Weatherizing Mobile Homes

While weatherizing between 400 and 500 mobile homes every year, The West Virginia Weatherization Assistance Program has gotten enough practice to practically perfect the art of transforming leaky, uncomfortable mobile homes into models of efficiency.

by Bob Scott and Lyn M. Bartges

West Virginia, in the heart of the Appalachian Mountains, is often thought of as a state with a lower than average per-capita income, so it comes as a surprise to most people that it has one of the nation's highest rates of home ownership. One of the answers to this seeming paradox is that low-income West Virginians tend to own and live in mobile homes. Typically, over 40% of the homes weatherized by the West Virginia Weatherization Assistance program are mobile homes, a slightly higher percentage than that for single-family, site-built homes. We weatherize between 400 and 500 mobile homes each year in West Virginia, and usually fewer than 10 of these homes are rental units.

Mobile homes often use more energy per ft^2 than site-built homes. They often have very low insulation levels, particularly the older models. Many of the mobile homes found in West Virginia were manufactured in the South and are ill equipped for the cold mountain winters. Fortunately, most mobile homes are very similar to each other, which can make the establishment of efficiency measures and standards fairly consistent and straightforward.

Weatherization program managers have long realized that to have a cost-effective program with significant energy savings, we had to evolve from our early practice of installing perimeter underpinning and wholesale window and door replacement to a more diagnostic whole-house approach to mobile home weatherization. I'd like to report that our approach has been based on scientific studies of possible measures and their energy savings. The truth is, we really just improved our practices by paying close attention to trends and advances made by leaders in the field throughout the country. Not without some growing pains, we tried to apply changing Weatherization program diagnostics, which were developed for use in site built homes and are a little better suited to them, to weatherizing a mobile home. Our evolution wasn't so much audit driven as audit justified. We let the engineers figure out the best thing to do; we focused on the best ways to do it.

Our approach to weatherizing mobile homes has five major components. They are

- cleaning, tuning up, repairing and occasionally replacing the heating system;
- repairing and sealing the ducts;
- insulating the roof cavity;
- insulating the floor; and
- air sealing the mobile home shell.

Heating Systems

The vast majority of mobile home heating systems in West Virginia are either electric furnaces or sealed-combustion natural gas or propane furnaces. These furnaces are generally centrally located in the hallway, in their own compartment, or in a closet. We also see some oil furnaces, an occasional heat pump, wood stoves—which are usually not UL listed for mobile homes—and the dread unvented kerosene heaters.

Usually, kerosene heaters are being used because the original heating system is inoperable or is too expensive to operate. We make every effort to repair, or if necessary replace, the original heating system to make it operable and affordable so that kerosene heaters do not have to be used. As part of our client education, we stress to the residents the potential health and safety problems associated with using kerosene heaters or any open-combustion heat source. We explain the potential moisture problems, the indoor air quality (IAQ) problems associated with incomplete combustion, and the fire hazards. We try to remove all

(left) Missing or badly damaged boots can be replaced to help air seal and increase the efficiency of the heating delivery system. *(right)* It is important to test the parts of an electric furnace. Many times, wires have been disconnected or improperly connected. This can pose a serious safety hazard.

kerosene heaters, or at least to have them stored in a place where they will be used only in an emergency, such as in a power outage.

Far too often, Weatherization heating system technicians encounter mobile home furnaces that have been neglected. The units rarely, if ever, receive routine seasonal maintenance. Often, air filters are dirty enough that they restrict air flow and drastically reduce the overall efficiency and performance of the system. All systems receive at least a tune-up and cleaning. A clean and tune involves a visual inspection that is often very revealing, testing procedures, and cleaning and adjusting to improve the safety and efficiency of the system.

The visual inspection includes checking the burners for dirt, debris, and misalignment; looking for soot or evidence of flame roll-out; and inspecting the heat exchanger and vent system. Steady-state efficiency testing and CO testing are done with a combustion analyzer. After cleaning and tuning the furnace to maximum efficiency, we test the pilot safety control and the high-limit switch. Filters are replaced, and additional filters are left with the client. Smoke and CO detectors are installed.

Duct Repair and Sealing

Making the heating unit safe and efficient, while important, is only part of making the entire heating system as efficient as possible. The condition of the delivery system will define the amount of useful heat that is actually delivered to the home. Most often, single-wide mobile homes have only a single main duct run booted into registers in a straight line under the center of the floor. If the floor joists run lengthwise in the home, the duct line runs in a joist cavity just under the floor. If the joists run perpendicular to the long walls of the home, the main duct line runs under the joists. The joints between the main duct line and boots to registers are usually fairly easy to access from inside the home at the registers. Other seams may be more difficult to access from underneath the mobile home. Usually mobile homes do not have ducted return systems; instead they take their return air from the home through a large vented grille in the furnace closet.

The plenum is a major area of air leakage. Too often when the mobile home is transported, movement causes the furnace plenum and the main duct run to separate, causing heat from the furnace to flow directly into the belly board instead of the ductwork.

We test ducts both by visual inspection and with a blower door, a digital manometer, and a pressure pan. Visual inspections can be done, at least in part, from the inside of the home with inspection mirrors and flashlights. This procedure isn't difficult, but it does take a little practice for the technician to become proficient. Quite a few mobile homes have torn belly boards, and the ducts can also be accessed and inspected from underneath the home. This is especially useful for finding leaks that are farther away from the registers; it can be difficult to see these leaks using lights and mirrors from the register openings.

When technicians are inspecting the supply ducts for air leaks and blockages, the first place we instruct them to look is at the seams in the system. Branch ducts, if present, and crossover ducts in double-wide homes, often leak at their connection to the main duct. Other obvious leaks are at the connections of the duct to the boot and of the boot to the floor. All registers should be checked to see whether they are functioning properly and are unobstructed. Registers should be replaced when necessary. Missing, loose-fitting, or blocked ductwork should be repaired.

Carefully inspecting the end of the main duct line past the last registers is another critical task. We have had several cases where the duct line was left open to the underbelly cavity. To fix this problem, we seal and insulate at the end of duct runs with either two-part foam or a patch

of fiberglass insulation outside a cap of sheet metal sealed to the main duct with mastic and fibered tape.

A much harder place to inspect and repair, but a critical location for leaks, is the connection between the furnace plenum and the main duct run. A leak that is that close to the furnace, where duct air pressure is greatest, can be an enormous waste of energy. It can also cause pressure imbalances and make it difficult for sufficient conditioned air to reach the far ends of the duct run. Unfortunately, the best way to access and repair the leak is usually by going underneath the mobile home and cutting through the underbelly and the duct bottom from below. You need to be very cautious when examining the connection, since there are several seams that may leak.

Get Out the Blower Door

To better assess the connection between the furnace and the main duct run, this area can be tested with a digital manometer and pressure pan in conjunction with a blower door. Here's how we conduct our pressure pan testing procedures.

Make sure there are holes or tears in the underbelly so that leaks in the ducts are to the outside and are therefore detectable. Generally, there are enough tears to get accurate tests but, if necessary, slits can be cut in the underbelly close to the main ductwork.

Install the blower door and set the house to winter conditions. All windows should be closed tightly, inside storm panels (if any) installed, and exterior doors closed. Open all interior doors.

Make sure the furnace is off and no exhaust fans are running. Remove the furnace filter and remove all floor registers.

With the blower door running and the house depressurized to 50 Pa, begin pressure pan testing at each register. We recommend always beginning the testing process at the register that is at the end of the duct run, farthest from the furnace.

Place the pressure pan completely over the register opening to form a tight seal. Allow enough time for the reading on the digital manometer to stabilize; record the reading. The reading gives an indication of the severity of duct leakage to the unconditioned area under the home. If ducts are perfectly sealed with no leakage to the unconditioned space, the reading will be zero. The higher the pressure pan reading, the more connected the duct is to the outside.

The goal is for all readings to be 1 Pa or less. If all readings are under 2 Pa, no additional sealing is required unless leaks can be easily detected and sealed, such as at a boot. A reading greater than 4 Pa indicates a breach in the duct system that needs further inspection and treatment.

We test the area where the furnace plenum connects to the main duct line by isolating this area. We seal off the duct run at the closest registers on either side of the furnace by stuffing loose-fill insulation in a trash bag to make a pillow that will conform to the size and shape of the duct. On the testing side, seal the duct run with the pillow on the far side of the register, right next to the register. On the nontesting side, seal the duct run on the furnace side of the register, stuffing the pillow as far as you can reasonably reach from the register toward the furnace. The idea is to have as small a duct run as possible around the furnace. Take a pressure pan reading. A reading of 4 Pa or more indicates that further inspection and repairs of the duct connection need to be made.

Along with a visual inspection, a pressure pan test is performed.

Rich Courtney, West Virginia Weatherization program specialist, takes a blower door reading in a mobile home to see how much air leakage there is. Rich has over 20 years' experience with retrofitting mobile homes and helped to develop a mobile home model used in statewide and national trainings.

Getting to Sealing

Before you start to seal the ductwork, it should be vacuumed and cleaned. If necessary, use hot soapy water to clean the area. It may even be necessary to use a cleaning solvent, such as a paint thinner or denatured alcohol, to get rid of any greasy buildup in the system and to help ensure that the duct sealing material will adhere properly and last a long time.

Seal all holes and leaks. Mastic and embedded fibered tape must be used to seal any duct leaks from the living space. Two-part foam can be used to seal leaks beneath the home. The following joints should be inspected and sealed when necessary:

- joints between the furnace and supply and return ducts;
- joints between main and branch ducts; and
- joints between registers and the floor, wall, or ceiling to which they are attached.

When there is no ducted cold-air return system—which is nearly always—the interior doors must be undercut at least 2 inches from the floor, and the furnace closet door must be ventilated with no less than 1 ft^2 of free air space, which

typically means a grille of at last 2 ft^2. If the joist cavity of an older mobile home serves as the cold-air return system, seal off the system from the living space and treat it as described above.

Roof Cavity Insulation

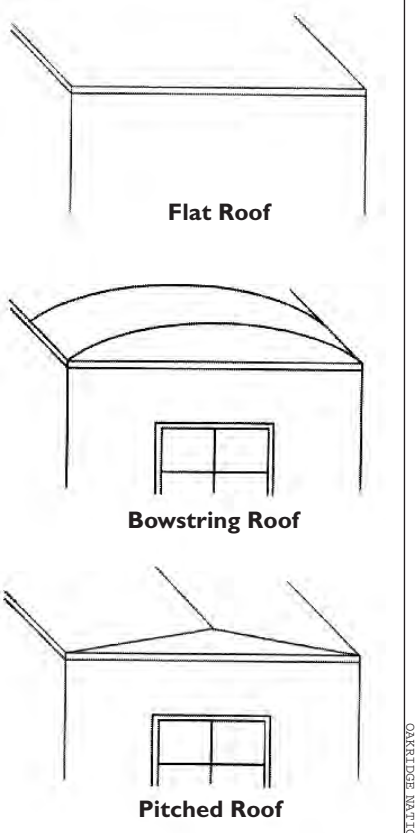
Adding more insulation to the roof of a mobile home is one of the most obvious—and most cost-effective—ways to increase the energy efficiency and extend the life of the home. Many of the homes we work on, especially models that were manufactured in the South before 1976, may have only 1 inch of insulation in the roof cavity. When we add insulation, we use blown fiberglass instead of cellulose, since blown fiberglass is less likely to absorb moisture. It is also less likely to react with the metal roofs of trailers than is cellulose that is treated with certain chemicals.

There are three basic types of mobile home roof construction: pitched roof, flat roof, and bowstring (see Figure 1). The flat roof has the least insulation, but since the ceiling and roof are usually separated by 2 x 6 framing, a flat roof will not have a large enough cavity to add a substantial amount of insulation. A bowstring roof can be 8 inches high at the center and will usually have a larger cavity to hold additional insulation. Pitched roofs can have as much as 2 ft of space between the ceiling and the roof. In West Virginia, many mobile homes have bowstring roof construction. In this type of construction, the roof edge is usually attached with screws or staples to the top edge of the walls and not to the trusses. No matter what the roof construction, before you begin to install any insulation, you must inspect the roof to see if any repairs need to be made; Insulation loses thermal resistance and can cause other problems if it becomes wet.

Insulating mobile home roofs can be more difficult than insulating the roof of a site-built house because it is so difficult to see what is between the roof and the ceiling. One way to inspect this cavity is to drill a 3- or 4-inch inspection hole in the ceiling of a closet or pantry, as near to the center of the trailer as possible. Through this hole, you can inspect the existing insulation and see if there is room in the cavity to add more.

There are several accepted ways to insulate the roofs of mobile homes. Since we mostly encounter bowstring construction, we generally insulate roofs using what is called the edge lift

Figure 1. Typical Manufactured Home Roof Configurations



method. To add insulation using this method, remove the screws from the j-rail along the side of the mobile home you are going to work from. This can be done from the roof, or using a ladder or scaffolding from the side, whichever is easier. After removing the old gutter, unscrew the roof edge and loosen the gable end so that you will be able to lift the roof. Next, remove the staples along the edge of the roof. Make sure you clean off the old caulk as best you can, so that when you replace the edge and caulk it back down, the new caulk will have a clean surface to adhere to. Lift about 8–10 ft of the edge about 4–6 inches and insert a wooden wedge block made out of either a 2 x 4 or 2 x 6 to prop the roof cavity open. At this point, you can get a better picture of the existing insulation in the cavity.

With the roof propped up, slide a 10-14 foot rigid tube with a 2-inch diameter through the truss space to the other side of the trailer. Use plastic electric conduit, since conventional PVC pipe used for plumbing can build up static electricity and shock the workers. With the tube as close as possible to the edge of the trailer on the other side, blow fiberglass insulation into the cavity, pulling the tube toward you as you hear and feel resistance with the flow tube. Remember: You are not dense-packing the cavity and you don't want to fill it so much that you can't get the roof back down. (Most people learn this the hard way.) Work your way along the length of the trailer, filling each truss cavity. Set the insulation machine on high but as you get within 3 ft of the edge, cut the air back to prevent blowback and to keep the fiberglass from blowing in your face. Workers should wear either half- or full-face respirators, not just dust masks. Seal the roof edge back down, using putty tape, caulk, and screws. Make sure you seal the back of the new gutter with caulk. Extend the new gutter 4-6 inches out from the gable ends to help keep rain away from the bottom of the mobile home.

Floor Insulation

The floor is one of the major structural parts of a mobile home. Repairing, air sealing, and adding insulation to the floor cavity will extend the life of the mobile home and increase energy savings.

As with roof construction, there are different types of floor construction in mobile homes. Floor joists may be parallel (lengthwise) or perpendicular (crosswise). In parallel construction, the joists run lengthwise in the trailer and the main heating duct is flat against the floor between the joists. Any existing insulation and belly board material is attached flat to the bottom of the joists. In perpendicular construction, the joists run across the width of the trailer and the underbelly sags in the center since the insulation and belly board are attached only at the perimeter. The main heating duct is enclosed within the insulation.

(left) After the duct is cleaned, fibered tape and mastic are used to air seal. A paint brush is the easiest ways to apply the mastic to the duct. *(right)* The end of the blow tube should be cut at an angle to help the tube slide over the existing insulation and past any obstructions in the cavity.

There are several ways to insulate the area under the floor. The type of construction, and whether or not the underbelly is accessible from underneath, will determine which method is best. In West Virginia, we mostly insulate the floor from the crawlspace underneath the mobile home using blown-in fiberglass insulation.

Preparation is important. Before you begin installing insulation, inspect the floor and the belly board underneath. Make any necessary repairs. A ground vapor barrier of at least 6-mil black plastic should be installed under the mobile home. This will not only help to prevent ground moisture from contacting the structure, but it will also make it easier for the workers to lie on the ground and move around. Before insulating, you should also inspect and repair any ductwork, so that insulation does not fill the runs. Note where the water lines are located, and check to see whether there are any leaks.

For both types of floor construction, start at one end and cut a row of access holes in the belly board so that you can insert the blower hose into the joist cavities. If the floor joists run crosswise, cut your holes near the center of the trailer. Usually you will be able to snake the flexible hose to each of the long edges of the home from holes along the center. If the floor joists run lengthwise, cut a row of holes into each joist cavity across the belly. With either construction, fill the cavity from one direction and then from the other. Make sure to fill the entire cavity without leaving any voids. Again: You are not dense-packing the cavity; fill it only until you feel resistance with the flow tube.

A worker blows fiberglass into the cavity of the mobile home roof. Note the 2 x 4s used as wedges to hold the roof cavity open. A small amount of blowback can be seen.

Once the cavities are filled, you must repair all of the holes that you cut, to form a continuous underbelly. Cut a patch of belly board material that is slightly larger than the hole; spray an adhesive on; and stitch staple the patch, using a stitch stapler. (The staples are installed about 1 inch apart, and appear to be stitched together, hence the name.)

Air Sealing the Mobile Home Shell

Air sealing a mobile home is more straightforward than air sealing a site-built house, because we are usually dealing with a simple rectangular box, with four walls, a ceiling, and a floor. Defining the air and thermal boundary is relatively simple. We always use a blower door to identify and seal air leaks, and we have set our air sealing target at 1,500 CFM_{50}. This minimum airtightness standard increases some if there are unvented space heaters that will not be removed, or if there are many people and/or smokers in the home. Likewise, we may tighten a home to below 1500 CFM_{50} if it is all-electric, has a floor area of less than 720 ft^2, and shows no sign of IAQ problems.

We know that certain locations are notorious for leaking air. It may come as a surprise to some that doors and windows are not among them—although many doors and windows do need to be repaired or replaced. The notorious areas include

- the duct system;
- a torn underbelly;
- the interior wall that frames a water heater closet that can be accessed through an exterior door;
- the plumbing under the bathtub, sinks, and especially behind the washing machine;
- electric service panel boxes;
- the areas around electrical receptacles, light fixtures, exhaust fans, room air conditioners, and flues; and
- damaged doors and windows, and all jalousie windows.

Initial blower door tests vary greatly. Occasionally a mobile home is already under our 1,500 CFM_{50} target. We will still check for large leaks in the shell, although probably none exist, seal any duct leaks, and make sure that there are

(left) To fill the outer area of the mobile home floor, a muffler pipe is attached to the flexible hose. The natural curve of the pipe makes it easy to rotate the pipe in the cavity to get maximum fill. *(right)* Batt stuffing is one way to reinsulate the walls of mobile homes. Remove the bottom two rows of screws, and you can stuff the insulation into the cavity using a strong, flexible plastic stuffer.

no significant air leaks into the roof cavity or in the floor.

We go through the same steps when we air seal a leakier mobile home: address large shell leaks, duct leaks, and significant air leaks into the roof cavity or in the floor. We repair tears in the underbelly after duct sealing is completed. Then we normally insulate the ceiling and floor. Although neither area is dense-packed, the CFM rates are usually lower after these steps are completed. Then we do another blower door test and additional air sealing if we detect any leaks that are still cost-effective to seal.

The Final Roundup

Water heater tanks are routinely set to 120° F, or the medium setting, and insulated with a water heater insulation blanket with a minimum of R-5. All exposed hot water lines and the first 3 ft of cold water lines from the water heater are insulated. Low-flow showerheads are installed if the water flow exceeds 3 gallons per minute. One way to measure the flow is to mark the inside of a 5-gallon joint compound bucket in 1-gallon increments, run the shower into the bucket for a minute, and determine the flow.

The West Virginia WAP has recently started to perform electric baseload measures. Compact fluorescent bulbs can be used to replace any incandescent bulb that is on at least two hours per day. Refrigerators can be replaced with energy-efficient models if the replacement can be shown to have a savings-to-investment ratio (SIR) greater than 1. Old models can be metered. Or the manufacturer and model number can be entered into the database built into the Manufactured Home Energy Audit (MHEA) component of the Weatherization Assistant software to determine the SIR of a potential replacement (see "MHEA Comes of Age," *HE* Jan/Feb '04, p. 6). The West Virginia Weatherization program has established a bulk order purchase agreement with Whirlpool Corporation for refrigerator replacements. The arrangement includes delivery, setup, and proper removal and disposal of the old unit.

After cutting access holes through the belly board of the mobile home, push any existing insulation aside so that the flexible fill tube can slide the length of the joist cavity for a complete fill.

We are beginning to look into the feasibility of adding insulation to the sidewalls of mobile homes. Common sense and trial runs of the MHEA software program suggest that significant savings can be achieved on mobile homes with wall insulation insufficient for the size of the cavity, particularly on homes manufactured before 1976. One of our more progressive agencies has been loosening the siding and stuffing fiberglass batts into the stud cavities. This is a pretty labor-intensive technique. We need to determine if and when it will save enough energy to be cost-effective. We plan to use the recently updated and revised MHEA to analyze this issue.

In conclusion, we believe that a complete and effective weatherization job can be done on mobile homes if the crew is knowledgeable about the construction of the home and knows where energy waste is most likely to occur; and if the crew is willing to undertake the sometimes labor-intensive measures that are required. With appropriate renovation, older mobile homes can be even more energy efficient than newer models, and can provide many more years of affordable housing for our low-income customers.

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