Sidewall Insulation and Air Leakage Control

by Jim Fitzgerald, Gary Nelson, and Lester Shen

What makes a quality blown insulation job? Careful attention to densely packing the insulation and sealing bypasses, say the authors. And they have the diagnostic equipment, experience, and science to prove it. The technique not only avoids voids, it air seals in the process.

For the past several years, we at Fitzgerald Contracting have used a blower door and an infrared camera on nearly every house that we insulate. Using this diagnostic equipment, we have learned to slightly modify our normal insulation techniques to achieve large reductions in air infiltration. This modification reduces the amount of time that is normally needed to air-tighten the house while greatly improving quality.

As we gain a better understanding of how buildings function, we have learned that heat loss in buildings is much more complicated than simple formulas would suggest. Effective insulation retrofits must treat the building as a total system, including not only the envelope but the mechanical system and occupants as well. Concentrating on a single aspect of the building may lead one to overlook possible interactions that exist with the rest of the building. We found that cavity-fill insulation and air leakage form one of the important points of interaction, or links in the system. We no longer think of ourselves as just insulation contractors but as weatherization contractors. With this perspective, our goal should be to maximize our customer's energy savings per dollar spent rather than to maximize the area of insulation installed per dollar spent.

Jim Fitzgerald, insulation contractor and weatherization trainer, has specialized in House Doctoring and troubleshooting houses with ice dams, moisture, and air-infiltration problems.

Gary Nelson is a partner in The Energy Conservatory, an energy research and training company and manufacturer of the Minneapolis Blower Door.

Lester Shen is a research associate with the Underground Space Center, Minnesota Cold Climate Building Research Center, at the University of Minnesota. He is the principal investigator of the Minnesota M200 Enhanced Low-Income Weatherization Demonstration Project.

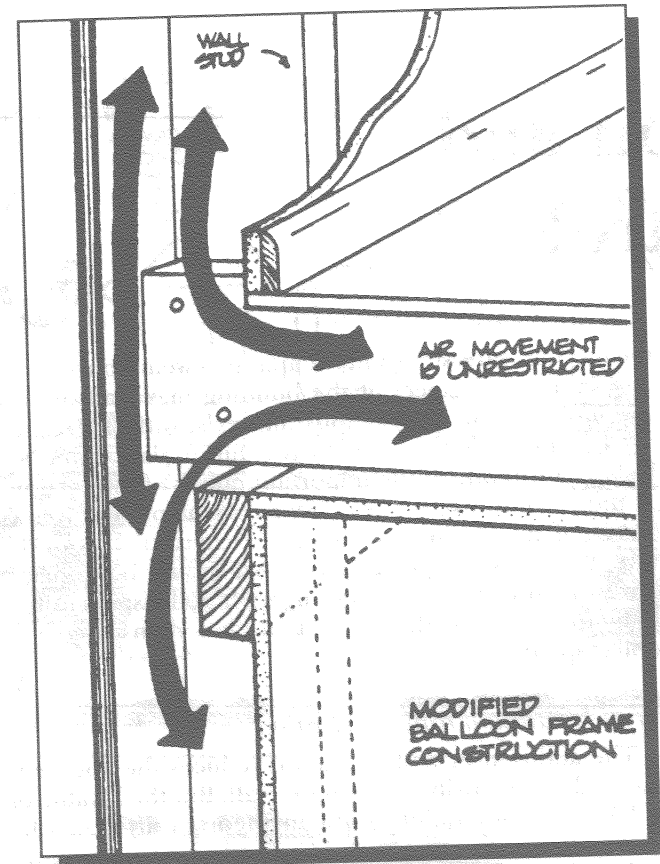
Gautam Dutt is an energy expert and consultant, currently based in Mexico City. He was one of the original developers of the Princeton House Doctor procedure.

Wall Insulation and Infiltration

The addition of wall insulation reduces the apparent thermal conductivity through the wall. But the R-value of a 3.5" cavity of absolutely still air theoretically would be R–20. Obviously, more than just conduction is going on within the wall cavity. Thermal insulation actually works primarily by slowing the movement of air.

Air circulates within the cavity because of temperature differences in the wall, and heat flow through the wall is greatly enhanced due to this natural convection. ASHRAE reports that the thermal resistance of a 3.5" air space under typical temperature differences can be in the range of R-1 to R-3.6 (five to 20 times below that of "still" air!). When wall insulation is added to the cavity, it acts to break the space up into tiny air pockets, impeding the natural convection in the wall and taking greater advantage of the insulating properties of "still" air. The heat flow through the wall will depend on the conductive properties of the insulating material (such as fiber glass, cellulose, or mineral wool) and the size of the air pockets (i.e., the density of the insulation).

Heat loss can also occur through forced convection when air is able to flow into the wall cavity from either inside or outside the building. This air flow is driven by pressure differences caused by the stack effect, wind, and/or mechanical systems (exhaust fans, air handlers, etc.). Most failed insulation jobs we have remedied were caused by gross air leaks. These failures can result in such problems as ice dams and frozen pipes. Often the largest air leaks result in air flowing right through the insulation, thereby counteracting the beneficial effects of the insulation. These air leaks can be readily identified with an infrared camera used with a blower door.



from *Air Sealing Homes for Energy Conservation, 2nd Draft,* Energy, Mines and Resources Canada, Ottawa, 1984.

Figure 1. One of the most important air leakage paths that can be sealed by dense cavity fill insulation occurs at the wall/floor connection.

We often find wide open air flow paths at the interstitial connections within the house (i.e., open framing spaces at connections between floors and walls, walls and vaulted ceilings, plumbing chaseways, etc.) and these paths are often responsible for the majority of the air leakage in the house. (See Figure 1.) Sometimes these connections are closed off at one end with a batt of fiber glass instead of an air barrier. The fiber-glass batt acts as a good filter for the air flowing through. Blackened, dirty fiber glass is a tip-off to the bypass. These connection and transition areas are often hidden and difficult to find. Tightly blown insulation greatly reduces the flow through these paths.

Blocking Air Flow

In fixing failed jobs, we install rigid, durable barriers to air flow. We generally use foam or cardboard blocking. When rigid barriers are impossible to install or too expensive, we blow insulation tightly into the air leakage pathways. We are able to blow cellulose and mineral wool insulation at a high enough density to stop the air leakage. Infrared scans with the blower door running have shown us that high density insulation works. Most importantly, moisture problems and ice dams stop, the pipes quit bursting, and our clients are satisfied.

Pre- and post-retrofit blower door tests have shown that large reductions in air leakage result from our procedures. In 32 houses we sealed accessible bypasses and blew insulation tightly into walls and other closed cavities. From before and after blower door tests, we learned that we had obtained an average air infiltration reduction of 2,000 cubic feet per minute at 50 Pascals (cfm_{50}—for background on this measurement, see *HE* Jul/Aug '86, p. 16), a reduction of 46%. While everyone knows that sealing accessible bypasses is important, no bypasses were accessible in four of these houses. Consequently, our only action was to blow cellulose into the wall and closed cavities. We took extra care to pack all hidden connection areas. Table 1 shows the results for these houses. From just cavity fill, we obtained about a 50% average reduction in cfm_{50}. Air movement within hidden cavities appeared to be a major component of shell leakage in these cases. These reductions were obtained before any interior caulking or weatherstripping work was done. In fact, in a third of the houses, no further sealing work was needed. For a large part, these big air leakage reductions were a side effect of higher quality insulation work. In Minnesota at 50¢ per therm of natural gas, a reduction in 1 cfm at 50 Pa is worth about 5-6¢ per year. Thus, the additional payback from the convection savings improves the simple payback of the wall insulation.

Mark Freeland

Jim fills a hidden bypass above the front porch. Don't skip anything, he says.

Table 1. Infiltration Reduction from Sidewall Insulation

siding	surface area* ft.^{2}	volume ft.^{3}	pre-ins cfm_{50}	post-ins cfm_{50}	% change	cfm_{50} saved
woodlap	3,700	26,000	5,325	2,411	54.0	2,916
stucco	5,000	37,000	8,836	5,333	39.6	3,503
asbestos shake	5,300	39,200	8,500	4,462	48.0	4,038
asbestos shake (multifamily)	7,900	51,000	9,099	4,400	51.1	4,659

* above ground

An independent field study of dense-pack insulation in 92 houses in Ohio yielded similar results. According to Don Michael Jones, Director of the Ohio Weatherization Training Center, "Sidewall and attic insulation measures accounted for over 50% of the air leakage reductions achieved (38% average reduction). The simple payback benefits associated with sidewall insulation have, as a necessity, been calculated from its [increase in R-value] alone. Considering the interactive nature of the building structure, our perspective on the effects of sidewall insulation must be broadened to include the additional benefit of bypass sealing and overall air leakage reduction."

For the M200 study of enhanced weatherization in Minnesota, weatherization crews from nine agencies were trained to integrate wall insulation and air-sealing techniques. By sealing all attic bypasses and blowing walls first, the crews gained the air-sealing side effect of cavity fill and did not waste crew time on air-sealing if the house was tight enough. Results indicate average air infiltration reductions of 36%, with costs within the normal DOE weatherization guidelines (see box).

Most insulation contractors do not get these large air leakage reductions. A post-retrofit test of 120 houses in St. Paul found an average air change per hour rate (ACH) of 11; our dense pack work in 28 houses stood out at 7 ACH. Unfortunately, there is no incentive for contractors to strive for these reductions because they do not get paid for infiltration reduction. Strong economic forces push the installer to use less and less material at a faster rate. It is no surprise that the results are diminished by fluffed insulation and missed cavities. Normal insulation procedures, being guided by production, are not stretched by a performance standard or guided by the necessary diagnostic equipment. When a contractor is paid for both conduction and infiltration work, he can do a better job at a lower cost.

The M200 Enhanced Low-Income Weatherization Demonstration Project

by Lester Shen and Gautam Dutt

The goal of the M200 Enhanced Low-Income Weatherization Demonstration Project is to refine and transfer enhanced weatherization procedures from pilot projects into an approach that can be implemented by local weatherization agencies in Minnesota. The result should be a higher level of energy savings and cost-effectiveness within the framework of current DOE and state weatherization guidelines.

Description of the M200 Weatherization Protocol

The intent of the project is to combine the best-known proven techniques for insulation and air sealing with appropriate heating system measures. Included in the protocol is effective education of the residents to stimulate practices that save energy and reduce the risk of moisture problems or indoor air pollutants. The energy advisor (an auditor and consumer educator), the weatherization crew, and the inspector were trained to identify (and correct whenever possible) health and safety hazards already present in the house (e.g., in the heating system) and to ensure that none are added as a result of the interventions (e.g., moisture). From intake person to final inspector, all personnel who interact with the residents participate in educating them about energy use.

The role of the energy advisor is to conduct a thorough inspection of the heating and heat-distribution system as well as to educate the client. The advisor does not focus on defects in the building shell, such as locating air leaks or conducting infrared scans, but only collects information the weatherization crew will need. This information includes: How much insulation will be needed (if any)? What type of insulation is appropriate? and What are the dimensions of windows and storm windows needing repair, installation, or replacement? A blower door measurement is also made to give a preliminary evaluation of air leakage. If the house is tight enough and needs no insulation, the visit by the weatherization crew can be entirely eliminated.

The heating contractor visits the house if the energy advisor specifies any corrective action to improve efficiency and/or safety. This visit normally precedes the crew, which can then address any insulation or duct air leakage problems with the heating system in its "corrected" form.

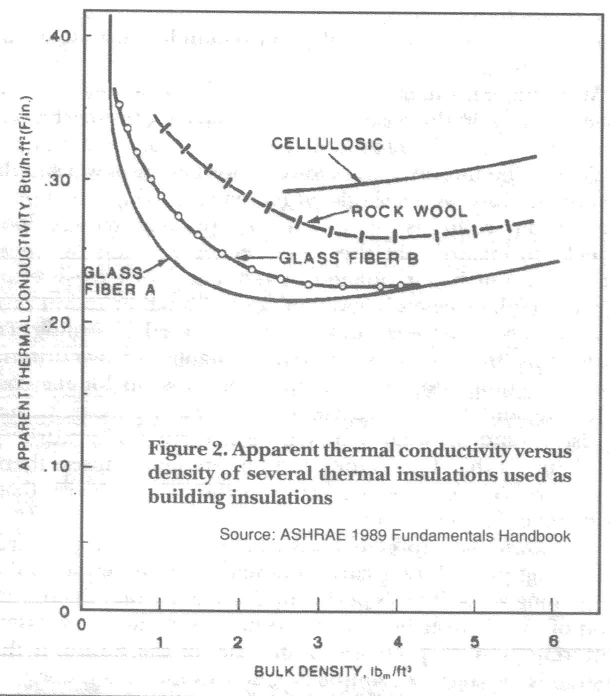


Figure 2. Apparent thermal conductivity versus density of several thermal insulations used as building insulations

Source: ASHRAE 1989 Fundamentals Handbook

The weatherization work crew conducts any necessary diagnostics to locate defects in the building shell. The crew starts with a blower door test to establish initial house leakiness. If called for by the energy advisor, wall insulation is then done. The wall insulation is intended to reduce conductive heat losses and seal miscellaneous air leakage sites that are difficult and time-consuming to fix using conventional air-sealing methods. This wall insulation procedure is substantially different from that practiced by most insulation crews of low-income weatherization. In particular, the procedure includes special techniques for certain large air-flow paths that may be hidden in the walls. Simultaneous with, or immediately following wall insulation, the crew seals all attic bypass heat-loss paths. Attic insulation can then be installed, if called for, and any major window work carried out. Note that the crew does not caulk or weatherstrip at this time, if at all. First, the crew seals large leaks in the supply and return ducts if the

(continued on next page)

INSULATION

During the 1970s David Harrje, Gautam Dutt, and Ken Gadsby at Princeton University discovered the large energy penalties of hidden air movement in buildings. This work demonstrated the importance of bypass sealing. Our wall insulation method arose out of the need to bring Princeton's insights into the real world of the insulation marketplace.

No Voids, No Bypasses

Natural and forced convection in the wall cavity significantly reduces the effectiveness of wall insulation. To achieve the thermal resistance values measured by standard test methods, minimizing convection is essential. This is nothing new, of course. Since the 1930s, old-time insulators have known that a good wall insulation job meant filling all the cavities as tightly as possible.

In practice, this meant mineral wool blown in using a 2-hole-per-cavity method. Exterior siding was removed near the top and bottom of each stud space, and 2 ⅝" holes were drilled through the sheathing. To find firestops and blockers, each run was plumbed with a weight. Any wall cavity taller than 3-4' required two holes, for both pressure release and tight packing. This prevented voids and settling. (As noted in *HE*, Sept/Oct '85, p. 6, a void area in the wall insulation can degrade the R-value of the retrofit by 7% to 40%.) Siding was replaced to look as good as new and energy bills were reduced by as much as one-half. However, the customer often chose the low bidder. In order to keep costs low, the contractor drilled one hole per cavity (not a manufacturer-approved procedure), did not probe every cavity, and ignored voids and settling. These cheap jobs have provided high quality insulators with a lot of business in the 1980s.

(continued from previous page)
house has a forced air distribution system for heating or air conditioning.

With major insulation completed and air leaks sealed everywhere except in the basement or crawlspace, another blower door reading is taken to evaluate the extent of remaining air leakage. The intermediate blower door tests follow a simplified procedure with a single 50 Pa reading being taken. Any further air sealing is carried out with periodic blower door checks to ensure that the cost-effectiveness and tightness limits are not being violated. A tendency for excessive air tightening has been observed by several weatherization programs when crews perform blower-door-aided air sealing. To avoid this, the Minnesota program established two criteria for air sealing: stop air sealing when it is no longer cost effective, and stop before the house is made so airtight that moisture and air quality may pose hazards. (The working guideline is that 1,200 cfm_{50} is "tight enough," unless there are more than five people living in the house. Above that, add 225 cfm_{50} per person.)

For houses with forced-air distribution systems, a pressure-balancing procedure is carried out at the completion of the air-sealing work. This is performed to ensure that the operation of the air distribution system does not lead to excessive differences in air pressure in any part of the house. If the system is unbalanced, simple diagnostics indicate the way to correct the problem (by sealing ducts or other fixes).

Any additional retrofit measures noted by the energy advisor, such as rim joist insulation or crawl space insulation, are then performed. Finally, if the house has natural draft combustion equipment for heating and/or hot water, a simplified backdrafting test is conducted. Depending on the findings, corrective action is taken or referred to the heating contractor. At the end of the visit, the house tightness is measured using the blower door and recorded by the crew. If possible, a final infrared thermography inspection is done. This is the most important quality control check point.

The final inspection is performed by the agency inspector and, in some cases, in conjunction with the state monitor. It is the role of the inspector to review the work orders and crew report to determine what has been done to the house. A blower door test is carried out to verify the final leakiness of the house. During the walk-through inspection, visible measures such as window repair or installation are checked. An infrared inspection is performed, when possible, and duct pressure balancing and backdrafting tests are also performed. The inspector also reinforces conservation education with the residents, as listed in the advisor report form.

Results

Nine local non-profit weatherization agencies, representing both metropolitan and rural regions, participated in the project. During the summer of 1988, the agencies weatherized nearly 200 low-income houses using the enhanced procedures and protocols. In order to determine the cost-effectiveness of the procedure, a PRISM analysis of the fuel bill data for the 1987–1988 heating season was performed on each of the houses. The average pre-weatherization normalized annual consumption (NAC) was about 1,400 therms per house. This represents an annual fuel bill of $688 (assuming a natural gas cost of $0.50 per therm). The results of the air-sealing work found an average 36% reduction in air leakage per house, going from blower door readings of 2,400 cfm_{50} at before weatherization down to 1,600 cfm_{50} afterwards. The average cost per house for the crew, audit, and inspection work was $1,300. Total costs including administration and overhead were $1,600 per house. This is equal to the current DOE guidelines for low-income weatherization.

Final analysis of the post-weatherization heating season and determination of the cost-effectiveness of the project were performed during the autumn of 1989. The average reduction in natural gas use was calculated to be about 250 therms per house, for a savings per house of 18%. This is about two times the savings per year found by the Minnesota statewide utility bill study of standard weatherization programs performed in 1986. This reduction in gas use represents a dollar savings of $126 per year per house and a simple payback of 10 years. Using total program costs (including administration and overhead), the payback is 12 years, or half the simple payback of total program costs calculated in the 1986 study. The final report of the project will be available from the University of Minnesota in the winter of 1990.

Acknowledgement

The M200 Project is a joint demonstration project performed by the State of Minnesota Department of Jobs and Training, nine local non-profit weatherization agencies, and the University of Minnesota Underground Space Center and Minnesota Cold Climate Building Research Center. Funding for the project is provided jointly by the Department of Jobs and Training and an Exxon Petroleum Violation Escrow Grant from the State of Minnesota.

Typical Costs

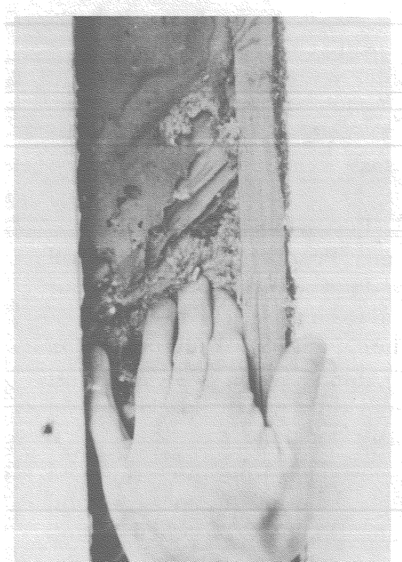
Here are typical costs in Minnesota to blow 800 ft.^{2} of sidewall insulation. The estimate is for a two-person crew, which should be able to do the job in a day.

16 person-hours @ $15/hr.	$240
800 lbs of cellulose (1 lb./ft.^{2} = 3.5–4 lb./ft.^{3})	$100
Supplies	$50
Overhead	$150
Total	$540

In Minnesota, the typical gas price is 50¢/therm and furnaces typically are 65–70% efficient. So 800 ft.^{2} of wall insulation saves $50–80 per season on R-value alone (assuming an improvement of R-4 to R-15). Infiltration savings can add another $0–40 per season depending on the house and how well we do our job.

Once we've garnered the infiltration savings from the insulation, we figure further air sealing is cost-effective as long as we reduce infiltration by at least 100 cfm_{50} for every $40 worth of work. (Cost-effectiveness criteria is 10-year simple payback.)

Our working standard is "no voids, no bypasses." To meet this standard, we blow the wall insulation so tight that it does not allow any air movement. We also seal any accessible bypasses with the barrier method. An infrared scan, with the blower door maintaining a 20 Pa pressure difference for 15–30 minutes, ensures that we accomplish this. How tight is tight enough? With cellulose, infrared thermography shows bypasses at less than 3.5 lb./ft.^{3} density but we have blown off walls at over 4 lb./ft.^{3}—we've actually forced the indoor wallboard off the framing with that much pressure. For mineral wool, we can blow at 4 to 6 lb./ft.^{3} density. We blow fiber glass at 3 lb./ft.^{3} density but still see some air flow. Blowing at these higher densities does not greatly affect the R-value of the insulation. Increasing from 2.5 up to 4 lb./ft.^{3} density of cellulose or 3.5 up to 6 lb./ft.^{3} density for mineral wool results in only a 7% increase in the apparent thermal conductivity. The effect is even less for fiber glass. Figure 2 shows how insulation density influences the apparent thermal conductivity. These numbers do not reflect the possible increased savings due to air infiltration. In an actual house, we may be giving up $10 per year in conduction savings to gain $100 per year in infiltration savings. In general, we prefer using cellulose on most of our jobs because it gives us the biggest reductions and costs less.



Mark Freeland

The big danger of the method is to blow the wall right off the studs. Turn the problem into an opportunity—get a feel for what's "tight enough."

Counting bags helps us estimate the density, but the true test is by finger; only direct training and experience can teach the optimal feel.

Drilling and Filling

The following discussion describes the procedures we use for cavity fill insulation. The methods were developed for the heating-dominated climate of Minnesota and may not be completely transferable to other climates. This checklist is intended as a supplement to in-field training.

Before starting the work, we do the following:

- Pressurize the house at 50 Pa and take a preliminary reading of the cfm_{50} flow and run the test with all inside and basement doors open.
- Ask the homeowner about the cost to heat or cool the house and whether any special problems exist such as ice dams, drafts, pipes freezing, cold rooms, condensation, and roof leaks.
- Visually inspect the interior for holes in the plaster, loose paneling, back-plaster walls (which contain two layers of plaster lathe, one in the middle of the cavity), pocket doors, missing wall sections under the kitchen sink, and any other places where insulation might blow into the house. Note the location of electrical fixtures.
- Check for unvented space heaters and any gross furnace safety problems. We do not want to start work until these are fixed. Tightening a house with an existing health and safety problem is bad business; dead customers provide lousy word-of-mouth advertising.
- While looking for possible trouble spots, note the location of major wall leakage sites, i.e., the ceiling-to-joist connection at the porch roof, flat roof connections, plumbing chaseways on an outside wall, slanted roof cavities crossing joist volumes, and any place the air barrier cannot be inspected and may be discontinuous.

Now insulation can begin. For filling walls, we prefer the tube-fill method over the two-hole-reducer method

Mark Freeland

Jim demonstrates how to drill up at an angle, bracing himself against the torque of the powerful 2 ⅛" drill.

(as described above). In the 1950s, cellulose insulation was introduced and the one-hole tube-fill method was developed as a cheaper alternative that gave a good job without voids or settling. This is how we do it:

1. Choose which pieces of siding must be removed to give the quickest production, i.e., the fastest access to the most full-height wall cavities. We prefer to drill

Dealing With Siding

If we cut, drill, or break any siding, we replace it. This is a description of how we remove and reinstall siding. Of course, hands-on training has no substitute.

1. Before we describe various siding types, it's important to know how to drill from the inside. This is the fastest method if the house is empty. The method is also a useful backup for other methods in trouble spots.
   - Have the residents clear all outside walls 4' back. Prepare them for intrusion and dust. They will also be responsible for the light sanding of patches.
   - Mask contents of house with 2 mil poly. Extra care should be taken on electronic equipment such as stereos, VCRs, and home computers.
   - Drill 2" holes in the plaster with a carbide-tipped hole-saw. Don't cut into the same lath on both sides of the stud. This prevents cracks from showing up later. (Drill two 1-1/4" holes per cavity and use the old-timer's two-hole procedure with a trickle feed for cavities too narrow to tube fill, e.g., back-plaster.)
   - Fill the cavities as normal. Unless probing proves it unnecessary, the exterior run of the partition walls should also be filled as a bypass preventer.
   - Patch the base coat as soon as the driller is free. We mix Structolite and Durabond 45 half-and-half, stiff enough not to sag. Never put on too much. Top coat with joint compound or spackle.

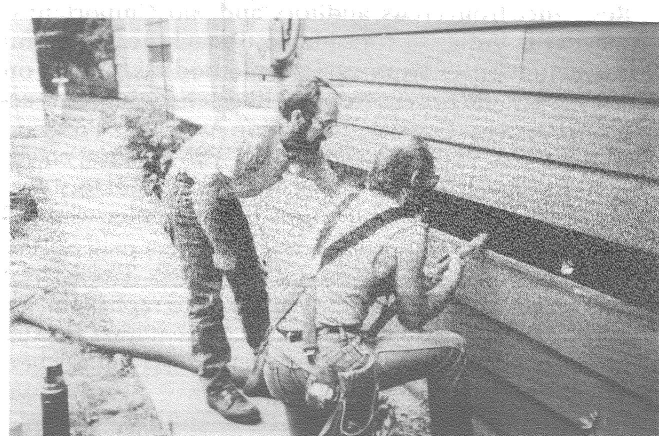
Mark Freeland

Finishing touches: plastering over a bit of fiber-glass batting forms a plug and restores the wall to its original shape.

   - Roll up poly and clean up residual dust.
2. On wood lap siding, start in the middle of the piece if the ends bind. Use a thin-edge prybar or sharpen yours to slide between laps and lift out nails. Remove nails from two courses and drop out the lower board. Tack the board on the house right there or put it in a safe place nearby. Replace any broken pieces with primed, new siding. Renail with galvanized or aluminum 6p–7p box nails.
3. For wood shakes and shingles, score the paint vertically on each shake to be removed. Pry loose with a prybar and pull down. Only take off the shake over a drill hole. Replace by tapping up and face nail with shake nails or 4p galvanized box nails.
4. With aluminum, steel, or vinyl siding, start either at a corner or if it has continuous corner ports, a seam. Pull open the J-lock at the bottom of the piece above the one you're removing. Use a zip tool to start the process. A clothes line with a knot at one end can be pulled along inside the lock-seam to open the siding without bending it. Vinyl is real easy but shouldn't be done in cold weather. Old oxidized aluminum is harder. (One local agency uses a metal saw to cut the top of the chosen piece just wide enough to accept a colored plastic strip that covers the gap.) Remove the nails from the top of the siding and push it down; the J-lock should open, and the siding will come off. Be careful not to bend the siding, and tack it on the wall right there to protect it. When reinstalling siding, snap it back on the bottom and put nails through the same hole to center it where it was before. Use the zip tool to rehook the J-lock.
5. Cement asbestos shakes are either face-nailed or blind-nailed. Face-nailed are easy. Pull the nails out with pliers or end cutter. Be careful not to drop them. Blind-nailed are more difficult to do. Avoid blind-nailed shakes until you're more experienced. Pull the nails from two runs. Remove the blind nails from the top of the lower shake with the prybar. Don't force it. If the house is back-plastered or full of firestops, it's cheaper to drill and patch the plaster from the inside. Never drill or saw shakes (to keep asbestos out of air and lungs). Always wear a respirator. If there is any question that the asbestos might be friable, call in an asbestos specialist and have it tested before working on it.
6. We break a 2 ¼" hole through the stucco with a rock pick, air chisel, or rotary hammer. Pry open wire lath and drill and fill as usual. A licensed stucco contractor patches our holes. When the patch has to be perfect, we drill two 1 ¼" holes per cavity and use the old-timer's two-hole procedure.
7. With masonite lap siding, don't attempt to pry it off. Just drive the nail head through with a punch. Spackle the old nail holes when you replace the siding.
8. For asphalt shingles, remove nails from three runs and remove shingles like siding. Fold the tarpaper back and drill through the sheathing. Do not do this when it's hot.
9. If you can't patch built-up roofing, don't touch it. Hire a roofer to open and close for you or do it from the inside.
10. Vertical siding, 4x8 plywood or masonite sheets, brick veneer, etc., should all be done from the inside.

holes near the floor to minimize ladder work and hassle with the tube. The house design, however, determines the easiest approach.

2. Remove wall siding. Do this carefully, since the goal is to return the house to its original condition or better. It is a false economy to save $300 on installing the insulation by destroying a $3,000 siding job. (See box.)
3. Drill through the sheathing with a low-speed ½" drill (400–600 rpm) using a 2 ⅛" self-feed bit or equivalent. Angle the hole up in the direction the tube will go. This allows easier insertion of the tube. If the hole is in the middle of the cavity, angle up and down. Brace yourself because you will take a hit if the bit suddenly binds. The larger the bit and the greater the speed and torque of the drill, the greater the risk of sending yourself airborne. Take care not to plunge blindly with the drill bit; do not drill into outlet boxes or wiring. Use non-conducting ladders and GFCI protection. Do not drill in the rain. The most highly skilled person on the crew should be the driller.
4. It is the driller's responsibility to open holes and find all blockers that are either side-to-side in the wall or close to the hole. Use a wire to probe each hole. The hoser's job is to find all blockers up and down and to tell the driller to make any additional openings as needed. The hoser uses the tube to probe while filling each cavity. Together, they probe 100% of the wall cavities. Sometimes, the driller may leave easy holes for the hoser to drill while waiting for larger cavities to fill.



Mark Freeland

Using the hose to plumb the cavity.

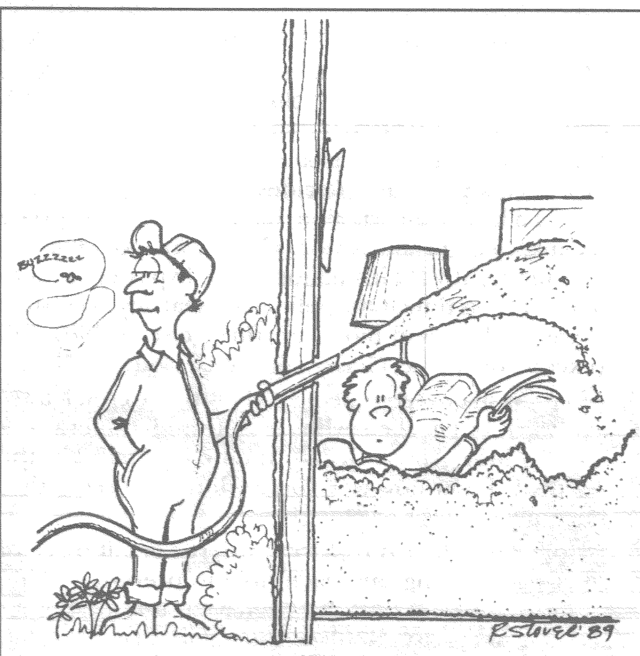
5. We try to start filling within a half-hour of arriving. As one of the crew begins to remove siding, someone should be setting up the blower. The blower must be in good working order. Find adequate power for the blower: either 1–3 (depending on the brand) 20-amp circuits, a generator, or a self-contained truck-mounted blower. Typically, there are two types of blowers: through-the-fan, cellulose-only blowers and positive air-lock, all-fiber blowers. On old-style cellulose-only blowers, start with the air gate wide open. For the truck mount or positive-displacement portable blower, start with the feed gate totally closed and set the air

Karina Lutz

The homeowner looks on as Gary adjusts the settings on the blower for the hoser on the roof.

to a level where it will not blow open the wall (this, unfortunately, must be learned by trial and error). Add a switch to the feeder if the blower cannot be run in the air-only mode. For both blowers, always start with the hose clean and, whenever there is a clog or other problem, go back and clean the hose. We recommend a 1¼" internal diameter vinyl tube for quick and clean work.

6. Start in a normal, 2x4, eight-foot-tall wall without a lot of windows or busy details. Put the tube all the way into the cavity until you actually feel the blocker at the end. Verify that you have 8' of tube into the 8' cavity. Turn on the blower and time the fill. Cellulose should be moving fast, crackling through the tube.
7. For the cellulose-only blower, pull the hose out one foot at a time as the material packs up and stops flowing. Close the air gate to pack tight an 8' cavity in 2–4 minutes. Before the cavity packs, there is time for



More isn't necessarily denser.

the operator to drill 3 or 4 more holes nearby or to start a second cellulose-only blower. Our crew does not stand around and wait for cavities to fill.

8. For the positive-displacement blower, a different procedure is used. As the cavity packs tight, the blower will continue to supply material at the same rate even though much less material leaves the tube. This lowers density in the wall and clogs the hose. Therefore, as the cavity fills and the wall starts to pack tight, switch off the feeder and allow the air to run. This prevents excess material from building up in the hose as you finish the stud run. Open the feed gate slowly to pack the 8' cavity in 90 seconds to 2 minutes.
9. Start with three 8' cavities, 16" on center, and one 30 lb. bag of cellulose. If done correctly, a 30 lb. bag should run out just before completion of the third run. The holes should be so tight that your finger will not go through. The target is 1 lb./ft.^{2} of gross wall area or 3.5–4 lb./ft.^{3} density. As you go, you should feel air coming out of the empty hole of the next cavity but you should not feel air exhausting from the cavity you just filled. Go back and pack more insulation in if the cavity is leaking.
10. If the cavity does not fill up after 4 minutes, shut down and go inside to see where it's going. Never run over 4 minutes without a look. Either you're filling up a bedroom (bad public relations) or, hopefully, a hidden bypass.
11. As the hoser is filling the big areas first opened, the driller proceeds to open the detail areas around windows and potential hidden bypasses.
12. Any hidden connections that have not been probed by the tube must be opened and examined. This includes adding roof vents for access to side attics, removing ceiling boards on enclosed porches, dropping soffit panels, lifting fascia, removing shingles, drilling holes inside where siding cannot be removed, and lifting stair treads.
13. After discovering a bypass, the driller chooses the best access point and decides how to block off this one-of-a-kind construction detail. The appropriate fix might be foam, a vent chute, tin, poly bag, or blowing tight with insulation. Attic bypasses are also sealed at this time. Our policy is to seal any accessible bypass with a rigid block; anything else we blow full (except, of course, chases around combustion flues).
14. After this stage is complete and before the crew leaves, the work is checked with an infrared camera and blower door. Any faults are then corrected. Let the residents know how well you've done and see if they have any requests or complaints.
15. Before the siding is replaced, insert a small piece of fiber-glass batting into each hole to prevent wicking of moisture from outside. We have found that plugs are not necessary. Replace the siding and clean up the job site, both inside and out.
16. The final step is to check for house and basement depressurization. Check for negative pressures produced by exhaust fans or the HVAC system, which can lead to spillage and backdrafting of combustion appliances. Take appropriate actions to balance pressures. For further details, refer to the MWX90 Training Manual to be published soon by the University of Minnesota Underground Space Center.

Opportunities and Obstacles

Obviously, if the cavity is not leaky, it will not tighten with filling. Very tight construction, like airtight-drywall-assembly walls, do not release air, and voids occur when air back-pressure prevents the flow of material. In tight, new construction, we prefer fiber-glass batting. High density blowing works better on leakier houses. We have found that the houses that show the greatest impact are those that have a pre-weatherization blower door reading (in cfm_{50}) that is greater than the above-ground surface area of the house (in ft.^{2}).

Settling of insulation is not an issue at 3.5 to 4 lb./ft.^{3} density; blowing open the wall *is*. The higher air pressure required to pack insulation tight enough to stop air leaks is sometimes too much for wallboard and paneling. This is disastrous occasionally and will continue until the crew learns vigilance. If you crack a wall, please do not continue to fill the entire room. Cleaning and patching are unfortunate facts of life with wall filling, but need not be a part of every job. We strongly encourage proper training in the field.

Resistance from crews, auditors, and, most importantly, managers is the most formidable obstacle to successful implementation of an integrated method based only on cost-effective measures. Nobody likes changing old, accepted practices. The Weatherization Assistance Program rule that limits the proportion of labor to material cost is seen as another obstacle. Incentives and mandatory performance testing may be the only ways to collect the full benefit of the new method. Crews should get paid for the infiltration work they do. We test every job. The cost of blower door testing with infrared thermography is more than made up for with time saved by determining the unnecessary measures and by preventing major faults when doing the necessary ones.

Cavity fill insulation can reduce air infiltration. However, these reductions will not be realized if a leaky cavity is filled with low-density insulation or if voids are left behind. Indeed, we have had reports of increased air change rates after wall insulation, perhaps due to the holes drilled. Good quality control is an essential part of the process. ■

Endnotes

This article was written in part for the *MWX90: Minnesota Model Low-Income Weatherization Program for the 1990s Training Manual.* The work is funded by Exxon oil overcharge monies. Principal investigator for this project is Lester Shen at the Underground Space Center, University of Minnesota, Minneapolis, MN 55455. Inquiries should be made to him. A training video will soon be available through The Energy Conservatory at (612)827–1117.