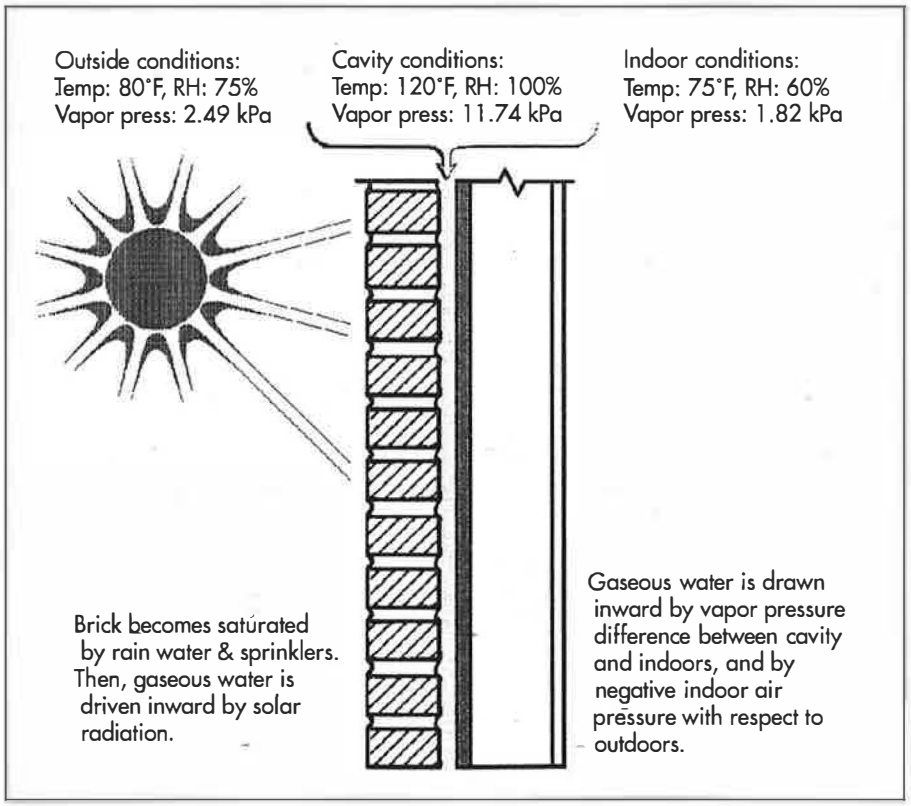
Further investigation revealed the following factors contributing to the sheathing mold growth:

- The indoor air pressure with respect to outdoors, as measured by a digital manometer, was always 0.5 to 7 Pascals (Pa) negative (due to dominant supply duct leaks); it should have been neutral or slightly positive.
- The refrigerated air flow to the troubled room, as measured by a low-flow balometer, was only 59 CFM, but our load calculation determined that 110 CFM was required.
- There was no air-egress from the room, a design fault that further lessens air flow when the bedroom door is closed.
- The relative humidity of the room, as measured by a sling psychrometer (electronic RH instruments are often inaccurate), stabilized at 66% (75°F dry bulb) after the door was open for three hours with the A/C running continuously. Mold growth on furnishings begins at about 60% RH.
- The 2½-ton central A/C unit was undercharged by approximately one pound of R22 refrigerant, thus reducing its ability to remove moisture.
- Water from irrigation sprinklers was being driven by wind onto the outside face of the brick.
- The home's wall construction ignored a number of brick water control standards.

We next investigated possible liquid water sources that might have affected the troubled room—although we suspected that these would turn out to be irrelevant. We searched for subslab water leaks from supply water lines, leaks from the main sprinkler trunk, and water leaks at the window of Megan's bedroom. No evidence of such leaks was apparent. We also used the moisture meter, coupled with masonry nail probes, to check the slab surface moisture content of this and all nearby rooms. We found it was negligible—less than 50%. We also dug a 3-ft well adjacent to the nearby sprinkler manifold to determine the water table height, which was below 3 ft. Finally, we sprayed water on the bedroom window, while monitoring inside by sight and moisture meter. When a 4-inch diameter section of sheathing was removed afterward, it emitted a strong mold odor, but there was no evidence of liquid water presence. However, liquid water wetting is not needed for the development of mold odors in wood panel sheathing, and some molds are colorless.

Why Haunt This House?

Wall deterioration due to moisture problems is widespread, but it occurs with different degrees of severity. A moldy odor can be the earliest signal to a homeowner that moisture damage is occurring somewhere in the home. Moldy odors are really mold spores' digestive outgases—microbial volatile organic compounds (MVOCs). For a moldy odor to be discernible, a critical level of spore metabolic activity must be present. Unfortunately, homeowners can be fairly tolerant of moldy smells. Many believe that some mold odors are to be expected in a hot, humid climate, even when the home is fairly new. But this new Jacksonville house had a combination of problems that resulted in moldy odors that went way beyond anyone's definition of tolerable.



PHILIP WEINHOFF

Figure 1. Note the relative humidity of 100% that occurs in the cavity between the brick and the sheathing cavity when the water-soaked brick is heated by the sun.

In our troubled house, moisture damage occurred from the following process. The face brick was absorbing liquid water from rain and from sprinklers. This water in gaseous form was then being driven inward by solar radiation. The relative humidity within the brick-sheathing cavity was 100%, or complete air saturation (see Figure 1). Because the indoor pressure with respect to outdoors was always 0.5–7 Pa negative, the gaseous moisture was being drawn into the waferboard sheathing and into the wall cavity, and odors were carried indoors by the incoming diffuse airstream. The gaseous moisture also passed around the interior windowsill, causing it to warp. The higher moisture content low on the sheathing may have been caused by extra water loading from irrigation sprinklers, which were striking the face brick below mid-window height. Also, the roof overhang shields the upper brick courses from some solar radiation, reducing the tendency for moisture to be driven inward there.

Fundamentally, the high sheathing moisture content could be traced to duct leakage, incorrect duct sizing, and poor sprinkler head location. A primary cause, defective veneer wall construction, could not be easily corrected.

The Exorcism

The builder implemented our recommendations sequentially, rather than all at once as we advocated, so the recovery process stretched out over several months. At the beginning of a correction, when the sheathing begins to dry, odors may actually increase, due to a short-term increased procreation of spores—an intelligent response to stress. But this subsides faster if the drying continues quickly.

The repairs we recommended were:

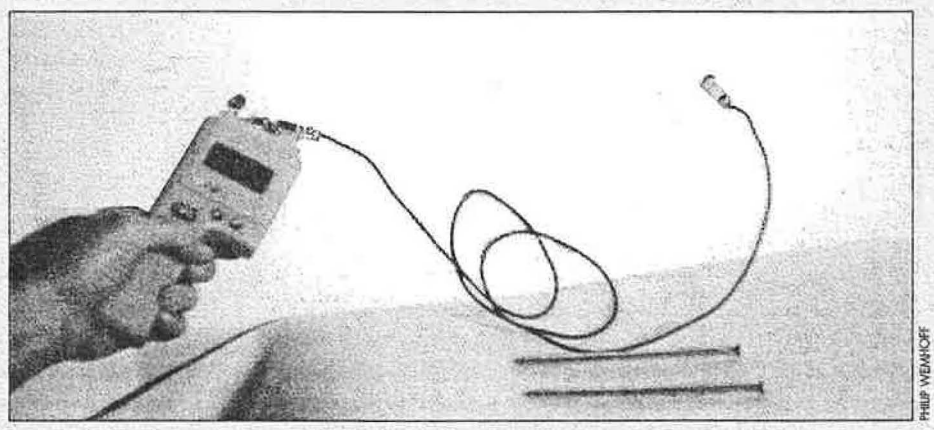
Relocate the sprinklers. The sprinklers were physically relocated to an area east of the shrubbery and to ground level, so they could no longer wet the brick. A drip irrigation system, to manage the shrubs, may be added later.

Eliminate the negative indoor pressure. Supply leaks had caused the house to operate at 0.5–7 Pa negative with respect to outdoors whenever the air handler fan was operating, drawing moisture-laden outside air from the brick cavity into the nearby sheathing. All the supply duct leaks were repaired, and the joints between register/grille boots and the ceiling board were sealed. Also, a fresh-air duct was added to the main return. It originated under the roof soffit, passed over the wall top plate by means of a custom rectangular-to-round fitting, and joined the main return where it was equipped with a manual damper. Using the damper, the incoming air flow was fixed at a value between 40 CFM to 90 CFM, as measured by a flow hood—enough to give the house a slightly positive pressure with respect to outdoors.

Correct the air flow. The measured air flows to all the bedrooms, including the troubled room, were compared to the required air flows as determined by careful load calculations, and were found to be deficient—not enough dehumidified air was being supplied to manage the moisture loads. The owners had complained that these rooms were always too warm in summer and too cold in winter. The principal trunk and all the bedroom branches were replaced with very large diameter ductwork, and the joints were sealed with fabric-reinforced mastic (see Figure 2 on p. 23). The air flow to Megan's

Moisture Meter Selection

We've found that the best moisture meter for serious diagnostic work is a Delmhorst BD-2100 conductivity type meter, whose programming allows it to test wood, masonry and gypsumboard on different scales. For each material there is a user-adjustable set-point that alerts the user when the predetermined moisture limit has been reached. Conductivity meters have two needle-like probes that are inserted into the tested material. The other popular type, which utilizes electromagnetic waves, can test only the surface material. It may be good for the house inspector, but it is unable to detect problems deep in a building composite.



PHILIP WEINHOFF

We think this Delmhorst BD-2100 is the best moisture meter available.

With this better conductivity meter you can incorporate an arrangement of nails as substitute probes and a length of wire to determine the width and height of a "wet" area. If high moisture content is noticed from probe to probe, the entire area between the probes is "wet". And, with minimal damage we can use a BD conductivity meter to search deep within a wall, if we utilize very long nails, whose shafts, except for their tips, are insulated with vinyl tubing. As the insulated nail tip penetrates the gypsumboad, the wall insulation, then the outside sheathing, we learn the moisture content of each, although we have to change the diagnostic settings from gypsum to wood. Surface measurements for masonry (concrete, stucco and brick) are not accurate, because water evaporation is very rapid at the surface. So, to get accurate masonry measurements a ½-inch well needs to be drilled in the masonry, and a hardened fluted masonry nail driven slightly into the bottom of the well, in such a way that no part of the nail shaft touches the well sides.

Waterproof Brick Veneer Walls

Fortunately, we were able to fix this house's moisture problem without rebuilding the brick veneer wall, a wall with many waterproofing defects. Sometimes, however, reconstruction will be necessary. To do the rebuild properly or to ensure waterproofing during initial construction, certain wall features and long-standing brick standards (given below) need to be implemented, though they are commonly disregarded. (Of course, we must be certain that duct leakage is prevented, that there is proper airflow and air-egress to rooms, and that the AC is charged correctly.)

Outside moisture barrier. The composite of our problem wall, from outside to inside, is brick veneer, plastic housewrap, waferboard sheathing, wood framing, batt insulation and gypsumboard. The plastic housewrap in this application presents a water intrusion danger. Its high permeability fails to protect the sheathing against gaseous water entry. And, recent research suggests that surfactants in the sheathing alter the water repellencies of some housewraps, allowing liquid water to pass through. In addition, a housewrap will not be an effective air infiltration barrier, if it is not sealed to the wall's top and bottom plates and to the frames of windows, and if adjacent sheets are not sealed to one another.

Instead of housewrap, we recommend sealing the sheathing using acoustical sealant and covering its outside surface with 30 pound asphaltized roofing felt (building paper will not work as well). Such asphaltized felt has very good liquid water shedding properties, and its permeance is about 5, far lower and therefore better than the 50+ perm rating of many popular housewraps. Good installation requires (1) that the felt be frequently fastened using plastic-headed nails, (2) that all edges be lapped 4 inches, and (3) that the felt be positioned properly to cover flashings above and below windows and at the bottom of the wall.

Drainage plane. Wind-driven rain will penetrate beyond the brick veneer, so it is paramount that a clear 1-inch minimum drainage plane be created between the brick and the frame wall sheathing—one which allows this potentially damaging water to drain to the flashings below and to be directed by them through the weepholes to the outside. A typical but bad practice is the misapplication of mortar, causing an excess to reach across and obstruct the 1-inch drainage cavity, even mushrooming against the sheathing on the other side. At each course, these damaging mortar fins become reservoirs which store rainwater for delivery into the wood panel sheathing. There are about 24 courses and thus 24 of these harmful reservoirs in an 8-foot high wall.

Waterproofing: Flashings and Felt

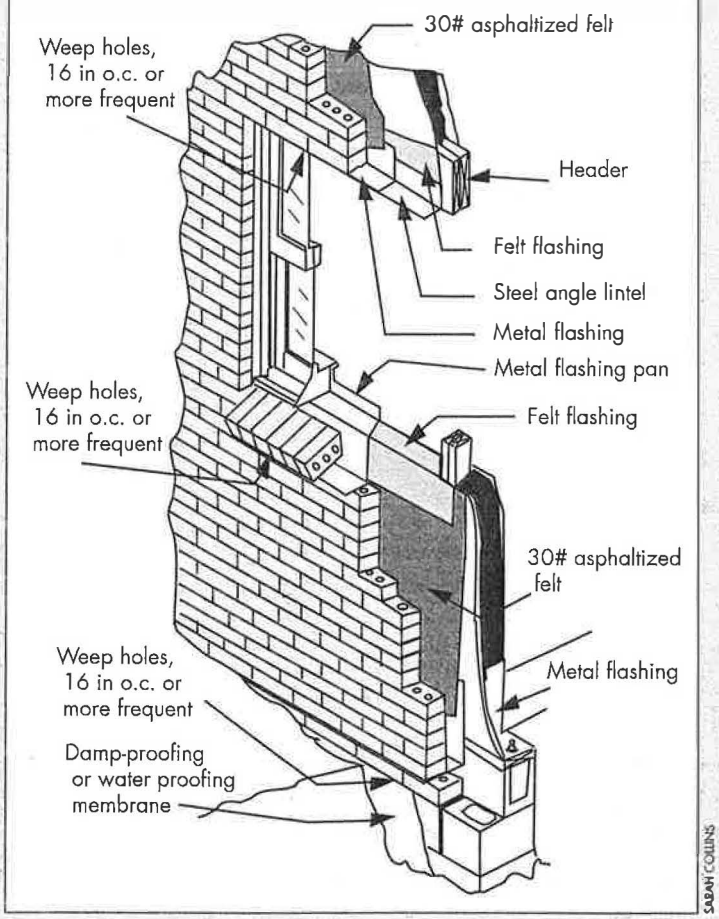


Figure A. Proper location of flashings and weep holes, as well as correct mating of flashings with asphaltized felt, helps avoiding moisture intrusion.

The cavity and the entire brick installation must be consistent with the construction standards of the Brick Industry Association (BIA).

Flashings. The specific locations of flashings are shown in the attached illustrations. Consistent with BIA standards, they should be located above and below windows and at the bottom of the wall, and they should pass through the brick course and have a drip edge on the outside. In many cases the flashing under the window should be a flashing-pan whose three inner edges are turned up and corners soldered. All flashings should be overlapped by the 30 pound felt. Weepholes must be placed every 16 inches along the flashing. In coastal areas Type 316 stainless steel flashing material is recommended. Avoid the use of any material, including foam caulk, to seal the cavity between wood shim-mounted windows and the rough framing. Any obstructions in this cavity will prevent intruding water from draining to the flashing pan below the window and contribute to window rotting.

Before windows are installed, traditional interlocking asphalt-felt flashings, shown in a good framing manual, should be placed around rough framing openings. If the newer peal & stick products are used they should be nailed with plastic-head nails as if there were no adhesion, in anticipation of future separation.

Brick and mortar. Brick should be chosen based on its water repellency. One should seek brick having an Initial Rate of Absorption (IRA) less than 5 gm/in²/min and having a boiling water absorption of 8% or lower, both tested under ASTM C216. Such brick need NOT have a glossy appearance, and the manufacturers and their representatives will have the ASTM test results.

Very important to the prevention of water penetration is the brick-to-mortar bond and adherence to proper installation procedures. Brick whose IRA is less than 5 should be set with Type S mortar; brick with IRA of 5 to 30 can use any mortar type, and brick with IRA's of 30 should be set with Type N mortar. In addition, all mortar mixing, brick pre-wetting, joint tooling, and other procedures defined by BIA should be followed in every detail.

room was corrected from 59 CFM to 110 CFM; a second bedroom, from 58 to 90 CFM; the master bedroom, from 87 to 184 CFM; and its closet, from 52 down to 24 CFM.

Create return air pathways. Return air pathways were missing from all the bedrooms, reducing the bedroom air flow when the doors were closed and causing other parts of the house to depressurize. Return ducts were added and equipped with manual dampers, allowing the return air flow to be set at a lower CFM than the supply. The bedrooms now have a slightly positive pressure when the doors are closed.

Correct the refrigerant charge. An incorrect refrigerant charge had reduced the moisture removal capacity of the central A/C, contributing to high indoor relative humidity. The incoming air temperature in several rooms was 59°F, but it should have been about 53°F. Approximately one pound of R22 refrigerant was added.

Provide constant air flow to the troubled rooms. Corrections were initiated in the fall when A/C use and blower fan on-time are minimal. To maintain constant air flow and pressurization for the more troubled bedroom during the drying-out period, a temporary 120 CFM inline fan was installed in the supply duct leading to that bedroom. The fan was located near the trunk to reduce noise. The relay controlled fan operates only when the main air handler fan is off (see Figure 2).

Apply a brick coating. To reduce the water absorbency of the brick, a clear reactive sealer, called a siloxane, was applied to the outside surface, after the windows were carefully masked. Another product, a silane, could have been used with about equal performance.

Several weeks following the duct repair and the consequent reversal of the negative house pressure, we were quite encouraged by the odor reduction. Once all the recommendations were implemented, it took only a few weeks for the odors to become undetectable to us. However, the owner insisted that the builder replace the bedroom drywall and insulation to ensure elimination of any residual odor. This step may have been unnecessary, but appeasement of the owner was certainly wise after these long years of waiting. Now, after three years in the hall, Megan finally sleeps in her bedroom.

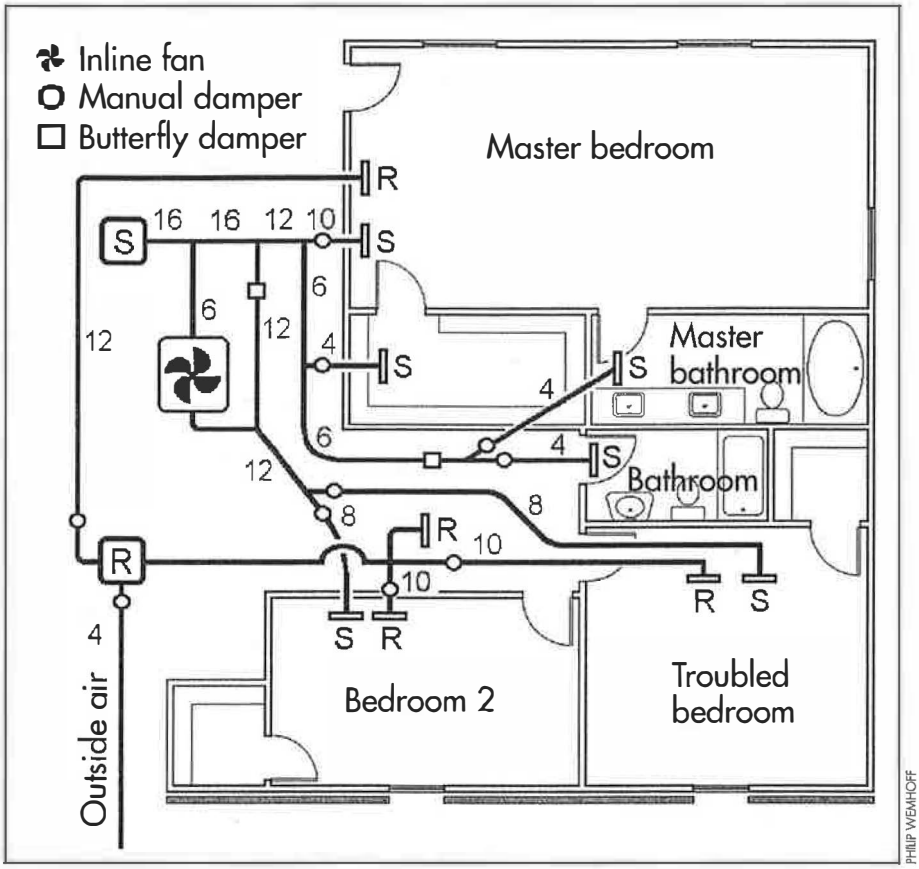


Figure 2. A bypass loop was created, equipped with a one-way butterfly damper, to ensure air delivery solely to the intended destinations. Manual dampers on all the returns allowed us to reduce each return air flow till the receiving room pressure was neutral or positive with respect to outdoors.

The Gremlin Count

The fee for the investigation was $450, and the correction costs came to $2,100, including $500 for the disputable drywall and insulation work, all paid by the builder. Replacement of the wall itself would have been a more costly alternative. The mold would also have returned again, if the builder had continued to neglect the fundamental issues: pressurization, air flow, air-egress, refrigerant charge, and proper brick veneer construction.

Ultimately, prevention is the prescription, through code compliance and attention to detail. All of the ills assaulting this house were direct violations of Florida codes and sound industry standards. The sheathing deterioration would have been prevented had the contractors merely complied with Florida's requirements for duct sealing and duct sizing, and with brick industry standards for veneer wall construction. Almost universally in Florida, brick veneer walls are erected without the industry-recommended flashings and functional drainage planes. Furthermore, A/C contractors rarely, if ever, rigorously follow the refrigerant system assembly, evacuation, and charging recommendations of manufacturers. Most don't even calibrate their thermometers or manifold gauges—the critical charging instruments. To address the issue of proper return air flow from closable rooms a code mandate will take effect in Florida next year requiring that pressure differences across partitions do not exceed 2.5 Pa. Following such measures will keep the poltergiest of mold from haunting any Florida homes.

Philip Wemhoff is a Florida-licensed builder, physicist, and principal of the investigation firm, Building Diagnostic Technologies. He can be reached at wemhoffp@buildingsleuth.com.

For more information:

Brick Industry Association (BIA)
11490 Commerce Park Drive
Reston, VA 22091
Tel: (703)620-0010
Web site: www.bia.org