Wisconsin Weatherization Field Guide

2018

WISCONSIN DEPARTMENT OF ADMINISTRATION DOA.WI.GOV

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Forward

The Wisconsin Weatherization Field Guide is a comprehensive guide to installing weatherization measures and verifying the quality of the work. The Field Guide is a tool for crew workers, energy auditors, and inspectors. The program's policies and administrative practices are identified in the Wisconsin Weatherization Program Manual.

The Field Guide started with dedicated weatherization crew workers determined to improve their trade and the services provided to their customers. It evolved from there to documenting those practices to share them with the rest of the weatherization network. The original Wisconsin Weatherization Field Guide was produced through a collaboration of the 2005 Weatherization Technical Advisory Group, Wisconsin Energy Conservation Corporation (WECC), and Saturn Resource Management.

Wisconsin is one of the national leaders in the Weatherization Assistance Program, and this guide represents the ongoing effort to continually improve our practices and procedures to deliver the best product to our customers.

Credits

The original document was developed in 2005 through collaboration between Wisconsin Division of Energy Services, Wisconsin Energy Conservation Corporation (WECC), Saturn Resource Management, the Technical Assistance Group (TAG) and various technical consultants.

Weatherization Works

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SATURN RESOURCE MANAGEMENT

WECC

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Chapter 1: Diagnosing and Sealing Air Leakage

1.1 Air Leakage Diagnostics Policy

Blower door testing is required on all buildings (except for mobile homes weatherized using the Mobile Home Measures List) before weatherization is started ("As-Is" test), and upon completion of all measures that effect building tightness ("Final" test). Conduct a pressurization test when hazards (such as friable asbestos, vermiculite or excessive, unmanaged pet waste) exist in the building. Follow the air- sealing protocol to complete air-sealing measures on the building. Always perform Zone Pressure Diagnostics Testing on buildings with an attached garage. Document the results of air-leakage diagnostic testing in the Diagnostic Workbook. Take corrective action when air- sealing activities have contributed to a safety hazard or an indoor air quality issue.

1.2 Diagnostic Overview

The testing described here will help to analyze the existing air barriers and decide whether and where air sealing is needed.

Air barrier materials in a building form the building's **pressure boundary**, while insulation materials form the building's **thermal boundary**. The location and condition of these barriers have a substantial effect on the insulation's effectiveness. Optimal energy savings and minimal heat loss are achieved when the two systems are continuous and aligned in direct contact with each other, with the air barrier positioned between the conditioned space and the insulation materials.

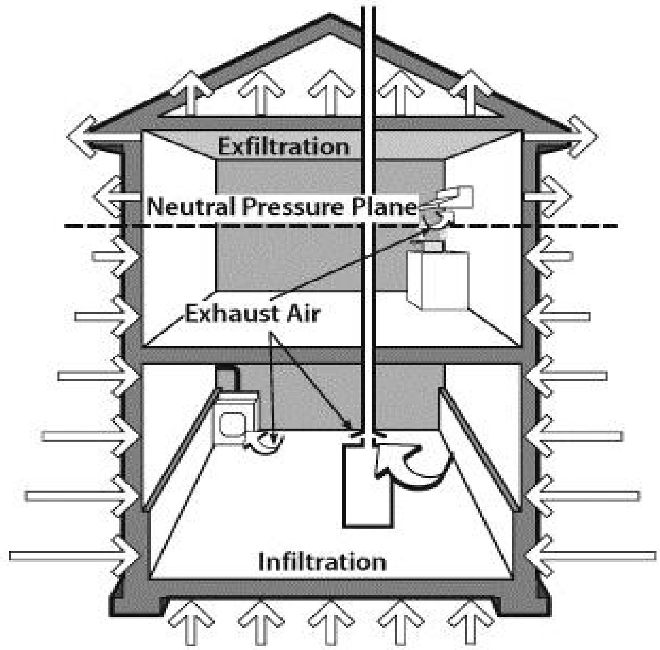
1.2.1 Air Leakage Effects

Controlling shell air leakage is a key to a successful weatherization job. Decisions made about sealing air leaks will affect a building throughout its lifetime. The following list highlights important ways air leakage effects buildings.

1. Air leakage can significantly change the net heat loss through a framing cavity.
2. Air leakage typically accounts for a significant percentage of a building's heat loss.
3. Air leakage can carry moisture into and out of the house, affecting the relative humidity indoors, potentially creating mold and moisture problems.
4. The location and amount of air leakage can affect the draft of natural-draft combustion appliances or fireplaces.
5. Air leakage provides ventilation for exhausting pollutants and admitting fresh air. However, air leaks can bring pollutants into the home as easily as they can expel them.

Building height and location, weather, and mechanical equipment effect air leakage in buildings. Strong winds may create a positive pressure on one side of a building, and a negative pressure on the opposite side. A forced air distribution system, a chimney, or an exhaust fan may create a negative pressure in the building.

Often air moves through a conditioned building as if the building is a chimney or smoke stack. Unconditioned air enters low in the building (infiltration) and conditioned air exits at the top of the building (exfiltration). This is called the **stack effect**. The area between the air coming in at the bottom (infiltration) and the air leaving the building at the top (exfiltration) is called the **neutral pressure plane**. Not much air leakage comes in or goes out at the neutral pressure plane. As the building is tightened at the bottom, the neutral pressure plane moves upward in the building. As the building is tightened at the top, the neutral pressure plane moves downward. For the best results, seal at both the top and bottom of the building.



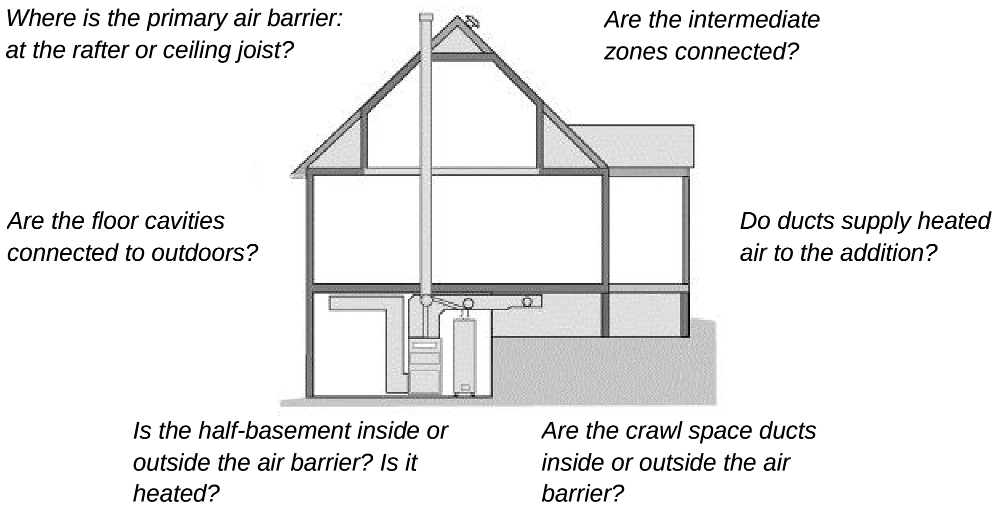
Air leakage concepts: When performing air sealing, it helps to understand the effects of exhaust appliances, the stack effect, and wind effect.

Air sealing may affect the natural draft of combustion appliances that are connected to a non-positive venting system. After all weatherization measures are completed, worst-case draft testing must be done on all buildings that contain natural-draft combustion appliances or fireplaces. The exception is that draft testing cannot be completed on wood heating systems or when the design of the appliance is not conducive to measurement of its draft. See *Worst- Case Draft Protocol in Chapter 5 – Section 5.6*.

1.2.2 Goals of Air Leakage Testing

Air leakage tests are the tools used to determine the location and amount of air leakage through a building's pressure boundary. Accurate tests allow fast, effective air sealing of the pressure boundary, while at the same time safeguarding indoor air quality.

A secondary goal of air leakage testing is to decide where to locate the air barrier when an intermediate zone, like an attic or crawl space, provides a choice of air-barrier locations. The ceiling is usually the thermal boundary of a building, for example, rather than the roof. However, at the foundation, the air barrier may be located at the first floor deck or at the foundation wall. Air leakage testing helps establish the best, fastest, or least expensive place to locate a functioning air barrier. Whenever possible, locate the air barrier to include plumbing and the air distribution system inside the pressure boundary. In most buildings, the



Questions to ask and answer before air sealing: Your answers help determine the most efficient and cost-effective location for the air barrier.

air barrier can be located at the concrete/block foundation wall. In a building with a rubble foundation, the floor deck may be the best place to complete a functional air barrier, especially if limited (or no) air distribution or plumbing is in the area. If plumbing is isolated outside the thermal boundary, take precautions to prevent pipes from freezing.

Air-leakage testing is needed because there simply is no accurate prescriptive method for determining the severity and location of leaks. Varying levels of testing may need to be performed to assess shell leakage. A simple blower door test may be sufficient for a simple home. Work can be completed more efficiently in complex buildings when zone pressure tests and infrared diagnostic tests provide added information.

It is most efficient and cost-effective to seal the large air leaks first. Chasing small leaks consumes time, and is not usually cost-effective. Refer to the "Air-Sealing Protocol" worksheet in the Diagnostic Workbook for guidance about air-sealing protocol.

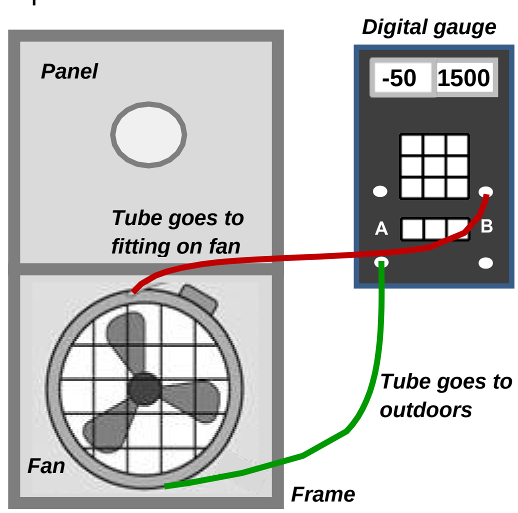
1.3 House Airtightness Testing

The blower door measures a home's leakage rate at a standard pressure difference of 50 Pascals. This leakage measurement can be used to compare air-leakage rates before and after air sealing. The blower door also allows the technician to test parts of the home's air barrier to locate air leaks. Sometimes air leaks are obvious. More often, the leaks are hidden, and the technician uses the blower door to obtain clues about their location.

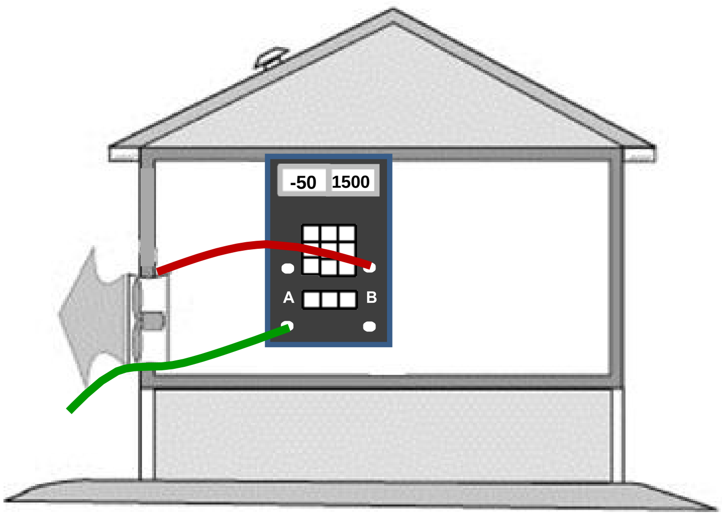
This section outlines the basics of blower door air-leakage measurement along with some techniques for gathering clues about the location of air leaks.

1.3.1 Blower Door Testing

The blower door creates a 50 Pascal pressure difference across the building shell and measures airflow in cubic feet per minute at 50 Pascals. This provides an objective measure of the leakiness of a building. The blower door also creates pressure differences between rooms in the house and intermediate zones like attics, crawl spaces, and garages. Measuring these pressure differences can give clues about the location and size of a home's hidden air leaks.



Blower door components: Include the frame, panel, fan and digital gauge.

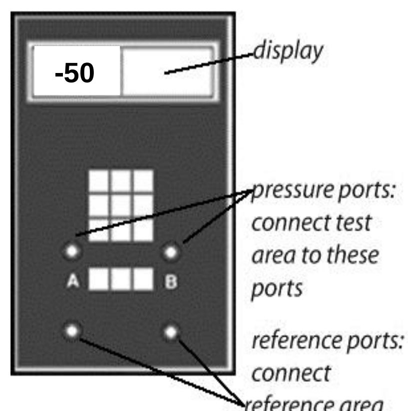


Blower door test: Air barriers are tested during a blower-door test, with the house at a pressure of 50 Pascals negative with reference to outdoors. This house has 1,500 CFM_{50} of air leakage. Further diagnostic tests can help determine where that leakage is coming from.

Blower Door Terminology

Connecting the digital gauge's hoses correctly is essential for accurate testing. There is an accepted method for communicating correct hose connections that helps avoid confusion.

This method uses the phrase "*with reference to*" (WRT) to distinguish between the input zone and reference zone for a particular pressure measurement. The outdoors is the most commonly used reference zone for blower door testing. The reference zone is considered the zero point on the pressure scale.



Digital gauges: Used to diagnose house and duct pressures quickly and accurately.

For example, *"House WRT Outdoors = –50 Pascals"* means the house (Input) is 50 Pascals negative compared with the outdoors (Reference or zero-point). This pressure reading is called the house-to-outdoors pressure difference.

Flow Rings

During the blower door test, the digital gauge measures the airflow pressure through the fan and the size of the fan opening to calculate the air leakage of the building. For the digital gauge to calculate the building's air leakage accurately, the air must be flowing at an adequate pressure through the fan. Tighter buildings may not have enough air leakage to create an adequate pressure for the airflow through an open fan. When the air pressure is too low through the fan, the digital gauge will indicate insufficient airflow by flashing "LO".

To increase fan pressure and airflow, use the flow rings commonly provided with the blower door, to reduce the fan's opening and increase pressure of the airflow through the fan. After attaching the flow ring(s), follow the manufacturer's instructions for selecting the proper setting on the digital gauge.

1.3.2 Preparing for a Blower Door Test

Preparing the house for a blower door test involves putting the house in "closed up condition." Interior doors should be open to **all** conditioned areas (e.g., conditioned knee-wall spaces, conditioned crawl spaces, etc.), while all exterior doors and windows including all storms, as well as accesses to unconditioned spaces, are closed. These conditions must be maintained for the duration of the test.

Try to anticipate problems the blower door test could cause. When a blower door test is being completed in depressurization mode, it can cause flame rollout and back drafting in combustion appliances, as well as debris being drawn out of fireplaces, opening unlatched attic access doors or ceiling tiles to be sucked down.

Follow these steps when preparing for a blower door test:

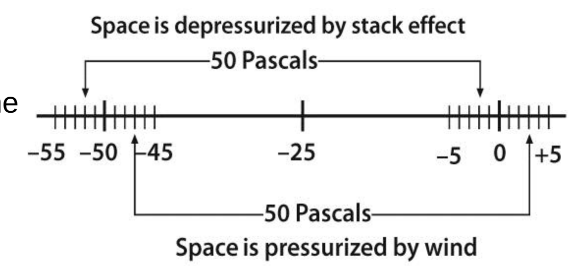
1. Identify the location of the pressure boundary.
2. Open interior doors to connect all conditioned areas of the house.
3. Close all exterior doors and windows including storms.
4. Survey outside air and intermediate zones for possible pollutants that may be drawn into the home during a blower door test. Test in pressurization mode if necessary.
5. Turn off combustion appliances connected to negative pressure venting systems—but do not forget to turn them back on after completing the test. ***Tip:*** Leaving vehicle keys next to or on an appliance that has been turned off, prevents departure without turning the appliance back on.

6. Close all fireplace and stove dampers. When the dwelling has an open-hearth fireplace, verify hot ashes/coals will not be blown out of the hearth, or complete test in pressurization mode. Proceed with caution when pressurizing to ensure that you do not stoke the fire in the fireplace with the added combustion air.

1.3.3 Blower Door Test Procedures

Follow this general procedure when performing a blower door test:

1. Install blower door frame, panel, and fan in an exterior doorway with a clear path to the outdoors and indoors. On windy days, try to place the fan parallel to the wind direction. FOR PRESSURIZATION TEST ONLY: Install the blower door fan with the inlet side facing outdoors (flow rings to the outside), so the fan is moving air from outdoors to indoors. Do not use the fan switch to reverse direction of air flow.
2. Place the digital gauge on the support bracket attached to the blower door frame or house door. Turn gauge on prior to placing any hoses on taps.
3. Connect a hose to the Reference tap of Channel A on the digital gauge. Run this hose outdoors, at least 5 feet to the side of the fan, and ensure the end of the hose is protected from the wind.
4. FOR PRESSURIZATION TEST ONLY: Connect an additional hose to the reference tap of Channel B. Run this hose outdoors with the end of the hose located next to the side of the fan.
5. Connect a hose to the Input tap of Channel B on the digital gauge. Connect the other end of this hose to the pressure tap on the blower door fan.
6. Set up the digital gauge mode to measure air flow at 50 Pascals (“PR/FL@50”). Select a configuration setting to match the flow ring installed on the blower door fan.
7. To obtain accurate blower door measurements, readings must be adjusted for wind and stack effect. This adjustment is also referred to as “adjusting for the baseline.” Use the “baseline” feature of the digital gauge to adjust for the baseline. Cover the fan opening, run the baseline function for 20 to 30 seconds, then press “enter” to accept the baseline reading. On windy days, allow the baseline function to record for 60 seconds or longer.



8. Remove flow rings as needed. Confirm the digital gauge’s mode is still pressure flow at 50 Pascals (mode is set to “PR/FL@50”). Also, confirm the gauge’s configuration setting matches the flow ring(s) installed on the blower door fan.

9. Turn on the blower fan to begin the test and manually adjust the fan speed using the controller. Gradually increase the fan speed by slowly turning the fan controller clockwise. As the fan speed increases, the pressure reading displayed on Channel A should also increase. Continue to increase the fan speed until the pressure reading on Channel A is between 45 and 55 Pascals.

   OR

   To test using “Cruise” control: Many systems now allow the gauge and the fan speed control to be linked with a cable, so that the gauge may be set to “cruise control” the fan at a desired house pressure. To use: Plug the appropriate cable into the jacks on the gauge and the fan speed control. Turn the Blower Door speed control knob to the “just on” position (i.e. the control is on but the fan is not turning). Now press the **Begin Cruise (Enter)** button on the gauge. The **Channel A** display will now show the number 50 (your target Cruise pressure). Press the **Start Fan (Start)** button. The Blower Door fan will now slowly increase speed until the building depressurization displayed on **Channel A** is approximately 50 Pascals.

10. If the Channel B displays “LO”, install a flow ring if the fan is open. Add a smaller flow ring is one is already installed., Remember to change the “CONFIG” setting on the gauge to match the flow ring installed.
11. Adjust the “time average” setting to 5 seconds after reaching 50 Pascals of pressure difference. On windy days, use a time average setting of 10 seconds, or long term.
12. CAN’T REACH FIFTY - If the building is extremely leaky, you may not be able to reach a pressure difference of at least 45 Pascals.with the fan open. Testing can still be completed and as long as the gauge is in the PR/FL@50 mode, a CFM_{50} leakage estimate will automatically be displayed on Channel B.
13. Document the CFM_{50} from Channel B of the digital gauge in the Diagnostic Workbook. Measure the inside and outside temperatures and record in the Diagnostic Workbook.

Blower Door Test Follow-up

1. Return the house to its original condition.
2. Inspect combustion appliance pilot lights to ensure blower door testing did not extinguish them.
3. Reset thermostats of heaters and water heaters that were turned down for testing.
4. Document any unusual conditions affecting the blower door test and location where the blower door was set up. Photo document the test if needed.

1.4 Air Sealing and Indoor Air Quality

Air sealing affects the home’s indoor air quality by reducing the amount of natural ventilation. When natural ventilation is reduced below a certain level, mechanical exhaust ventilation is sometimes needed to ensure pollutants are exhausted to the outside and enough fresh air is brought into the building.

For instructions on how to calculate the whole-house ventilation requirement, refer to the Diagnostic Workbook. Whenever feasible, install 100 percent of the required mechanical ventilation rate.

See *Mechanical Ventilation in Chapter 5 – Section 5.9* for more information about ventilation requirements.

1.4.1. Air Sealing

Complete air sealing work in a reasonable and cost-effective manner. The first blower door test (As-Is test) documents the overall leakiness of the building before weatherization work begins. It helps crews determine the potential for air sealing work to be completed. To identify what air sealing should be completed and where, use the blower door along with an infrared camera, smoke, or “feel” with your hands locates air leaks. Another tool to help guide air sealing is zone pressure diagnostics. See *Zone Pressure Diagnostics (ZPD) in Chapter 1 – Section 1.5* for instructions regarding the use of zone-pressure testing to guide air sealing.

Major air sealing is completed on the building along with or prior to installing any other shell measures. It includes installing window glass where missing, sealing gross holes in the building envelope, sealing construction key junctures, and sealing all major attic bypasses.

For gaps larger than ¼", use caulking, steel wool, or other pest-proof material to fill the penetration before sealing. If a span is greater than 24 inches, install support spans that are rated to span such distance under the existing (if not insulating) or prescribed load (if adding insulation). Penetrations shall be sealed with a durable material with a minimum expected service life of 10 years.

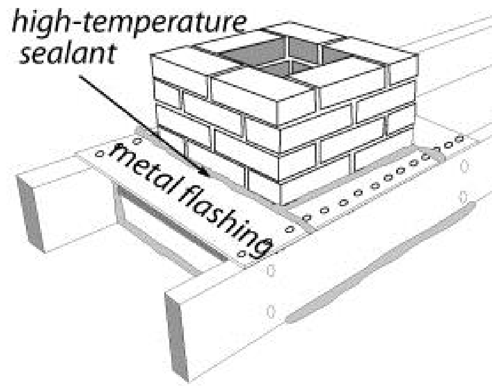
Minor air sealing is air-sealing that occurs after the completion of major air sealing and all shell measures and is limited to 1 labor hour. The decision to complete minor air sealing shall be determined by the crew leader. Often, minor air sealing has a minimal impact on energy savings, but can improve occupant comfort. Minor air sealing may include window and door weather-stripping, door sweeps, window air-sealing, and caulking around trim.

Common air barrier flaws requiring air sealing include, but are not limited to:

Attics and Other Concealed Spaces

1. **Interior dropped soffits:** Cap the soffit with rigid material, and air-seal around the perimeter of the cap. If the soffit is located in a hard-to-access area, or along an exterior wall, consider dense-packing the soffit. When the soffit contains a non-IC-rated light fixture, ensure any insulation will be kept at least 3 inches away from the top and sides of the fixture or obtain the homeowner's approval to replace with an IC-rated or flush-mounted fixture. ZPD sometimes reveals these areas do not leak. Consider testing prior to air sealing, and document based upon the test results the decision to seal or not seal.

Around masonry chimneys: Use 26-gauge or heavier metal and appropriate temperature rated sealant to seal within 2 inches of the chimney.



Sealing around chimneys: Only non-combustible materials, like metal, may be used for sealing around chimneys.

2. **Balloon framing/open partition walls:** **A)** Cap the stud openings with rigid material and air-seal around the perimeter of the cap. B) Stuff the cavity with batts so the infill backing will not bend, sag, or move once installed. Seal with foam or dense-pack with insulation.

3. **Recessed lights:** For IC rated fixtures, seal the fixture. Use sealant or mastic to prepare for insulation. For non-IC rated fixtures, either install an LED retrofit kit that is air sealed at the ceiling or build an air-tight cover in the attic using non-combustible materials that do not allow for rapid heat transfer. Drywall or cement board may be used only if a three-inch clearance is maintained. Sheet metal is not an allowable material.

4. **Wall top-plates identified as leaking (exterior and interior walls):** Look for dirty insulation above top plates — this indicates air leakage. Pressurizing the home with the blower door will magnify smaller, hard-to-locate leaks. Use foam or caulk to seal leaky top plates. On multifamily homes, this leak path may be present at the top plate of party walls.

5. **Electrical and other penetrations through wall top-plates:** Use one-part-foam or caulk.

6. **Ceiling penetrations:** These can include electrical fixtures, exhaust fans, soil stacks, dryer-exhaust pipes, and HVAC ductwork, etc. Seal with foam or caulk, as appropriate. Seal from the interior when possible, rather than from the attic.

7. **Key junctures:** Key junctures are framing voids and shared spaces where two or more building assemblies converge. Use foam or caulk to seal key junctures, another option is to utilize the bag method with cellulose. *See Installing Attic Insulation in 1½ Story Homes in Chapter 2 – Section 2.2.7* for information on the bag method.
8. **Whole-house fan:** If the fan is operational, box around it and install a removable and airtight cover. The occupant should be able to remove the cover easily for future use.

Basement

1. **Rim Joist:** Seal leaks between sill plate and foundation either from the interior or exterior depending on accessibility. Look for dirty sill-box insulation as evidence of air leakage. Using the blower door can magnify smaller leaks. Seal leaks with foam or caulk. If leaks are inaccessible from the interior, seal outside where the sill plate meets the foundation behind the siding.
2. **Foundation and Sillbox penetrations:** Use foam or caulk to seal large penetrations identified in the foundation. If the foam will be exposed to sunlight, take precautions to protect the foam from deterioration.
3. **Inactive chimneys and clean-outs:** Air-seal to prevent leakage and reduce convective looping. Clearly label the chimney to state it is no longer suitable for use.
4. **Bathtubs on exterior walls:** Install dense-packed insulation in the open space between the bathtub and the exterior wall, if feasible.

Windows

1. **Missing window glass:** Install new window glass, or otherwise seal the opening, following lead- and asbestos-safe work practices. See *Window Repair and Replacement in Chapter 6 – Section 6.1.1* for information on window repairs and replacements. *Note: Air sealing of cracked window glass is considered Minor Air Sealing.*

Doors

1. **Door repair**: Seal gaps between the stop and jamb with caulk. Note: Sealing gaps between the door stop or jam falls under Minor Air Sealing.
2. **Garage doors:** Weather-strip all doors connecting conditioned areas to an attached garage.

1.5 Zone Pressure Diagnostics

ZPD tests help to quantify the air leakage from the house to intermediate “zones.” By using ZPD tests, workers can prioritize air-sealing to areas of the pressure boundary where it will be most effective. ZPD tests may allow workers to save time working in zones whose air bypasses are insufficient to warrant extensive air sealing. Some common intermediate zones are attics, garages, and crawl spaces.

ZPD tests calculate a **total path** of CFM_{50} leakage from the outside through the zone into the conditioned space. For example, a good goal for “all major attic bypasses” is the total path through all attics into the conditioned space should equal no more than 10 percent of the home’s total air leakage. For example, a home with a final blower door test of 2200 CFM_{50} should have a total path through all intermediate attic zones of no more than 220 CFM_{50}.

When performing ZPD tests, use the auditors estimated final blower door test, not the in-progress blower door test, to calculate a zone’s leakiness. Document any unusual circumstances in the Comments section of the Blower Door Data worksheet within the Diagnostic Workbook.

Always perform ZPD testing when weatherizing a building with an attached garage. Record the results of the test on the Garage ZPD worksheet within the Diagnostic Workbook.

Use ZPD to guide decisions about where to direct air-sealing efforts. ZPD can allow workers to:

1. Evaluate the air tightness of specific sections of a building’s pressure boundary — especially floors and ceilings.
2. Decide which of two possible air barriers to air seal — for example, sealing at the first floor deck versus at the foundation walls. Please see table 1-2 in section 1.5.3
3. Estimate the air leakage in CFM through a particular air barrier.
4. Determine whether areas like floor cavities, porch roofs, and overhangs are conduits for air leakage.
5. Determine whether building cavities, intermediate zones, and ducts are connected by air leaks.

ZPD testing should be used whenever appropriate. Typically, that is when the dwelling has one or more of the following conditions:

1. Structural moisture problems related to moist air escaping into unheated zones.
2. Multiple zones where determining linkage between zones or setting air-sealing priorities is necessary.
3. Unusually high blower door result with no indication as to where the air leakage originates.
4. Results of completed ZPD should be documented on the required Zone Pressure Diagnostics Form within the Diagnostic Workbook.

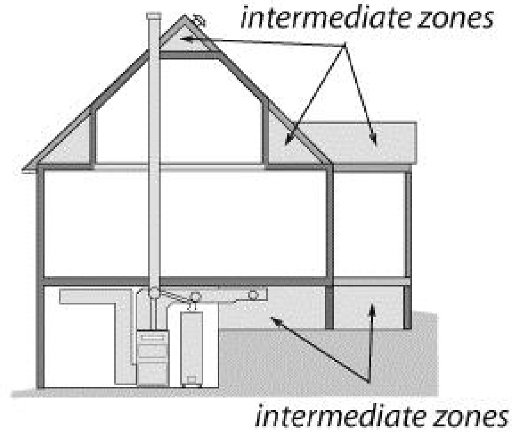
Table 1-1: Air Performance of Building Components

Good Air Barriers (<2 CFM_{50} per 100 $ft.^2$)	Fair Air Barriers (2-10 CFM_{50} per 100 $ft.^2$)	Poor Air Barriers (10-1000 CFM_{50} per 100 $ft.^2$)
5/8" oriented strand board	15# perforated felt	5/8" tongue-and-groove wood sheeting
½" drywall	concrete block	6" fiberglass batt
4-mil air barrier paper	rubble masonry	1½" wet-spray cellulose
asphalt shingles and perforated felt over ½" plywood	7/16" asphalt-coated fiberboard	wood siding over plank sheathing
1/8" tempered hard-board	1" expanded polystyrene	wood shingles over plank sheathing
painted un-cracked lath and plaster	brick veneer	blown fibrous insulation
Measurements taken at 50 Pascal pressure. Based on information from: “Air Permeance of Building Materials” by Canada Mortgage Housing Corporation, June 1988, and estimates of comparable assemblies by the author. Although cellulose reduces air leakage when blown into walls, it is not considered an air-barrier material.		

Primary vs. Secondary Pressure Boundary

The **primary pressure boundary**, or air barrier, comprises those building-shell surfaces which contain the dwelling’s conditioned air and which prevent air leakage. Ideally, the primary pressure boundary will be as continuous as possible, and it will be aligned with the building’s thermal boundary.

The **secondary pressure boundary** comprises building surfaces that are outside the thermal boundary and which combine with the primary pressure boundaries to form intermediate zones.



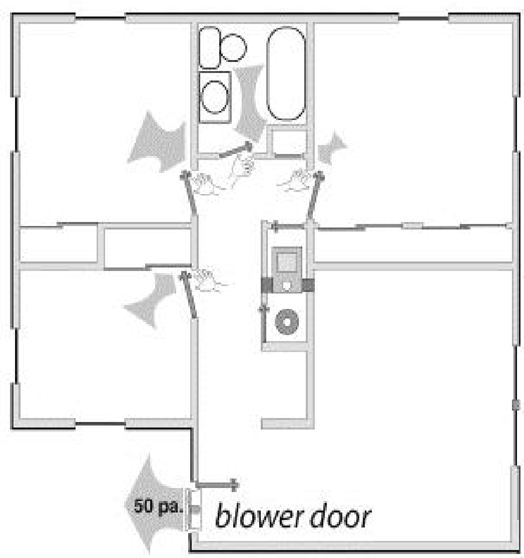
Intermediate zones are spaces that are isolated outside of the home's thermal boundary, but which are sheltered within the home's exterior shell. Intermediate zones may include such unconditioned areas as basements, crawl spaces, attics, enclosed porches, and attached garages. Pre-weatherization, intermediate zones may be included either inside the home's primary pressure boundary or outside it. One goal of weatherization is to improve the pressure boundary so these unconditioned zones are isolated outside the home's primary pressure boundary.

Intermediate zones have two potential pressure boundaries: one between the zone and house and one between the zone and outdoors. For example, an attic has two pressure boundaries: the ceiling and the roof deck. It is essential to determine which of the two serves as the primary pressure boundary.

After weatherization is complete, the most airtight boundary should be the primary pressure boundary and the least airtight should be the secondary pressure boundary. The primary pressure boundary should be adjacent to the insulation to ensure the insulation's effectiveness. The air barrier should be composed of materials that are continuous, sealed at seams, and relatively impermeable to airflow.

1.5.1 Simple Air-Leakage Tests

During a blower door test, valuable information about the relative leakiness of rooms or sections of the home can be identified. Following are five simple methods for locating air leakage.



Interior door test: Feeling airflow with your hand at the crack of an interior door gives a rough indication of the air leakage coming from the outdoors through that room.

1. **Feeling air leakage:** From inside the building along the primary pressure boundary, air movement will be felt during a depressurization test. From inside an intermediate zone along the primary pressure boundary, air movement will be felt during a pressurization test. Air leakage from a room can be felt by closing an interior door. A smaller gap between the door and doorjamb causes the airflow to speed up. Feel the airflow along the

length of that crack, and compare that airflow intensity with airflow from other rooms, using the same technique.

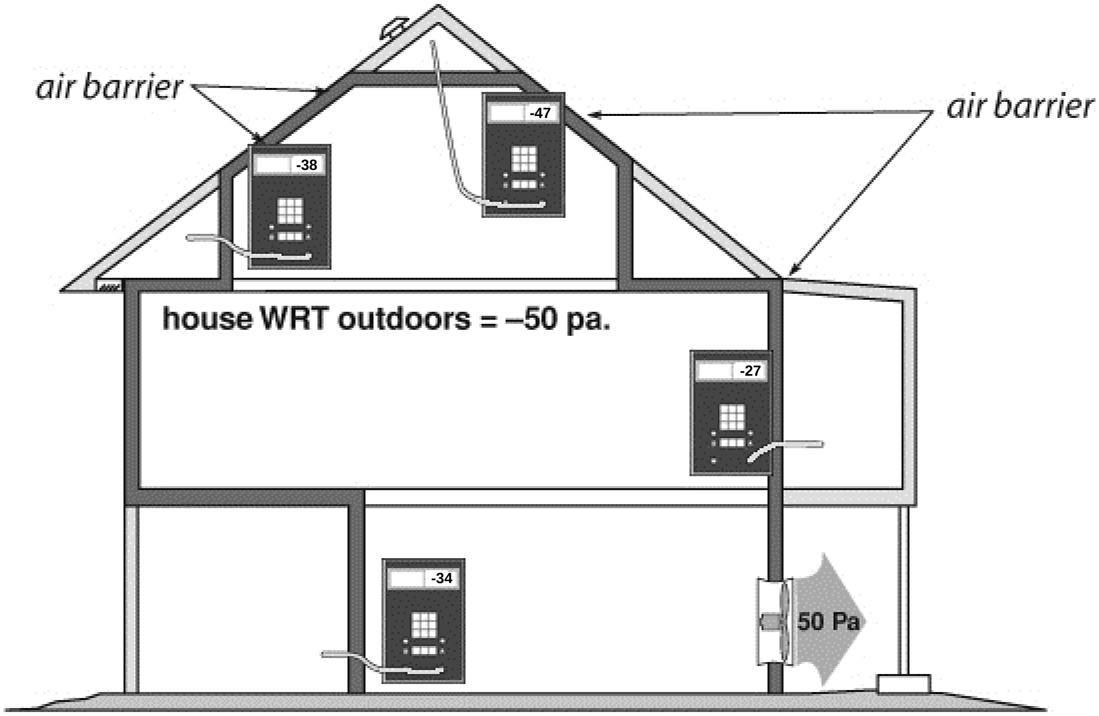
2. **Observing movement caused by air leakage:** To locate air leaks from the interior, depressurize the home and look for moving cobwebs, moving curtains, and blowing dust. To locate air leaks from intermediate zones, pressurize the home, and look for movement of loose-fill insulation, blowing dust, or moving cobwebs.
3. **Observing smoke movement:** Using a smoke generator to detect areas of air leakage is the best method to diagnose primary pressure boundary air leakage during a **pressurization** test.
4. **Thermal Imaging:** Observe surfaces with an infrared camera. Areas of high contrast or flaring along building trim can indicate the presence of air leakage. Observing surface before and then after running blower door can indicate changes in temperature of surface caused by air leakage.
5. **Room-airflow difference:** Measure the house CFM_{50} with all interior doors open. Close the door to a single room or the basement and note the difference in the CFM_{50} reading. The difference is the approximate leakage through that room or the basement.

Tests 1- 3 can be completed by the occupant as part of customer education. Feeling for airflow or observing smoke are simple observations and can identify many air leaks or reveal that windows and doors have minimal air leakage. Tests 4-5 require experience to interpret observations. High contrast surfaces may appear that way when using an infrared camera because they are warmer or cooler. This may be caused by lack of cavity insulation, or by air leakage across or behind the surface. When airflow within the home is restricted by closing a door, as in test 5, it may take alternative indoor paths that reduce the accuracy of the test. Experience and training can guide decisions about the applicability and usefulness of these simple tests.

1.5.2 Using a Digital Gauge to Test Pressure Boundaries

A digital gauge, used for blower door testing, also can measure pressures between the house and its intermediate zones during blower door tests. The blower door, when used to create a house-to-outdoors pressure difference of 50 Pascals, also creates house-to-zone pressures that can range from 0 to 50 Pascals in the building's intermediate zones. The amount of pressure differential depends on the relative leakiness of the zone's two pressure boundaries.

For example, in an attic with small holes in the ceiling and a well-ventilated roof, the house-to-zone pressure may be 45 to 50 Pascals. This attic is described as being "mostly outside" the house pressure boundary. The larger the holes in the ceiling with smaller holes in the roof, the smaller the house-to-zone pressure differential will be, and the more the attic could be described as "being inside." This principle holds true for other intermediate zones like crawl spaces, attached garages, and unheated basements.



Pressure-testing building zones: Measuring the pressure difference across the assumed thermal boundary tells you whether the air barrier and insulation are aligned. If the digital gauge reads close to -50 Pascals, they are aligned, assuming the tested intermediate zones are well-connected to outdoors.

Pressure-Only Zone Pressure Diagnostics

1. Find an existing hole between the conditioned space and the intermediate zone. Or, with the customer's permission, drill a hole through the floor, wall, or ceiling into the zone.
2. Run a hose into the zone, and connect the hose to the Channel B Reference tap of the digital gauge.
3. Leave the Input tap of the digital gauge open to the indoors.
4. Turn the blower door on and create a 50-Pascal pressure difference between the House with reference to Outdoors (HwrtO) using channel A.
5. Read the pressure differential on channel B. This is the House with reference to Zone (HwrtZ) pressure differential. As a rule, readings close to 50 Pascals indicate the zone is less connected to the house compared to the connection to outdoors. Test readings much lower than 50 Pascals generally indicate the presence of air leaks along the primary pressure boundary. The lower the house to zone pressure, the greater the size of holes from the house to the zone if the size of holes from the zone to outside are larger.

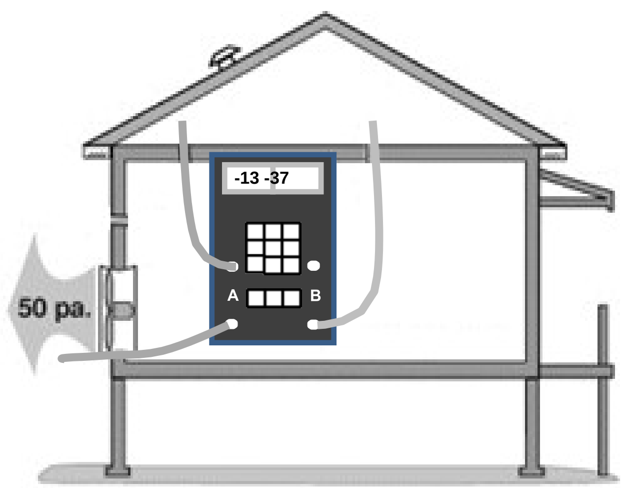
The main principle of series air leakage is a direct relationship between the measured pressure differentials and the ratio of the size of holes in the primary and secondary pressure boundaries.

This method allows the user to calculate the air-leakage surface area through one of the boundaries, if the air-leakage surface area through the other boundary is known or presumed.

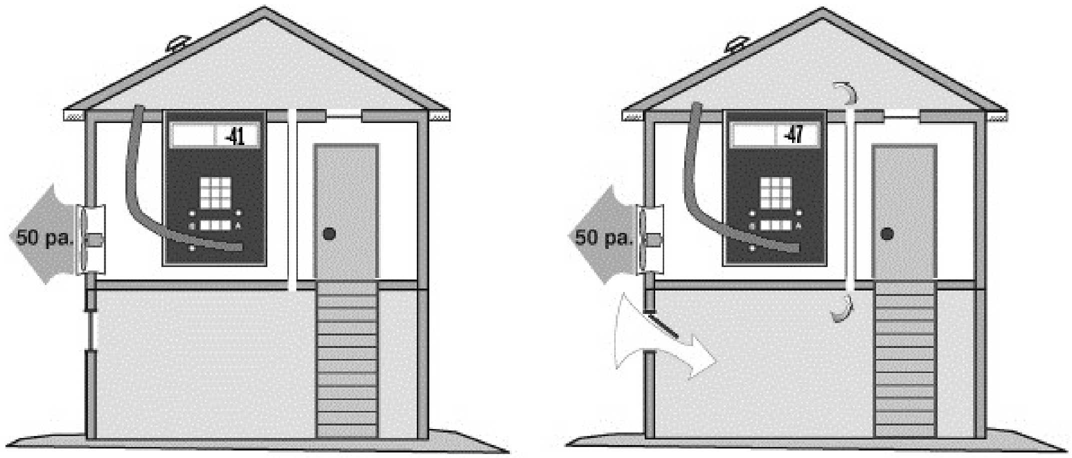
Attic Bypass Relationships		
Zone Pressures		Relative Size of Bypass Holes Compared to Roof Holes *(e.g., ventilation)*
ZwrtO	**HwrtZ**	**HwrtZ**
1	49	1/13
2	48	1/8
5	45	1/4
9	41	1/3
13	37	1/2
25	25	1
38	12	2

For example, testing may indicate a HwrtZ pressure differential of 41 Pascals and a ZwrtO differential of 9 Pa, when the HwrtO pressure difference is 50 Pascals. Per Attic Bypass Relationships chart, if the secondary pressure boundary (roof) contained 300 square inches of ventilation, then this would indicate the presence of roughly 100 square inches of bypasses located in the primary pressure boundary (ceiling).

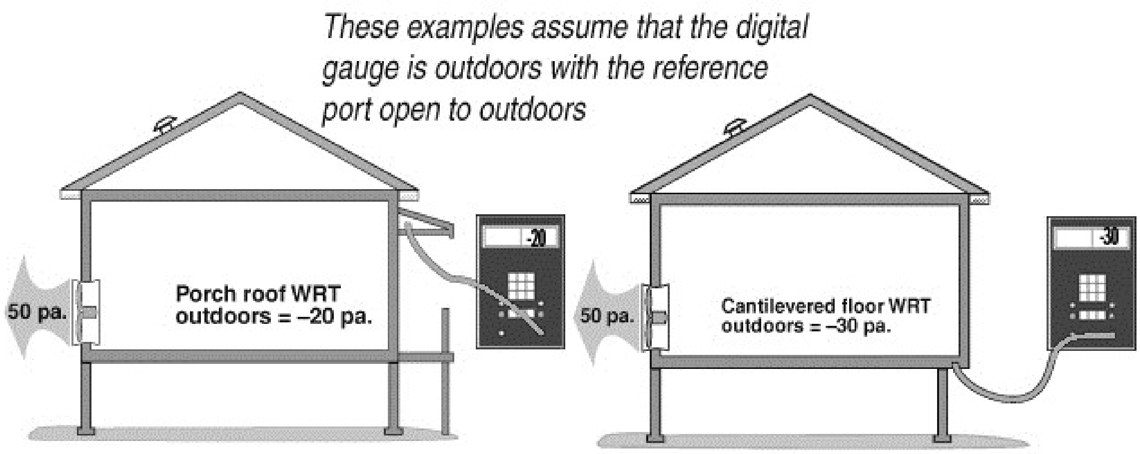
6. If testing indicates the presence of substantial air leaks, find and seal the air barrier's leaks.



Attic-to-outdoors pressure: The left side of the gauge shows an Attic WRT outside pressure of -13 Pascals and the right side of the gauge shows a House WRT Attic pressure of -37 Pascals. The two readings add up to -50 Pascals to confirm House WRT Outside of 50 Pascals.



Zone connectedness: The attic measures closer to outdoors after the basement window is opened, indicating that the attic and basement are connected by a large bypass.



Porch roof test: If the porch roof were outdoors, the digital gauge would read near 0 Pascals. We hope that the porch roof is outdoors because it is outside the insulation. We find; however, it is partially connected to indoors, indicating it may contain significant air leaks through the thermal boundary.

Cantilevered floor test: We hope to find the cantilevered floor to be indoors. A reading of -50 Pascals would indicate that it is completely indoors. A reading less negative than -50 Pascals is measured here, indicating that the floor cavity is partially connected to outdoors.

Leak-Testing Building Cavities

Building cavities such as wall cavities, floor cavities between stories, and dropped soffits in kitchens and bathrooms can also be pressure-tested with a digital gauge to determine their connection to the outdoors.

Testing Zone Connectedness

Sometimes it is useful to determine whether two intermediate zones are connected by an air passage like a large bypass. Determining whether two zones are connected can be completed by measuring the house-to-zone pressure during a blower door test and then later after opening the other zone to the outdoors. Opening an interior door leading into one of the zones and check for pressure changes in the other zone can also help determine connections.

1. Turn on the blower door and establish a house-to-outside pressure differential of 50 Pascals.
2. Test and record the house-to-zone pressure differential of one of the zones.
3. Open a door, or create some other pathway, into the other zone.
4. Re-establish a house-to-outside pressure differential of 50 Pascals, as opening the pathway will change the overall house pressure.
5. Re-test the house-to-zone pressure differential in the first zone. If opening the pathway has caused the test result to change, then this is evidence of a connection between the two zones.

1.5.3 Locating the Pressure/Thermal Boundary

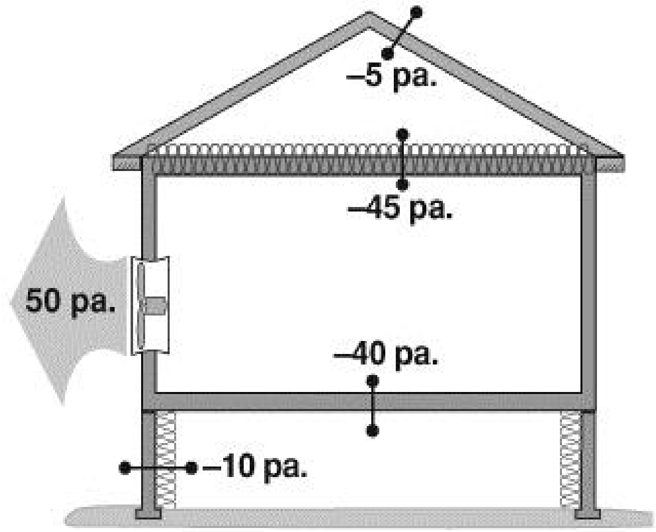
Where to air-seal and insulate are important retrofit decisions. Zone pressures are one of several factors used to determine where the thermal boundary should be located. When there are two choices of where to insulate and air-seal, zone pressures along with other considerations help decide where to locate the pressure and thermal boundaries.

For zone-leak-testing, the house-to-zone pressure is often used to determine which of the two pressure boundaries is tighter (has smaller sized holes).

For example, a house-to-zone pressure differential of 26 to 50 Pascals means the primary pressure boundary is likely tighter than the secondary boundary. If the secondary boundary is quite airtight, achieving a 50-Pascal house-to-zone pressure differential is difficult. However, if the roof is well ventilated, creating a nearly 50-Pascal differential is possible. If the roof is over-ventilated, creating a nearly 50-Pascal differential is easy.

By contrast, a house-to-zone pressure differential of zero to 25 Pascals means the secondary pressure boundary is tighter than the primary boundary. If the roof is well ventilated, then these readings indicate the ceiling has even more leakage surface area than the roof.

Floor vs. Crawl Space



Pressure measurements and air-barrier location: The air barrier and insulation are aligned at the ceiling as they should be. The crawl space pressure measurements show that the floor is the air barrier and the insulation is misaligned–installed at the foundation wall. We could decide to close the crawl space vents and air-seal the crawl space. Then the insulation would be aligned with the air barrier.

The floor shown here is tighter than the crawl-space foundation walls. If the crawl-space foundation walls are insulated, holes and vents in the foundation wall should be sealed until the pressure difference between the crawl space and outside is as close to 50 Pascals as possible—ideally more than 48 Pascals. A leaky foundation wall renders its insulation ineffective.

It might be more effective to weatherize the floor above the crawl space. If the floor is insulated instead of the foundation walls, completely air sealed, then the pressure and the thermal boundary would be in alignment at the floor. When the crawl space is adjacent to a basement and the thermal boundary is to be moved to the floor, remember the thermal boundary now includes the wall separating the basement from the crawl space. Insulate and air-seal this wall appropriately.

However, it will usually make more sense to locate the thermal boundary at the crawl-space foundation walls, rather than at the floor. Locating the thermal boundary at the foundation walls eliminates the concern about frozen pipes in the crawl space. In addition, treating the foundation walls usually requires less work and material than treating the floor.

Table 1-2: Crawl Space: Where Should the Air Barrier Be?

Factors Favoring Foundation Wall	Factors Favoring Floor
Ground moisture barrier and good perimeter drainage present or planned	Damp crawl space with little or no improvement offered by weatherization
Foundation walls test tighter than floor	Floor tests tighter than foundation walls
Furnace, ducts, and plumbing located in crawl space	No plumbing or heating located in crawl space
Foundation wall is insulated	Floor is insulated

Table 1-3: Unoccupied Basement: Where Should the Air Barrier Be?

Favors Foundation Wall	Favors Floor
Ground drainage and no existing moisture problems	Damp basement with no solution during weatherization
Interior stairway between house and basement	Floor air sealing and insulation is a reasonable option, considering access and obstacles
Ducts and furnace in basement	No furnace or ducts present
Foundation walls test tighter than the floor	Floor tests tighter than foundation walls
Basement may be occupied some day	Exterior entrance and stairway only
Laundry in basement	Rubble masonry foundation walls
Floor air sealing and insulation would be very difficult	Dirt floor or deteriorating concrete floor
Concrete floor	Badly cracked foundation walls

Garage Boundary

For a tuck-under or attached garage, locate the thermal and pressure boundaries at the floor and walls that separate the garage from the living spaces. Ensure plumbing pipes in these floor and wall cavities are located on the interior (warm) side of the thermal and pressure boundaries to prevent frozen pipes.

For tuck-under garages, make sure to air-seal the floor-joist key juncture above the wall that separates the garage from the home. Use the Bag Method if necessary. See *Installing Attic Insulation in 1½ Story Homes (Finished Attics) in Chapter 2 - Section 2.2.7* on for more information about the Bag Method.

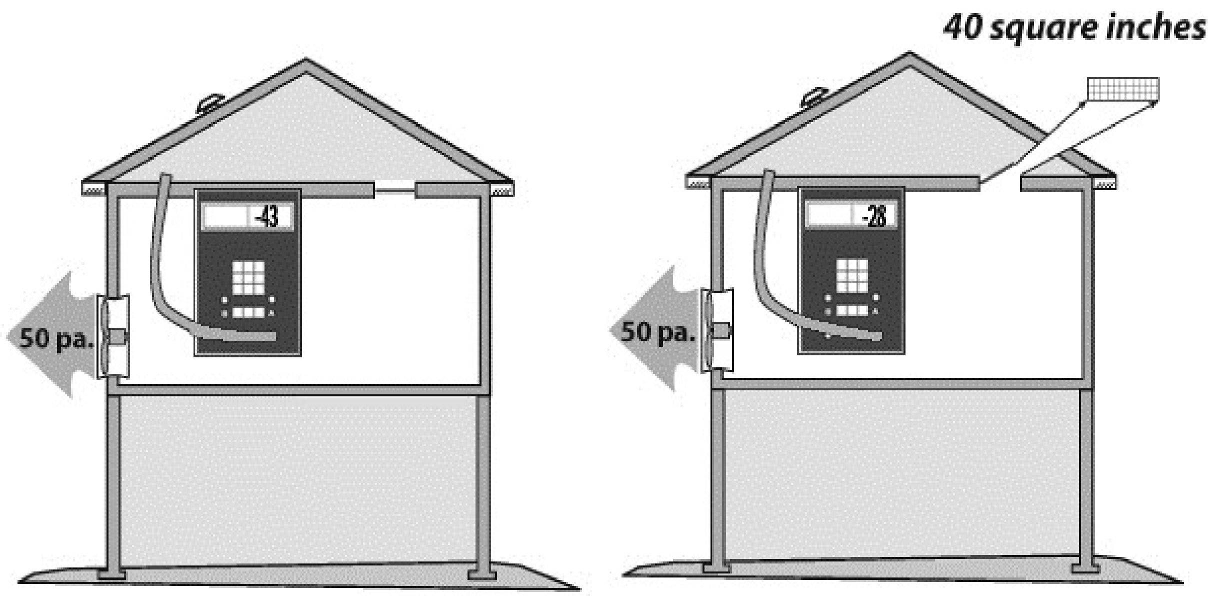
Duct Location

Whenever feasible, locate the thermal and pressure boundaries to include ductwork. This is a better option than isolating the ducts outside the thermal boundary, because it reduces energy waste from duct leakage.

1.5.4 Add-a-Hole Zone-Leakage Measurement

The Add-a-Hole procedure estimates the actual airflow between the house and zone. Use the Add-a-Hole worksheet within the Diagnostic Workbook to perform the calculations described here. This procedure works for most intermediate zones that have an opening or access to the indoors.

The Add-a-Hole worksheet calculates Leakage Results based on user data inputs. The three Leakage Results calculations are:



Add-a-hole test: The first house-to-attic pressure is -43 Pascals. This test works equally well with crawl spaces and attached garages.

Add-a-hole test 2: Opening a hole of approximately 40 square inches drops the second house-to-zone pressure by 15 Pascals.

Total path: This number represents the amount of leakage (inCFM_{50}) passing through both pressure boundaries.

House with reference to zone: This number represents the amount of leakage between the house and zone.

Zone with reference to outside: This number represents the amount of leakage between the zone and outside.

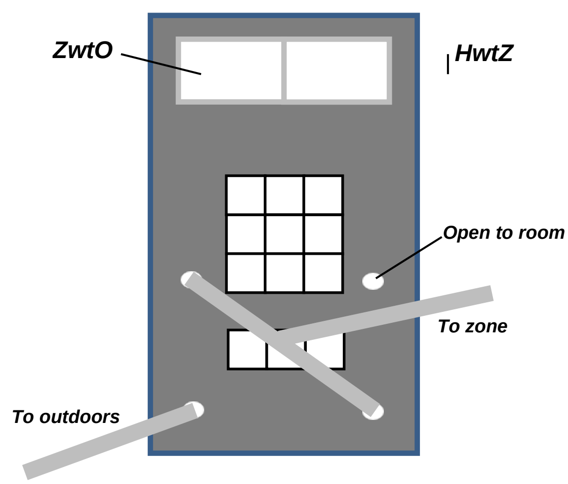
Ideally, total path leakage percentage through attics is 10 percent or less of the total blower door value. This number is calculated using the following equation:

$$\text{Percentage} = \text{Total Path} \div \text{Whole-House } CFM_{50}$$

Before starting an Add-a-Hole Zone-Leakage Test, confirm a “hole” can be opened between the house and the zone and/or between the zone and the outside. The hole might be an attic hatch, a door to the zone, or some other opening.

Follow these steps to complete the Add-a-Hole ZPD test:

1. Set up for a standard blower door test. Put the home in winter operating condition, turn off all combustion appliances, and keep interior doors open and stationary during testing.
2. Run a reference pressure hose to a location outdoors unaffected by the wind. Run a second pressure hose into the zone, keeping the hose end away from air currents that could be caused by roof vents and large bypasses. Both hoses will be connected to the digital pressure gauge later during the test. Ensure both hoses are long enough to reach the gauge at the same time.
3. Turn on the pressure gauge and leave in PR/PR mode for all testing. *Do not use the Adjusted Baseline feature of the digital gauge when completing zone-pressure diagnostics.*
4. Connect a jumper tee to the Channel A Input tap and the Channel B Reference tap. Leave the jumper tap open to the indoors for the time being, with no hose connected. Connect the outdoor pressure hose to the Channel A Reference tap of the digital pressure gauge.
5. Open the Add-a-Hole worksheet in the Diagnostic Workbook. Select the Type of Test — depressurization or pressurization — to be conducted.
6. Connect the zone pressure hose to the jumper tee. Record the baseline pressures, the Zone with reference to Outside (ZwrtO) baseline from Channel A, and the House with reference to Zone (HwrtZ) baseline from Channel B.
7. Remove the zone pressure hose. Measure the House with reference to Outdoors (HwrtO) baseline pressure differential. Enter the result in the Diagnostic Workbook, as a positive or a negative number. The Workbook will then calculate the Adjusted Pressure — which becomes the target building pressure for the blower door test.
8. Start the bower door fan to create an HwrtO pressure difference and adjust the fan speed to within 1 Pascal of the target building pressure.
9. Without changing the fan speed, reconnect the zone pressure hose to the jumper tee. Record the ZwrtO reading from Channel A, in the Pressure with House at 50 Pascals line



of the Add-a-Hole worksheet. Record the HwrtZ reading from Channel B, in the same line of the worksheet.

10. Turn off the blower door fan. Create a hole by opening the access between the zone and the house. The size of the hole created should be sufficient to change the measured HwrtZ Pressure with house at 50 Pascals by 6 to 20 Pascals. A hole that is too large or too small may lead to incorrect results.
11. Repeat Steps 6-9. If the HwrtZ reading is more than 20 Pascals different, reduce the size of the hole. If the HwrtZ reading is fewer than 6 Pascals different, increase the size of the hole. *If the size of the hole is changed, the baseline pressures will change, and should be re-measured (Go back to Step 6).*
12. Determine the surface area of the final hole, in square inches. Be sure to account for the triangular spaces created on either side of the access hatch, if the hatch was tilted open. Enter the dimensions of the opening so the Add-a-Hole worksheet calculates an Opening Size to match the hole's measured surface area.
13. When the HwrtZ reading from Channel B falls within the range of 6 to 20 Pascals difference, record it in the Pressure With House at 50 Pascals line of the Add-a-Hole worksheet, in the "Pressure Readings After Adding a Hole" section. Record the ZwrtO reading from Channel A, in the same line of the worksheet.
14. The worksheet will calculate leakage rates and total path leakage. Return the home to the pre-test conditions — and remember to turn combustion appliances back on.

Follow the warning indicators in the Add-a-Hole worksheet, if they appear.

1.5.5 Open-a-Door Zone-Leakage Measurement

The Open-a-Door method is another way of determining how much leakage in CFM_{50} travels through an intermediate zone like a walk-up attic, unoccupied basement, or attached garage. This method is used when a door exists between the house and zone or between the zone and outdoors. Use the Open-a-Door or garage ZPD worksheet within the Diagnostic Workbook to perform the calculations.

The Open-a-Door worksheet calculates Leakage Results based on user data inputs. The three Leakage Results calculations are:

Total path: This number represents the amount of CFM_{50} passing through both pressure boundaries.

House with reference to zone: This number represents the amount of leakage between the house and zone.

Zone with reference to outside: This number represents the amount of leakage between the zone and outside. If the attic is the zone, this is attic ventilation.

The target air leakage between a house and an attached garage is 50 CFM. Ideally the goal should be to have no leakage between a house and garage.

Follow these steps to complete the Open-a-Door test:

1. Set up for a standard blower door test. Put the home in winter condition, turn off all combustion appliances, and keep interior doors open and stationary during testing.
2. Run a pressure hose to the outdoors to a location unaffected by wind. Run a second pressure hose into the zone, keeping the hose end away from roof vents and large bypasses that may create air currents. Both hoses will be connected to the digital pressure gauge later during the test. Ensure both hoses are long enough to reach the gauge at the same time.
3. Turn on the pressure gauge and leave in PR/PR mode for pressure testing. *Do not use the Adjusted Baseline feature of the digital gauge when completing zone-pressure diagnostics.*
4. Connect a jumper tee to the Channel A Input tap and the Channel B Reference tap. Leave the jumper tap open to the indoors for the time being, with no hose connected to the third leg of the tee. Connect the outdoor pressure hose to the Channel A Reference tap of the digital pressure gauge.
5. Start the Open-a-Door or Garage ZPD worksheet in the Diagnostic Workbook. Select the Type of Test — depressurization or pressurization — to be conducted.
6. Connect the zone pressure hose to the jumper tee. Record the baseline pressures, the Zone with reference to Outside (ZwrtO) baseline from Channel A, and the House with reference to Zone (HwrtZ) baseline from Channel B.
7. Remove the zone pressure hose. Measure the House with reference to Outdoors (HwrtO) baseline pressure. Enter the result in the Diagnostic Workbook, as a positive or a negative number. The Workbook will then calculate the Adjusted Pressure — which is the target building pressure reading for the blower door test.
8. Start the bower door fan to create an HwrtO pressure difference and adjust to within 1 Pascal of the targeted pressure reading.
9. Without changing the fan speed, reconnect the zone pressure hose to the jumper tee. Record the ZwrtO reading from Channel A, in the Pressure with House at 50 Pascals line of the Open-a-Door or Garage ZPD worksheet. Record the HwrtZ reading from Channel B, in the same line of the worksheet.
10. Complete the blower door test with the door to the zone closed and record the reading on the worksheet.
11. Open the door between the house and the zone. The door to be opened will be between the basement and the outside when determining leakage to the basement from outside.

12. Complete a blower door test with the door wide open and record on the Open-a-Door or Garage ZPD worksheet.
13. The worksheet will calculate leakage rates and total path leakage. Return the building to the pre-test conditions — and remember to turn combustion appliances back on.
14. Follow the warning indicators in the Open-a-Door or Garage ZPD worksheet, if they appear.

The sum of the HwrtZ and ZwrtO pressures should be approximately equal to the actual HwrtO pressure. For example, if the HwrtZ pressure is -45 Pascals and the ZwrtO pressure is -6 Pa, then the indirect HwrtO pressure will calculate out to -51 Pascals (-45 + -6 = -51). The greater the difference between the HwrtO and the sum of the HwrtZ + ZwrtO pressures, the less accurate the test will be. If the sum difference is greater than 2 Pascals, the worksheet will instruct workers to consider re-testing.

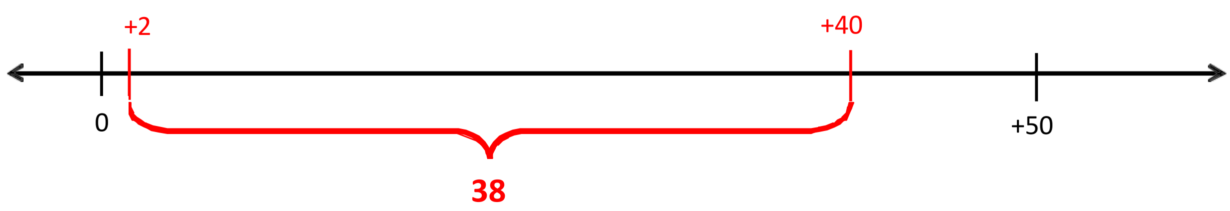
1.5.6 Adjusting Zone Pressure Measurements for Baseline

The Diagnostic Workbook automatically adjusts test results to measured baseline pressures. However, it is important to understand how baseline pressures (caused by stack effect, wind, or air handlers and fans) affect zone pressure measurements. The measured zone pressure baseline readings are subtracted from the measure zone pressure readings taken with the house at a 50 Pascal pressure difference. This can be confusing when subtracting a negative number from a negative reading (depressurization) or a positive reading (pressurization). The number lines below are examples on how to adjust for baseline for both pressurization and depressurization testing methods.

Pressurization

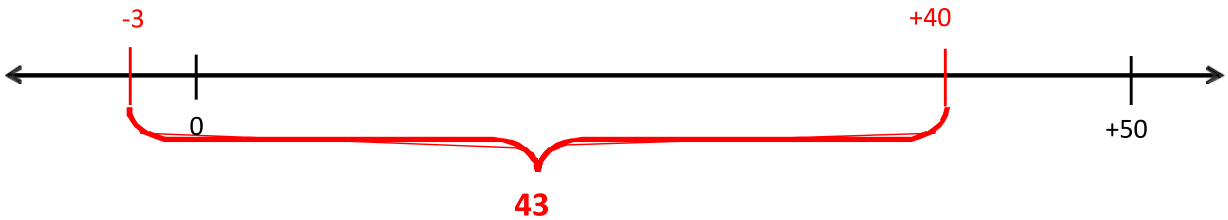
Positive baseline of +2, zone reading of 40 with house at 50.

Adjusted zone pressure reading is 38 (40 - (+2) = 38).



Negative baseline of -3, zone reading of 40 with house at 50.

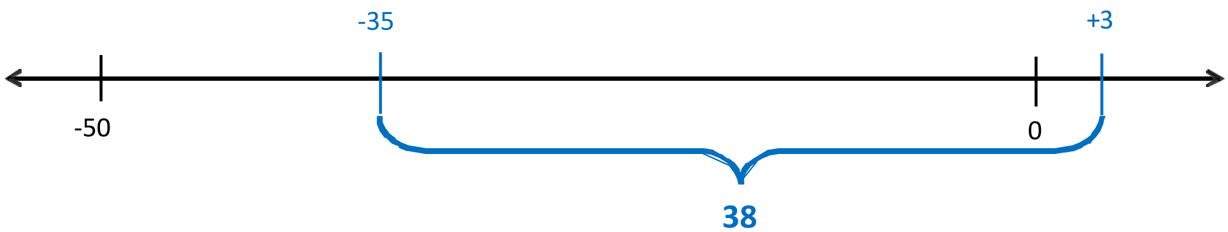
Adjusted zone pressure reading is 43 (40 - (-3) = 43).



Depressurization

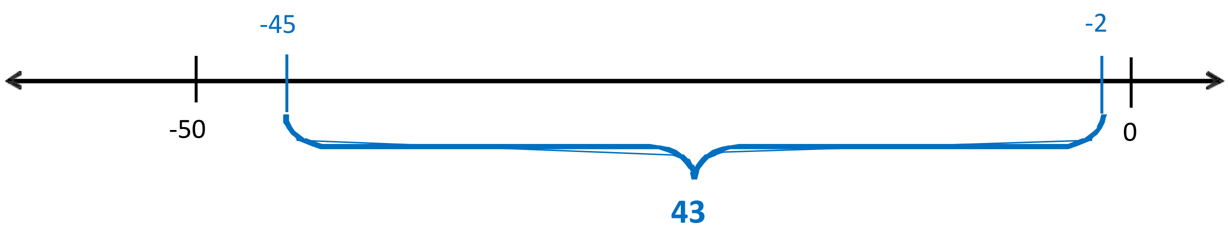
Positive baseline of +3, zone reading of -35 with house at -50.

Adjusted zone pressure reading is 38 (-35 – (+3) = -38).



Negative baseline of -2, zone reading of -45 with house at -50.

Adjusted zone pressure reading is 43 (-45 - (-2) = -43)



Final Inspection and Quality Assurance Standards

Acceptable installations shall meet the following standards.

Air Sealing and Building Diagnostics

General

1. The customer file contains documentation of all diagnostic, air-sealing, and combustion-safety testing that was performed at the building.
2. Diagnostic tests were appropriate for the building's configuration.
3. Program guidelines were followed in reducing air leakage (e.g., major and minor air sealing and ZPD testing).

Air Sealing

1. All major attic bypasses and building key junctures are sealed.
2. All major bypasses and gross holes in the box-sill are air sealed.
3. Broken or missing windows or window panes have been patched, repaired, or replaced.
4. The air sealing hours and testing are documented in the Diagnostic Workbook.
5. Air sealing materials perform the intended function. When cavities are dense-packed with cellulose to the proper density, chemical smoke will not be seen to move through penetrations, even when the building is at a pressure differential of 50 Pascals.
6. Paintable caulk was used where the occupant or owner is likely to paint the completed work.
7. If used, foam sealant was applied effectively and without waste. Overspray was cleaned up.
8. Weather-stripping is installed only on exterior doors, not on interior doors.

Blower Door Test

1. The equipment was calibrated per manufacturer instruction.
2. The final blower door value can be replicated to +/- 20%. (Final Inspection, QA Inspection).
3. The Diagnostic Workbook is complete.

Zone Pressure Diagnostics

1. Where required, ZPD testing was performed and is properly documented in Diagnostic Workbook.

2. The appropriate method was used when ZPD testing was completed (e.g., open-a-door, add-a-hole.
3. Total path leakage results are within acceptable range or documentation supports work as completed.

Chapter 2: Heating Envelope Building Measures

2.1 Heating Envelope Insulation

The building heating envelope comprises those surfaces that function as the thermal boundary between conditioned and unconditioned spaces. These surfaces may include, but are not limited to, exterior walls, attics, foundations, and exposed floors. Insulation reduces heat transmission by slowing conduction, convection, or radiation through the building envelope. The various insulating materials in the building make up the *thermal boundary* — the boundary that separates conditioned space from unconditioned space. Airtight materials that cover the walls, floor, and ceiling to prevent air movement form the *pressure boundary*. The thermal and pressure boundaries should be as continuous as possible and aligned properly so the insulation works effectively. The pressure boundary must be addressed before proceeding with work on the thermal boundary except in circumstances where both pressure and thermal boundaries are addressed at the same time, through measures such as dense-pack insulation. See *Chapter 1 – Section 1.5.3* for information on how to address the pressure boundary.

When insulation is installed, a dated insulation certificate is provided to the building owner that includes:

1. Insulation type
2. Coverage area
3. R-Value
4. Installed thickness and settled thickness
5. Number of bags installed in accordance with manufacturer instructions

2.2 Attic and Roof Insulation

2.2.1 Pre-insulation Attic and Roof Insulation Prep

Perform these preparatory steps and safety procedures before installing attic insulation:

1. Vent all exhaust appliances to the outdoors, as specified in *Chapter 3 – Section 3.13* using a dedicated exhaust termination. Seal and insulate exhaust ducts to R-8 to prevent condensation inside the duct. Check all fans for proper backdraft-damper operation. Repair or replace the damper, or the entire fan assembly, if the damper does not operate freely.

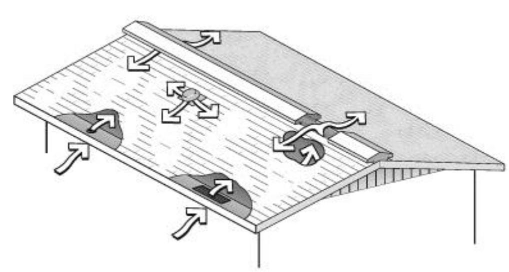
2. Isolate insulation a minimum of 2 inches from masonry chimneys and per manufacturer instruction for metal vents, using rigid damming material. Do not allow insulation to spill into clearance spaces.

3. Repair roof leaks and address other attic-related moisture problems before insulating attic.

4. Confirm all wire splices are enclosed in electrical junction boxes. Mark all junction boxes that will be covered with insulation with a sign or flag.
5. When not removing knob-and-tube wiring, maintain a 3-inch clearance from insulation around live knob-and-tube wiring using appropriate materials. See *Electrical Safety in Chapter 5 – Section 5.5*.
6. Remove or perforate existing vapor retarders on the cold side of the insulation.
7. Check the manufacturer's instructions to determine if fixtures can be covered with insulation. If fixtures cannot be covered with insulation, or if Insulation Contact (IC)-rating is unknown, keep all insulation three inches from these fixtures. Fasten shields or covers securely to the rafter or ceiling joist so that they maintain three inches of clearance and don't move or collapse.
8. If heating-system ductwork runs through the attic, seal and insulate as appropriate (see *Duct Leakage and Duct Insulation in Chapter 3 – Sections 3.4.2 and 3.4.3*). Do not apply duct insulation to ducts that will be surrounded by R-11 or more of loose-fill insulation.
9. If the attic is used for storage, eliminate or reduce the amount of storage area with the customer's approval. Storage area must maintain a minimum of R-19 for attic insulation. Build an insulation dam around the area. If items are present during insulation, temporarily either remove items from area or cover with plastic or a tarp.
10. Install depth markers for installed insulation every 300 square feet of attic area, with the measurement beginning at the air barrier.
11. When a whole-house fan is encountered in a home, construct a box around the fan at a height to protect the fan housing and motor from insulation. Insulate the exposed sides and top of the box assembly to the same R-value as the adjoining insulation. Use the appropriate adhesive or mechanical fasteners.
12. Consider placing a fiberglass batt on top of the exhaust-fan housing in the attic before blowing insulation. The batt will prevent loose-fill insulation from spilling into the home if the fan is replaced in the future.

2.2.2 Attic Ventilation

Install attic ventilation when it is needed. When installing ventilation, there should be an equal distribution of vent area across all attic areas whenever possible. Split the net free area of attic ventilation equally between high and low venting, if possible. Consult state and local building codes for requirements on the minimum amount of attic ventilation.



Low and high attic ventilation: A moderate amount of ventilation creates air exchange with outdoors.

Gable Vents

Install gable-end vents as high in the gable end as possible and above the final level of the attic insulation. Build a dam in front of existing gable vents if insulation comes up to the bottom of the vent.

Roof Vents

Install the top flashing of the roof vents under asphalt shingles and mechanically fasten and seal with plastic roof cement or with products specifically designed for this purpose. Center all roof vents between rafters. Where possible, mount vents no closer than 12 inches (measured vertically) from the ridge of the roof.

Soffit Vents

When soffit venting is required, use products specifically designed for this purpose. Eave chutes allow the installation of the maximum amount of insulation over the exterior top-plate. Chutes can also prevent wind-washing of the insulation, which degrades the insulation's R-value. Install eave chutes as necessary to promote sufficient ventilation of the attic.

Mechanically fasten eave chutes at the top, and install blocking at the base to prevent insulation from spilling over into the soffit area. In rafter cavities where a chute is not installed, make sure the cavity is blocked with fiberglass batts or a rigid barrier to prevent spillover into the soffit area. Chutes must be long enough to extend above the final insulation level.

Soffit chute: Allows installation of maximum amount of insulation in this cold area. Also prevents wind washing and airway blockage by blown insulation.

2.2.3 Attic Accesses, Walk-up Stairways, and Doors

Attic Accesses

Perform these tasks to address attic accesses, walk-up stairways, and doors prior to insulation:

1. Insulate accessible attic accesses to the R-value of the adjacent attic insulation or to the maximum structurally allowable, whichever is lower. Permanently attach the insulation and ensure it is in complete contact with the air barrier. Access must be operable, weather-stripped, and air-sealed.

2. Install durable damming material to maintain the R-value of the attic insulation up to the access, allow repeated access to the attic, and to prevent loose-fill insulation from entering the home.
3. Post warnings in access to attics with asbestos-containing materials or vermiculite. See the Wisconsin Weatherization Program Manual (Chapter 9 – Health & Safety) for more information about asbestos.

Walk-Up Stairways and Doors

Establish a continuous insulation and air barrier around or over the top of an attic stairway. If the attic is accessed using a stairwell and standard vertical door, there are two methods for treatment.

Method 1

Insulate the walls of the stairwell, as well as beneath landings, stair treads, and risers. Insulate and weather-strip the back of the door to the R-value of the adjacent wall insulation or the maximum structurally allowable, whichever is lower.

When planning to insulate stairwells, investigate for barriers, such as fire blocking, that might prevent insulation from filling cavities. Consider which passageways may lead to other areas where insulation should not be installed, such as closets or chimney chases. Balloon-framed walls and deep stair cavities complicate this measure.

Method 2

Establish the thermal boundary at the ceiling level by installing an insulated and air-sealed horizontal hatch at the top of the stairs. Insulate the hatch to the R-value of the adjacent attic insulation or the maximum structurally allowable, whicheve

Insulating and Sealing Retractable Attic Stairways

Building an insulated box is a good solution to insulating and sealing this weak point in the thermal boundary. Insulate the box and the cover to an R-value equal to the attic insulation level, or to the highest R-value structurally allowable. Use care in establishing a continuous thermal boundary when air sealing and insulating around the hatch opening.

2.2.4 Calculating Attic Loose-Fill Insulation

Install loose-fill attic insulation at a uniform depth to attain proper coverage (bags per square foot) and proper R-value at the manufacturer's specified installed thickness. Follow the manufacturer's instructions in order to achieve the correct density to meet the required R-value.

Loose-fill insulation always settles, and the manufacturer does account for settling in the listed minimum installation thickness charts. The installed thickness of cellulose decreases by 10 to 20 percent due to settling, and the installed thickness of blown fiberglass decreases by 3 to 10 percent. See *Appendix A-3* for the calculation of density and the number of bags needed to achieve the desired R-value at the settled density.

2.2.5 Installing Blown-in Attic Insulation

Blown insulation is preferred over batt insulation because blown insulation forms a seamless blanket. Blowing attic insulation at the highest structurally allowable density helps minimize settling and reduces convective currents within the insulation.

Follow these steps when installing loose-fill attic insulation:

1. Fill the edges of the attic first, near the eaves or gable end and work back toward the attic hatch. Ensure proper insulation density over the exterior top-plates.
2. Install insulation to a consistent depth. Use a stick to level the insulation if necessary.
3. Perform a bag count while blowing to confirm the proper depth and density of insulation is installed.
4. Avoid "fluffing," and maintain an adequate density by moving as much insulation as possible through the hose with the available air pressure. The more the insulation is packed together in the blowing hose, the greater its installed density will be.
5. Fill floored attic cavities to a higher density to minimize settling, if no electrical or material hazards are present. Install dense-packed or maximum structurally allowable density insulation in floored attic cavities when hidden bypasses have not been addressed by other methods.
6. Add additional insulation over floored attics not used for storage, as needed to achieve the specified R-value.

2.2.6 Installing Attic Batt Insulation

Follow these steps when installing fiberglass batts horizontally in the attic:

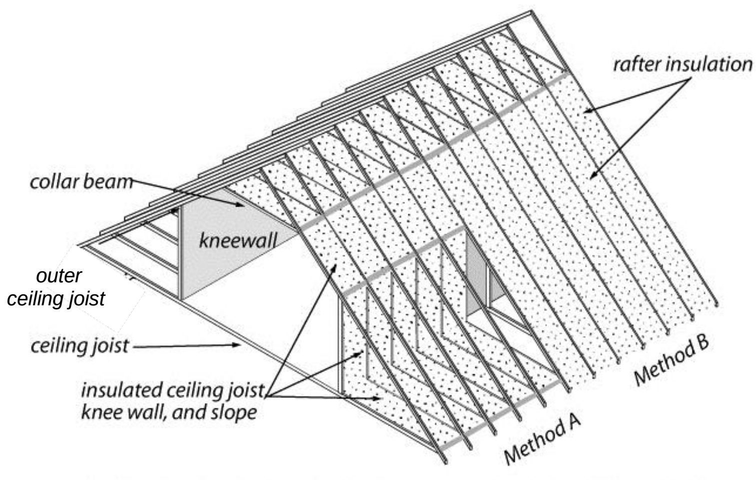
1. Install un-faced fiberglass-batt insulation. Cut batts carefully to ensure a tight fit against the ceiling joists and other framing.
2. Install two layers of batt insulation at a right angle to each other. This practice minimizes voids and produces better thermal resistance.

2.2.7 Installing Attic Insulation in 1½ Story Homes (Finished Attics)

Finished attics in 1½-story homes require special care when installing insulation. They often include four separate attic sections requiring different sealing and insulating methods:

Collar beam: The attic at the top of the building, which runs between and connects the two roof rafter attics.

Roof rafter: The cavities between the ceiling and the roof. The roof-rafter section that runs between the collar-beam attic and the top of the knee wall is sometimes referred to as the “slope” or “slant.”



Finished attic: This illustration depicts two approaches to insulating a finished attic. Either, A) insulate the kneewall and outer ceiling joist, or B) insulate the rafters. Method A reduces the size of the heating envelope, while Method B results in less surface area exposed to unconditioned air.

Knee wall: The short wall between the living area and the outside structural wall of the building. The space created behind the knee wall is often used for storage.

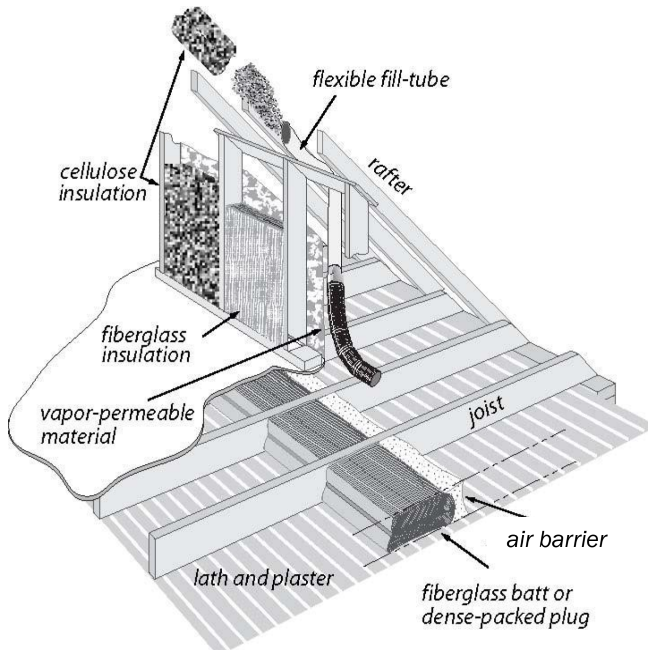
Outer ceiling joist: Flat attic surface located above the first-floor living area.
Follow these methods when insulating finished attics:

Method A

Method A treats the space behind the knee wall as *unconditioned* attic space. The thermal boundary includes the collar beam, the roof rafter, the knee wall, and the outer ceiling joist.

Follow these steps to treat the attics using ***Method A***:

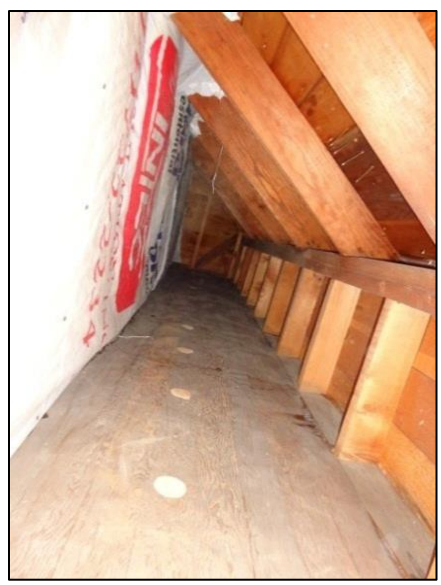
1. Seal and carefully insulate built-in closets, dressers, or cabinets that protrude into the thermal boundary through the knee wall. Two-part foam can be effective at sealing and insulating these areas from inside the knee wall attic. See *General Information on Spray Polyurethane Foam (SPF) in Appendix A-4* for additional information.
2. Create an airtight, permanent seal in the floor-joist space under the knee wall. Insert pieces of rigid board insulation, drywall, or ductboard in between each joist, and seal the perimeter of each piece with one-part foam; or by inserting a fiberglass batt into the cavity and spraying its face with two-part foam, or by using the ***Bag Method*** to blow a tight plug of dense-packed cellulose into the joist cavities.



Finished attic best practices: Air sealing and insulation combine to dramatically reduce heat transmission and air leakage in homes with finished attics.

To use the ***Bag Method***: place a plastic or mesh bag over the end of the fill tube and insert the tube and bag into the cavity. While holding on to the bag, start blowing insulation into the bag until full, then push the remaining part of the bag into the cavity. The bag will limit the amount of insulation it takes to plug this area.

3. Ensure insulation coverage is adequate where the knee wall meets the roof rafter and where the roof rafter meets the collar beam.
4. Insulate the roof rafters using dense-packed insulation. The roof rafters can be insulated from either the collar-beam attic or the outer-ceiling-joist attic. Ensure the opposite end has a barrier installed. Alternatively, dam both ends of each cavity and blow the roof rafters from the interior, like interior wall insulation. See *Dense-Packed Wall Insulation from the Interior in Chapter 2 – Section 2.3.5.*
5. Insulate knee walls using dense-packed insulation, fiberglass batts, or two-part foam. If dense-packing the knee walls, prepare them for blowing by fastening a vapor-permeable material to the cold side of the knee wall studs with reinforcement as needed.
6. When insulating knee walls with batt insulation, use appropriately sized batts to fit into the stud cavities.
7. Cover existing and/or installed fiberglass-batt insulation with a vapor-permeable material to prevent wind wash. Wrap or seal the vapor-permeable material around the studs at each end to prevent air movement behind the material. If a second layer of batt insulation leaves the studs inaccessible, fasten the vapor-permeable material to the roof rafters and deck at the top and to the floor at the bottom of the wall.



8. Insulate attic-access panels in the knee wall to the R-value of the adjacent knee wall insulation, or to the maximum structurally allowable, whichever is lower. Operable panels must be weather-stripped and must close with a tight seal. Vertical access panels require mechanical fasteners to maintain a tight seal.
9. Install a dam if needed to maintain the insulation's R-value near the access and to prevent loose-fill outer-ceiling-joist insulation from spilling into the living area. Secondary access panels in a knee wall may be sealed permanently, with the building owner's approval.
10. Follow steps in *Insulating Attics with Limited Accessibility in Chapter 2 – Section 2.2.8* for insulating the collar beam and outer ceiling joist attics.

Method B

Method B treats the attic space behind the knee wall as *conditioned* space. The thermal boundary is located at the roof deck and at the gable-end walls.

Method B, using foil-faced polyiso foam board as vapor barrier and air barrier.

Follow these steps to treat the attics using ***Method B***:

1. Create an airtight, permanent seal in the joist space over the top of the first-floor exterior top-plate. This can be done by inserting pieces of rigid board insulation, drywall, or ductboard and foaming the perimeter of each piece with one-part foam; or by inserting a fiberglass batt into the cavity and spraying its face with two-part foam; or by using the ***Bag Method*** to blow dense-packed cellulose into the joist cavities. See ***Method A*** above for information about the ***Bag Method***. See the *General Information on Spray Polyurethane Foam (SPF) in Appendix A-4* for additional information.
2. Air seal along the gable-end walls. Since the attic will become conditioned space, do not air seal at the floor of the outer ceiling joist, or at the floor-cavity key juncture beneath the knee wall.
3. Ensure insulation coverage is adequate and continuous where the roof rafter meets the outer ceiling joist and exterior top-plate.
4. Insulate the roof rafters and gable ends.
    a. Dense-pack insulation method:
        i. Existing sheathing: Drill holes and install dense-pack insulation using tubing method. Patch all drilled holes. The roof rafters can be insulated from the collar-beam attic using the tubing method.

ii. Exposed studs or rafters: If the cavities are to be dense-packed, prepare them for blowing by fastening a *non*-vapor-permeable material on the warm side of the rafters with reinforcement, as needed. Seal the edges to achieve a continuous vapor retarder. Blow the cavities from the outer-ceiling-joist attic through holes cut in the *non*-vapor-permeable material. Patch all cut holes. The roof rafters can be insulated from the collar-beam attic using the tubing method.

b. Batt insulation method: If batt insulation is installed, cover it with a vapor retarder. Air-seal the material, since it will now act as the primary pressure boundary.

c. Two-part foam method: If two-part foam is installed, do not install a vapor retarder, since two-part foam acts as both insulation and as an air seal. Typically, two-part foam insulation costs more than installing dense-packed cellulose or air sealing and then installing batts. If the side attic is to remain accessible, the foam must be covered with a thermal barrier.

5. Follow steps in *Section 2.2.8* for insulating the collar beam attic.

2.2.8 Insulating Attics with Limited Accessibility

In attics with limited access and no electrical or material hazards are present, insulate with loose fill insulation to a sufficient density to minimize settling. Install dense-packed insulation in inaccessible attic cavities when hidden bypasses have not been addressed by other methods.

These areas may include, but are not limited to:

- ✓ Shed style roof
- ✓ Inaccessible collar-beam attic
- ✓ Inaccessible outer-ceiling-joist attic and knee wall areas

When insulating attics with limited access:

1. Inspect the roof to verify it is in good condition, without visible deterioration.
2. Access the cavity through the gable ends, rafter tails, roof deck, or through the ceiling.
3. Inspect the attic for any air bypasses to the conditioned space. Seal discovered bypasses as directed in *Air Sealing and Indoor Air Quality in Chapter 1 – Section 1.4.*
4. Install blown-in insulation using an appropriate method.

2.2.9 Insulating Closed Roof Cavities

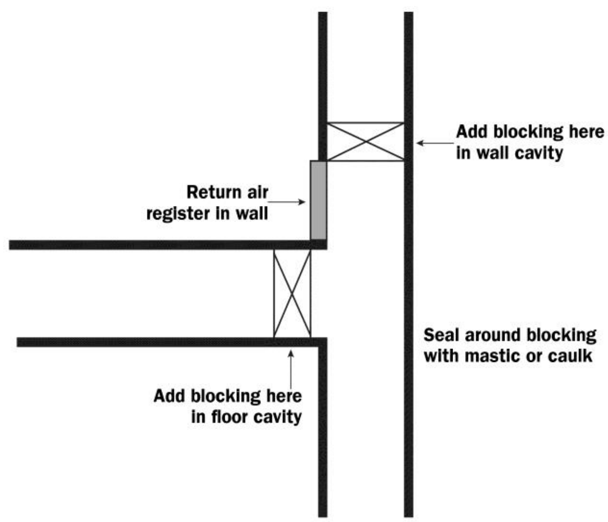
Insulate closed roof cavities with loose fill insulation at a sufficient density to minimize settling, if no electrical or other hazards are present. Install dense-packed insulation in attic cavities when hidden bypasses have not been addressed by other methods.

These areas may include, but are not limited to:

- ✓ Cathedral roof
- ✓ Flat roof
- ✓ Dormers
- ✓ Above bump-outs

When insulating closed roof cavities:

1. Inspect the roof to verify it is in good condition, without visible deterioration.
2. Access the cavity through its gable ends, rafter tails, roof deck, or through the ceiling.
3. Blow the insulation using an appropriate method to ensure proper density of installed insulation.



2.3 Wall Insulation

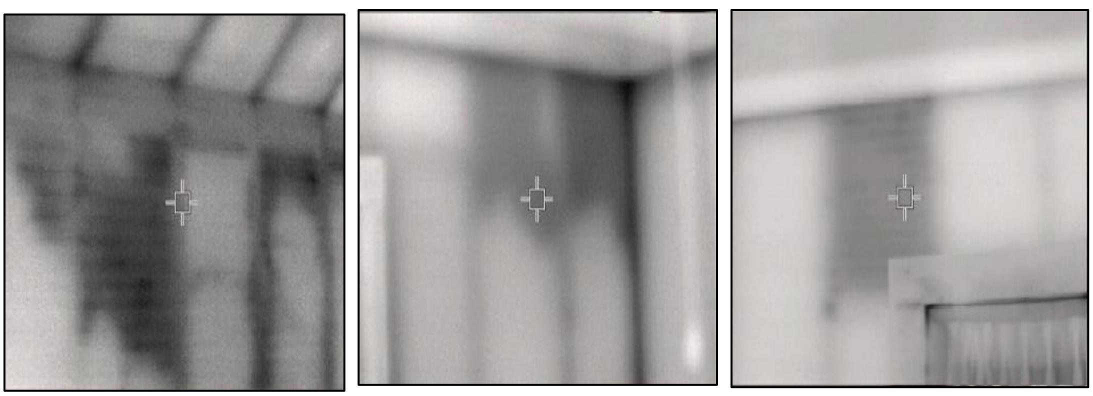
Properly installed dense-packed wall insulation reduces air leakage through walls and other closed building cavities because the fibers are driven into the cracks by the blowing machine.

Empty or partially empty wall cavities encourage airflow like chimneys. Convection currents or air leakage can significantly reduce wall insulation's thermal performance if spaces remain for air to flow. Installing dense-packed wall insulation with uniform coverage and density is important. The tube-fill dense-pack method is Wisconsin's chosen wall insulation method because it ensures adequate coverage and density of insulation.

Infrared scanner: Allows the user to see temperature differences, which verify insulation coverage in a wall cavity.

Caution is necessary when tube-filling walls, because the process puts pressure on the interior and exterior wall surfaces. If the pressure becomes too great on a particular material — such as plaster, drywall, or paneling — the wall could crack or burst. It is also important to check for hidden holes in exterior walls and balloon-framed structures where insulation can escape into basements, attics, closets, and other spaces. Inspect exterior walls to identify cavities that are open to, contain, or are part of the forced-air distribution system. Seal distribution systems in cavities to be insulated. Use extreme care to ensure insulation does not fill wall cavities that are part of the distribution system, which may result in damage to the furnace.

Adequate insulation coverage and density of insulation may be confirmed using an infrared camera or laser thermometer or by using a blower door with artificial smoke. Whenever possible, use these tools to verify complete insulation coverage. Un-insulated and poorly insulated parts of the wall will display differently on an infrared camera than a well-insulated wall. The tool is best used whenever a substantial temperature difference exists, or can be created, on either side of the wall. When cavities are packed to the proper density, chemical smoke will not be seen to move through penetrations, even when the building is brought to a pressure differential of 50 Pascals.



Infrared images of exterior surfaces: Dark patches indicate areas with little or no insulation – either insulation voids or framing members.

2.3.1 Calculating Wall Coverage and Density

Dense-packed wall insulation should be installed to a density of 3.5 to 4.5 pounds per cubic foot for cellulose, and 2.0 to 2.5 pounds per cubic foot for fiberglass. These calculations serve to determine the number of bags necessary to insulate walls and to judge density after completing the wall insulation job.

See *Appendix A-3* for the calculation of density and the number of bags needed to achieve the R-value at the settled density.

2.3.2 Inspecting and Repairing Walls Before Installing Insulation

1. Inspect walls for evidence of moisture damage.
2. Seal obvious gaps in external window trim or other areas that may permit the penetration of water into the wall.

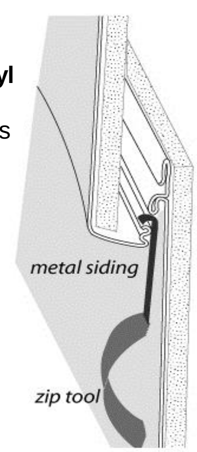
3. Before removing siding, detach any clamps that secure gutters and electrical conduit, etc. to the exterior siding.
4. Inspect indoor surfaces of exterior walls to ensure they are strong enough to withstand the force of dense-packing. Temporarily reinforce or permanently repair weak walls where necessary, prior to dense-packing.
5. Inspect for interior openings from which insulation may escape, such as pocket doors, un-backed cabinets, interior soffits, closets, and balloon-framing openings in the attic or crawl space. Taking a few minutes to investigate these areas will save a lot of time and mess later, if openings do exist. Seal openings as necessary to prevent blown insulation from escaping.
6. Do not insulate cavities used as forced-air distribution. Also, do not insulate cavities containing live knob-and-tube wiring, bare wires, open junctions, or unboxed wire connections. In the customer file, document the location of cavities used as distribution and with live knob-and-tube wiring. See *Electrical Safety in Chapter 5 – Section 5.5*.

2.3.3 Removing Siding and Drilling Sheathing

When insulating a wall from the exterior, remove the outer layer of siding to drill through sheathing and any sub-layers of siding. Removing the siding may make it easier to insert a flexible fill tube, since the tube must pass through one less layer of material. Carefully removed and handled siding is reinstalled after insulating, creating an appearance as close to the original as possible. Drill holes through siding (with building owner's consent) only as a last resort and only if siding cannot be removed. Documentation must be in the customer file detailing the conditions that precluded the removal of the siding.

Some siding materials require specialized procedures. Cement-asbestos board (transite, also called slate siding), and stucco may only be disturbed by persons with appropriate Department of Health Services (DHS) asbestos certification (see Wisconsin Weatherization Program Manual, Chapter 9 – Health & Safety for complete asbestos policy). Sidewall insulation procedures should follow lead-safe procedures under the direction of a Lead Safe Renovator when applicable (see Wisconsin Weatherization Program Manual, Chapter 9 – Health & Safety for complete lead policy). Any person who completes this work must be trained in lead-safe procedures.

Removing metal or vinyl siding: A zip tool separates joints in vinyl and metal siding.

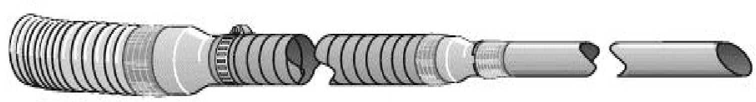


1. Metal or vinyl siding may be removed with a zip tool.
2. Lap siding requires careful prying with a flat bar underneath the nails that fasten the siding to the framing. Cut the paint between pieces of siding with a utility knife before prying.

For more information regarding siding removal, refer to “Dense-Pack Sidewall Insulation” video, available from the Weatherization Training Media Library.

2.3.4 Dense-Packed Wall Insulation from the Exterior

Dense-packed wall insulation is best installed using the tube method with an insulation blower equipped with separate controls for air and material feed. Mark the fill tube in one-foot intervals so the installer knows when the tube has reached the top of the wall cavity and when the end of the tube is almost removed upon completion of dense-packing the cavity.

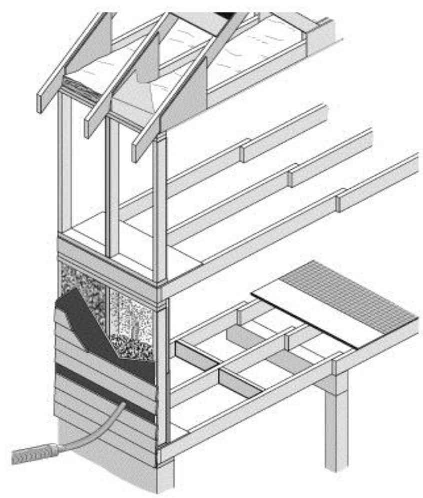


Insulation hoses, fittings and the fill tube: Gradual reductions in the hose diameter will reduce the chance of plugging the hose with insulation. The goal is to achieve a material to air mixture that maximizes production and correct density.

To prevent settling, loose-fill insulation must be blown at the recommended density of 3.5 to 4.5 pounds per cubic foot for cellulose and 2.0 to 2.5 pounds per cubic foot for fiberglass.

To insulate sidewalls from the exterior:

1. Remove siding, following lead-safe practices if required. See *Lead Paint and Lead-safe Work in Chapter 5 – Section 5.4.8.* Transite (slate) siding shall be removed intact only by persons with appropriate DHS asbestos certification, unless the siding has been tested and does not contain asbestos.
2. Drill or cut a two- to three-inch diameter hole to access each cavity to be insulated.
3. Probe all wall cavities through holes, to identify fire blocking, diagonal bracing, and other obstacles. After probing, drill or cut whatever additional holes are necessary to ensure complete coverage.
4. Start by insulating several full-height, unobstructed wall cavities with a known quantity



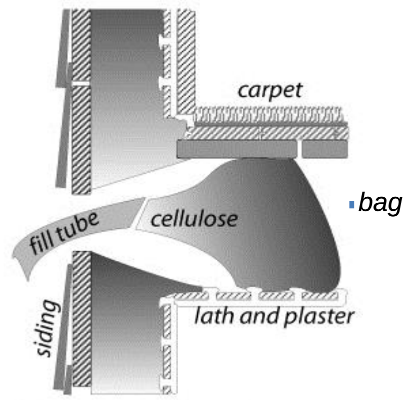
Tube-filling walls: This method can be accomplished from inside or outside the home. It is the preferred wall insulation method because it is a reliable way to achieve a uniform coverage and density.

of insulation so the installed density can be calculated and the blower controls can be set properly.

Tube-filling walls: Insulation is dense-packed into walls using a fill tube inserted into the wall cavity.

5. Depending on the location of the hole, insert the tube all the way to one end of the cavity Start the machine and back the hose out slowly as the cavity fills. Work the hose back and forth in the cavity to pack the insulation tighter, if necessary.
6. Shut off the flow of material when approximately one foot of tube is remaining in the wall. Re-insert the tube to the opposite end of the cavity, and repeat Step 5. Shut off the flow of material when the cavity is completely full.
7. Plug the holes, seal the plugs to prevent water and air infiltration, and replace the siding.

When insulating balloon-framed walls or the band-joist areas on multi-story buildings, insulate the perimeter between the two floors by blowing insulation into each floor cavity to create an insulation plug. This technique also prevents air movement through the floor cavity.



Plugging a balloon-framed floor cavity: Blow a plug of insulation into balloon-framed second floor cavities.

If the process is requiring too much insulation, use the ***Bag Method***. See *Method A in Chapter 2 – Section 2.2.7* for information about the ***Bag Method***.

2.3.5 Dense-Packed Wall Insulation from the Interior

In homes where the walls cannot be insulated from the exterior, insulating from the interior may be necessary. Holes drilled for insulation must be returned to an appearance as close to original as possible, or so the result is satisfactory to the customer.

To insulate sidewalls from the interior:

1. Practice lead-safe work techniques. See *Lead Paint and Lead-safe Work in Chapter 5 – Section 5.4.8*.
2. When testing results require, follow asbestos protocols. See Chapter 9 (Health & Safety) of the Wisconsin Weatherization Program Manual for comprehensive asbestos policies.
3. Remove the baseboard or chair rail when possible to allow drilling. Use wood plugs and joint compound or quick-setting plaster to seal the holes before re-installing the baseboard or chair rail. Or, drill holes and stagger them by at least six inches up and down, which will reduce horizontal cracking in lath-and-plaster walls.
4. Use a non-conductive probe to determine where to drill into the next cavity.

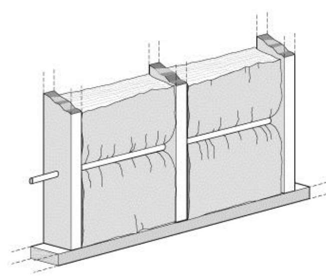
5. Insert a fill tube, and dense-pack the cavity following the procedures detailed in *Dense-Packed Wall Insulation from the Exterior in Chapter 2 - Section 2.3.4.*
6. Use wooden plugs along with joint compound or quick-setting plaster to seal and patch the holes.
7. Chair rail or wallpaper trim can be installed to conceal the holes if necessary.

2.3.6 Dense-Packing from Other Access Locations

Balloon-framed cavities can often be insulated from either the attic or basement where the cavity is open. In these cases, use a temporary dam to completely fill the cavity with dense-packed insulation, following the procedures described in *Installing Attic Insulation in 1½-Story Homes (Finished Attics) in Chapter 2 – Section 2.2.7.*

2.3.7 Interior Open-Cavity Wall Insulation

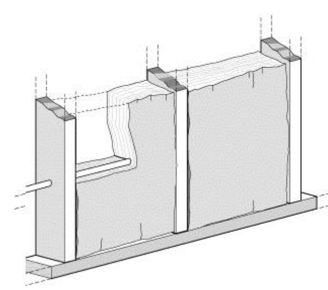
Fiberglass batts achieve their rated R-value only when installed correctly. If gaps exist between the cavity and batt at the top and bottom, or if the batt is compressed, the effective R-value can decrease by as much as 30 percent.



Fiberglass batts, compressed by a cable: This reduces the wall's R-value by creating a void between the insulation and interior wallboard.

To insulate open interior-wall cavities:

1. Prior to installing insulation, air-seal the exterior wall sheathing.
2. Use appropriately sized, un-faced friction-fit fiberglass batt insulation where possible.
3. Choose high-density batts whenever possible, and install to the maximum structurally allowable.
4. Install the batt to fill the entire cavity, without spaces at the corners or edges.
5. Cut batt insulation to the exact height of the cavity. A short batt creates air spaces above and beneath the batt, allowing convection. A long batt bunches up, creating air pockets.
6. Split batts around wiring, rather than letting the wiring bunch the batt to one side of the cavity.
7. Insulate behind and around obstacles with scrap pieces of batt.



Batt, split around a cable: The batt attains its rated R-value.

8. Prior to installing drywall, cover exposed un-faced insulation with an airtight polyethylene vapor retarder. Install the vapor retarder to the warm side of the wall.
9. Kraft- or foil-faced insulation exposed to the interior living space must be covered with minimum half-inch drywall or other material having an ASTM E84 flame spread rating of 25 or less. (Exception: Insulation with a Class A Facing with a flame spread of 25 or less.)

Dense-packed insulation may sometimes be blown into open stud cavities through an air barrier or plastic mesh. This is a good option if the insulation is packed densely enough to resist settling. The mesh will bulge if installed at the proper density; however, it could hinder drywall installation. Instead, consider cutting holes in the drywall to tube-fill the cavities with dense-packed insulation after installing drywall.

2.4 Crawl Space Requirements

Crawl spaces are usually small and difficult areas to complete work. Agencies should have a written policy for the minimum working requirements to effectively complete the necessary work in a crawl space.

2.4.1 Crawl Space Access Requirements

When creating new access to a crawl space, the following access sizing guide should be implemented:

Access Type	Size
Floor access	18" x 24"
Perimeter wall access	16" x 24"

A new access may need to be smaller if the existing framing members constrain work. Do not disturb framing or structural systems to install the access hatch.

2.4.2 Crawl Space Signage

A laminated sign, at least 8½" x 11" in size, should be posted at every access, inside of the crawl space. The sign will include the following information:

- ✓ Contact information for the installer.
- ✓ List of mechanical components installed in the crawl space.
- ✓ Statement prohibiting the storage of hazardous and flammable materials.
- ✓ Caution statement for those entering the crawlspace not to damage the air barrier, ground moisture barrier, and/or insulation.
- ✓ Installer contact information will be included on the sign in case there are questions or need for repairs.

2.5 Floor and Foundation Insulation

Insulation and air sealing of the foundation combine to complete the thermal boundary at the base of the building. As parts of the foundation are identified and defined as inside of the thermal and pressure boundaries, it is very important to ensure exposed soil is covered with a ground moisture barrier. Assess the crawl space ground area for health and safety issues and debris that could potentially damage the ground moisture barrier. Properly dispose of any identified items. Install a ground moisture barrier in accordance with 2012 *IRC* N1102.2.4 and 2012 *IRC* AF103.4.10 (minimum 6 mil in thickness) over exposed earth. Install a thicker ground moisture barrier if items are present in the crawl space that could reduce the effectiveness and durability of the barrier. Overlap the seams of the ground moisture barrier a minimum of 12 inches with a “reverse shingle” or “upslope lapping” technique (e.g., overlapping so water that leaks through the foundation wall will not flow in between the seams). Seal all seams, and around all penetrations. Install the wall vapor retarder under the ground moisture barrier at the wall to floor connection. The air barrier and ground moisture barrier should not interfere with the established drainage pattern. Interior drainage collection points must remain accessible.

Ensure the ground moisture barrier is not damaged when installed or when performing work. Seal holes and rips with the appropriate materials if it is damaged in the work process.

If an existing drain is present, the installed ground moisture barrier should not prevent flow of moisture to the drain.

The choice between insulating the floor or the foundation should be made based on accessibility and if heating distribution or plumbing runs through the area. Basements are generally not insulated during weatherization, but sealing is typically required to stop air infiltration. For other considerations, see *Locating the Pressure/Thermal Boundary in Chapter 1 – Section 1.5.3*.

2.5.1 Establishing a Thermal Boundary

To establish an effective thermal boundary, the insulation and air barrier should be adjacent to each other, with the air barrier located between the insulation and the conditioned space.

In most Northern climates, the preferred method is to insulate and air seal the foundation walls and not the floor. This includes sealing crawl space vents. This strategy encloses the furnace, ducts, pipes, and other features within the thermal and pressure boundaries.

Insulating and air sealing rim joist: Rigid board insulation installed in joist cavities, with spray foam to seal at the edges.

2.5.2 Rim Joist and Sill-Box Insulation

The joist spaces at the perimeter of the floor can be a weak point in the thermal boundary. Insulating both the rim joist and longitudinal box joist are appropriate either as individual procedures or as part of floor or foundation insulation.

Air seal stud cavities in balloon-framed homes as a part of insulating the rim joist. If the sill box will be insulated, two-part foam can be useful as it insulates and air-seals in one application. One primary advantage of two-part foam is its ease of installation in areas of limited accessibility. Follow the foam manufacturer's installation instructions and applicable building codes when installing two-part foam. Before applying spray foam, ensure the substrate is dry and reasonably clean. Do not apply more than 3 inches of spray foam in the sill-box area.

Use appropriate personal protective equipment (PPE) when installing two-part foam. Follow the manufacturer recommendations for safety precautions. See *Personal Protective Equipment in Chapter 5 – Section 5.1 and the General Information on Spray Polyurethane Foam (SPF) Appendix A-4* for additional information.

Rigid board insulation is also good for insulating and air sealing the rim-joist area. If foam board is used to insulate the rim, spray foam can be used to seal around the edges. Longitudinal box-joist cavities, enclosed by a floor joist, may be sealed and blown with wall insulation unless there is evidence of a moisture problem in the area. If the insulation will be in direct contact with the foundation, cellulose insulation should not be used to prevent potential moisture issues.

Use faced fiberglass batt insulation with caution. Air can circulate around the fiberglass, causing condensation and encouraging mold on the cold rim joist. Fiberglass batts may be used to insulate the rim joist only when:

1. The sill box is effectively air-sealed.
2. The batts are cut to the proper size and completely fill the cavity.

2.5.3 Floor Insulation

Prior to insulating the floor, take all appropriate measures to establish an effective air barrier at the floor, in order to prevent air from passing through or around floor insulation.

Insulating Open Floor Cavities

Install a ground-moisture barrier that runs up the foundation walls at least six inches in crawl spaces. Seal the ground-moisture barrier to the foundation wall with appropriate material, and seal all penetrations.

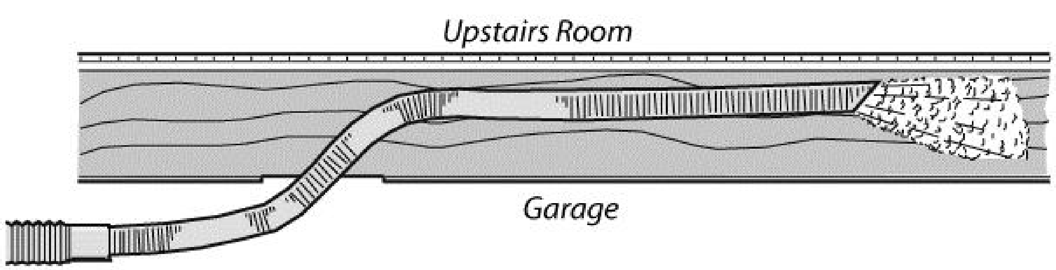
Caution: Moisture barriers are typically for use in crawl spaces. In basements, restrict their use to basements with dirt floors and limited access. If the ground-moisture barrier is installed in a seldom-used basement, install walk boards to prevent residents from slipping. Problems such as plumbing leaks or bad site drainage must be addressed prior to installing the barrier, to avoid water pooling on or under the barrier.

Complete the following when insulating open floor cavities:

1. If the walls are balloon-framed, contain wall insulation by air sealing the bottoms of the stud cavities prior to installing floor insulation.
2. Install the maximum thickness of insulation between floor joists that the structure allows. Fill the entire joist space if possible. Fit floor insulation tightly against the subfloor and the rim joist to reduce air convection.
3. Install insulation without voids, edge gaps, or end gaps. Fit insulation closely around cross bracing and other obstructions.
4. Securely support batt insulation within each cavity with insulation hangers, plastic mesh, a vapor-permeable air barrier, or other supporting material.
5. Seal and insulate ducts remaining in the crawl space or unoccupied basement. See *Forced-Air Furnace Air Distribution in Chapter 3 – Section 3.4* for information on sealing and insulating ductwork.
6. Consider installing a vapor-permeable air barrier to prevent convective looping, support the insulation, and keep pests out.

Insulating Enclosed Floor Cavities

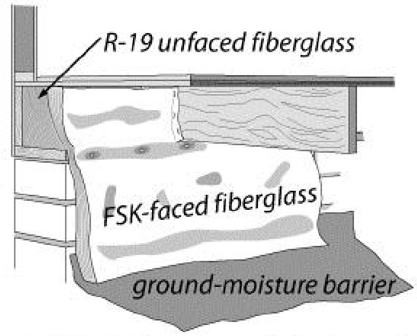
Install dense-pack insulation in floor cavities. Confirm the cavities are enclosed by rigid sheeting. This method works well in garage ceilings, cantilevered floors, and beneath bay windows.



Blowing a garage floor cavity: Uninsulated floor cavities can be insulated with blown fiberglass or cellulose insulation, using a fill tube.

2.5.4 Foundation Insulation

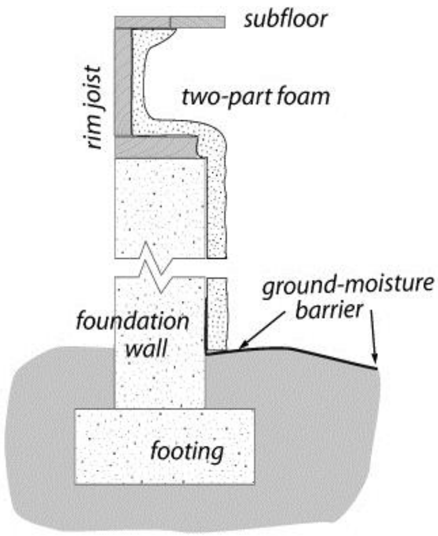
Foundation insulation is usually installed on the inside of the foundation wall. Less frequently, foundation insulation is applied from the home's exterior. Where termite pressure may exist, removable band joist insulation will be installed.



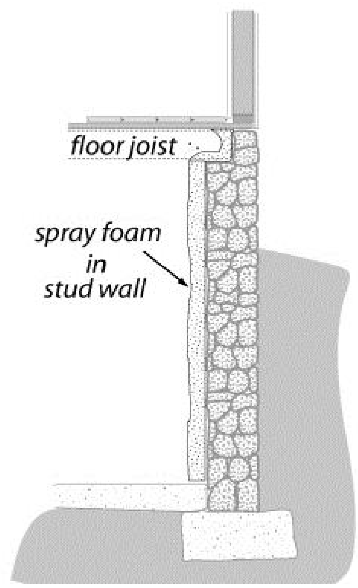
Fiberglass foundation insulation: Use this method only in dry conditions where the drainage outdoors is effective.

Interior Foundation Insulation

1. Attach insulation to the inside wall surface with appropriate fasteners and/or adhesive. Install insulation with no significant voids or edge gaps.
2. Foil Scrim Kraft (FSK) fiberglass insulation should be attached to the sill plate, floor joists, and/or floor. Insulate the rim joists with un-faced fiberglass before installing the FSK-faced insulation to prevent a void behind the FSK insulation at the rim joist.
3. Securely attach extruded or expanded polystyrene or foil-faced polyisocyanurate insulation boards when installed on flat foundation walls.



Foam-insulated crawl space: Two-part foam insulates and seals the rim joist as well as insulating the foundation walls.



Two-part foam sprayed on rubble masonry: Rubble masonry walls can be insulated on the interior with sprayed foam.

4. Spray two-part foam on the interior surface of the foundation to maintain the required insulation level. This may require application of more than one coat to assure full curing of the material. Take proper precautions for the safety of the crews and occupants during installation. Follow the manufacturer's recommendations for application and for safety equipment to be used. Follow all applicable building codes. When applied

correctly, two-part foam will insulate and air seal the foundation. Typically, two-part foam expands to twice the thickness of the initial application, so be careful not to over-insulate. See the *General Information on Spray Polyurethane Foam (SPF) in Appendix A-4* for additional information.

5. In cold weather, apply a skim-coat of foam first, before fully spraying the wall. The skim-coat will heat up the wall, which will help the foam adhere to the wall.
6. When two-part foam is used, a thermal barrier is required to separate the foam plastic from the living area. Thermal barriers can be applied to a wall that separates crawl space insulation from a basement. For buildings with only a crawl space, the plywood flooring serves as the separation.
7. Attach outside access hatches securely to the foundation wall, latched and weather-stripped. The hatch should be lockable. Insulate the hatch only when it is part of the thermal boundary.

Exterior Foundation Insulation

1. Install exterior foam insulation to a minimum depth of six-inches below grade, unless restricted by non- excavatable ground, such as a sidewalk. Apply a durable covering or coating to the entire surface of the insulation, including joints and corners.
2. Completely cover the exposed foundation with insulation.
3. All connecting joints must form a seal or be sealed with appropriate sealant.
4. If the insulation is not protected by the siding, install a drip edge.

Final Inspection and Quality Assurance Standards

Acceptable installations shall meet the following standards.

Attic Insulation

Attic Insulation Storage Area

1. The storage area is as small as possible and still meets the homeowner's needs.
2. Floor plugs installed if needed.
3. The insulation installed beneath the storage area is a minimum of R-19.
4. The storage area presents no hazards to occupant.
5. Items in the storage area were protected from insulation.
6. Floor boards were re-installed properly.

Damming and Boxing

1. The dam is the same height or higher than the surrounding insulation.
2. The dam is effective in performing its specified function.
3. When necessary, the dam is constructed of non-combustible material.
4. The chimney dam is at least two inches from an active chimney or per manufacturer's instructions.
5. Active chimneys meet chimney guidelines (e.g., no cracking, no creosote present, structurally sound, etc.)

Attic Access

1. Allows for repeated access to attic.
2. All trim is properly sealed and weather-stripped.
3. Access panel is insulated to same R-value as the attic or the maximum structurally allowable, whichever is lower.
4. Access is covered with an appropriate fire rated material, such as $^5/_8$" drywall (as required by code).

Attic Bypass Sealing

1. Bypasses are sealed to the level called for under Wisconsin's Weatherization Program requirements.
2. Bypasses are sealed with an appropriate material and amount of material.
3. All equipment mounted in the ceiling is properly air sealed.

Roof Leaks

1. No visible evidence of roof leaking is present.

Attic Wiring

1. All electrical boxes are covered, sealed, and flagged if concealed by insulation.
2. All live knob-and-tube wiring is boxed out prior to insulation, the boxing ends are sealed, and the boxing is flagged.
3. Rewired (permit pulled, if applicable) and inspected (if required).

Heat Producing Products (lights, chimneys, flues, attic furnaces)

1. Boxing is a minimum of three inches from device. Boxing material is gypsum wallboard, cement board, or other code-approved material.

Exhaust Fans and Vent Stacks

1. Vents will exhaust the specified area to the outdoors.
2. Stacks are properly sealed at intersection with building materials.

Attic Vapor Retarders

1. Installed correctly toward the warm side.
2. Installed in continuous manner, with edges sealed.

Attic Venting

1. Allows air to pass through vent.
2. Installed vents are higher than the insulation material.
3. Vents are made of corrosion-resistant material appropriate for their specific location.
4. Vents have screens with non-corroding wire mesh with openings of $^1/_{16}$" to ¼" to prevent pest entry (e.g., birds, bats, and bees).

Attic Floor Insulation, Open Blow

1. Installed to the R-value selected by the audit.
2. Insulation is installed to a uniform R-value, with no variances of greater than two inches.
3. All wiring is properly flagged, no bare wiring, junction boxes have covers.
4. Live knob-and-tube wiring is properly dammed, maintaining 3 inch clearance to insulation.
5. Insulation depth markers are in place and insulation certificate is properly posted.

Attic Cavities (site built)

1. All areas specified are insulated.

Knee Wall Attic Walls

1. All cavities are filled with insulation to the maximum structurally allowable, so that no voids are present.
2. The permeable air barrier seams and edges are sealed, and it is mechanically fastened.

Sidewall Insulation (site built)

1. All cavities are properly insulated to the maximum allowable amount and proper density. When cavities are dense-packed to reduce air leakage, artificial smoke does not move through penetrations when the building is pressurized to 50 Pascals.
2. Blown insulation is installed from the exterior or the attic unless limited by the building structure or health and safety issues, with prior approval of the building owner.
3. Based on file documentation (photos), work has been completed in a lead safe manner.
4. All siding that is suspect ACM has been addressed under the supervision of a competent person.

Sidewall Wiring

1. All hazards are addressed prior to insulating.

Floors Over Unheated Areas (site built including cantilevers)

1. Insulated to the maximum structurally allowable. When cavities are dense-packed to reduce air leakage, artificial smoke does not move through penetrations when the building is pressurized to 50 Pascals.
2. Vapor-permeable air barriers may be used on the cold side of the insulation.
3. Weather and pest-proof cover between cantilever insulation and the outside.

Sill Box Insulation

1. Area is sealed and filled to the R-value selected by the audit.

Interior Foundation Insulation

1. Area is insulated to the R-value selected by the audit.
2. If two-part foam is installed, there must be a thermal barrier between the area of application and living area of the building, including in unintentionally heated basements.
3. Continuous ground moisture barrier covers all exposed soil surfaces and is sealed to the wall.

Exterior Foundation Insulation

1. A minimum of R-5 insulation installed.
2. NEAT documentation in the file.
3. Depth of the insulation is at least six inches and not greater than 14 inches.
4. Material has protective coating at least six-inches below grade.
5. An effective drip edge makes a positive seal between the foundation and the wall assembly.

Chapter 3: Heating System Measures

3.1 Heating Systems

This chapter covers improvements to heating systems. The improvements include the replacement or the modification and repair of the appliance. Complete combustion safety testing for all systems and steady-state efficiency (SSE) testing on gas and oil heating systems. All heating system work shall be completed by qualified professionals.

3.2 General Heating System Replacement

All replacement heating systems, except for wood space heaters, shall meet the minimum efficiency standards as specified in the Wisconsin Weatherization Program Manual and listed in the AHRI Directory of Certified Product Performance. Wood heater installation shall conform to the requirement of NFPA 211. Observe the following standards for heating system replacement:

1. Disconnect refrigerant lines, plumbing, ducts, electric, control wires, vents, and fuel supply, when applicable.
2. Install heating systems in accordance with manufacturer's instructions and applicable state and local codes.
3. Use existing distribution system and fuel supply line, when possible.
4. Properly remove and dispose of existing unit.
5. Provide an owner's manual with heating system replacements on or near the heating system. The manual shall be attached in a durable device that allows for repeated customer access.
6. Properly size replacement heating systems units using an accurate analysis through REScheck, ACCA Manual J, or an equivalent industry-accepted sizing procedure.
    a. When sizing boiler systems, consider the capacity of the existing terminal devices and whether or not domestic hot water will be heated with the boiler.
7. Install gas pipe that is supported and electrically bonded (if required) in accordance with NFPA-54 and the WI Uniform Dwelling Code. Follow the manufacturer's specifications for installation. For more information see NFPA-54 and WI SPS 323.16.
    a. When CSST is already present in the building and not correctly bonded, bond the gas piping system to the electrical ground in accordance with NEC 250.94 and 250.104.
8. New heating systems require a dedicated electrical circuit rated or fused to match the amperage of the system's requirements for overcurrent protection. Condensate pumps are allowed to be on the same circuit.

9. Verify and make adjustments, if necessary, so flue-gas oxygen, stack temperature, and carbon-monoxide levels are within manufacturer's specifications. If manufacturer's specifications are not available, refer to *Table 3-2* or *Table 3-5*.
10. Install condensate tubing or piping to reach an appropriate drain. Utilize a hose protection ramp (trip strip) instead of a condensate pump where feasible.
11. Install a condensate pump when the condensate tubing will not drain adequately to an appropriate drain or may cause a tripping hazard. See *Condensate Removal* in *Chapter 3 – Section 3.8.2* for more information about condensate pumps.
12. Seal openings in chimneys where natural-draft or fan-assisted appliances are eliminated. Indicate with a written notice on the chimney, where sealed, that the chimney is no longer functional.
13. Ensure all remaining naturally-vented combustion appliances are drafting properly.
14. Test the heating system's safety mechanisms to confirm they are operating properly and per the manufacturer's specifications (e.g., blower compartment's safety switch and emergency heat circuit are functioning, etc.).
15. Provide in-home operation and maintenance instructions, including a review of safety precautions to the customer.
16. Affix a tag, displayed prominently, identifying who the customer should call for service to the heating unit. The tag information shall contain the name, address, and telephone number of the service organization as well as the date of installation.
17. WHEN A HEATING SYSTEM IS LOCATED IN A CRAWL SPACE: Complete and inspect all heating system work before performing any other measures in the crawl space.

3.3 Forced-Air Furnace Replacement

Observe the following standards specific to forced-air furnace installation:

1. Set fan speed and fuel input for optimal occupant comfort within the manufacturer's temperature rise limits.
2. Perform all required tests and document results.
3. Seal holes through the jacket of the air handler with mastic or foil tape that is UL181 listed.

3.4 Forced-Air Furnace Air Distribution

Forced-air duct systems present opportunities for saving energy in homes. Ducts waste energy through airflow problems, and from air leaks and lack of insulation when they pass through unconditioned spaces. This section addresses these forced-air distribution problems.

3.4.1 Duct System Modification

If adjusting the fan speed and gas pressure do not bring the furnace temperature rise within manufacturer's specifications, duct work modifications may be considered.

Ductwork runs installed to provide heat to individual spaces shall be as short as possible. The placement of a register shall be where it is least likely to be blocked by furniture or other obstacles.

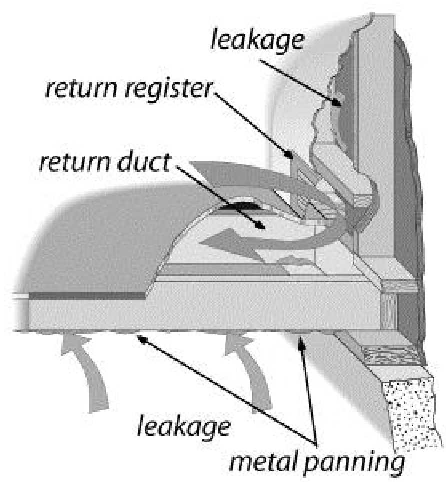
If possible, a single return air grill shall be provided to a central location on the main floor that is heated, with the shortest ductwork run possible. If another floor is heated that can be closed off from the main floor, an additional return air grill may be installed with the shortest ductwork run possible to a central location. This may not apply to a basement when back-drafting or other health and safety risks or efficiency issues are present.

1. Design new ducts in accordance with ANSI/ACCA Manual D and manufacturer's specifications.
2. Design terminations in accordance with ANSI/ACCA Manual T and manufacturer's instruction.
3. Do not add supply registers to the combustion-appliance zone (CAZ) unless it is an intentionally heated space. Consult with the customer about removing existing grills in the CAZ. If grills are removed, document the customer consultation in the file.
4. Mechanically fasten supply and return ductwork with screws. Seal the ductwork to the furnace cabinet with mastic and fabric mesh tape, caulk, or other UL 181-approved material, to form an essentially airtight connection on all sides of these joints.
5. Do not install new ductwork in unconditioned spaces unless necessary. If ducts are located in unconditioned spaces, seal the joints and insulate the ducts to a minimum R-11.
6. Connect new ducts to the existing distribution. Install a balancing damper in each new branch supply duct. Install registers to terminate each new supply or return branch duct.
7. Do not use building spaces, like basements or crawl spaces, as a plenum or duct.

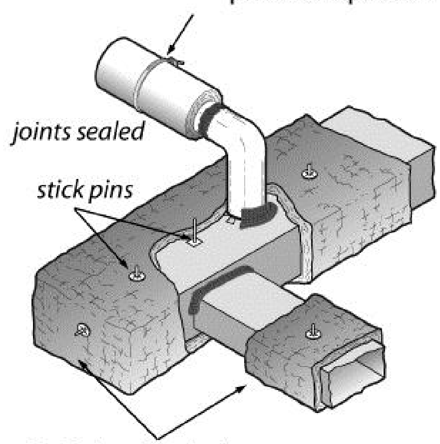
3.4.2 Duct Leakage

Leaky ductwork poses multiple problems: it may affect the occupants' health and safety, comfort, and the home's energy consumption.

Seal all heating and cooling ductwork that runs outside the dwelling's heated envelope. These duct leaks waste energy, and introduce health and safety hazards.



Panned floor joists: These return ducts are often very leaky and may require removing the panning to seal the cavity.



In the CAZ, return-ductwork leakage causes depressurization and increases the possibility that natural-draft appliances will backdraft. Supply-side leaks in the CAZ are less likely to cause backdrafts; rather, they may aid the appliances' natural draft by adding positive pressure to the room.

Duct leakage that occurs inside the heated envelope is less likely to contribute to increased energy consumption. Supply duct leakage to outside can introduce excessive moisture into unheated spaces and depressurize the CAZ. Return duct leaks from unheated spaces can draw pollutants into the distributed air causing health issues for the occupants in the home.

Follow these instructions when sealing ductwork:

1. Seal all ducts located outside the thermal boundary.
2. Seal the connection between the furnace and the supply plenum, as well as the connection between the furnace and the return drop.
3. Seal all gross holes in the supply and return ductwork. Repair/replace missing ducts in the return and supply systems.
4. Seal return and supply leaks as needed based on guidance in the Diagnostic Workbook.

Materials for Duct Air Sealing

Duct mastic is the preferred duct-sealing material because of its superior durability and adhesion. Apply mastic at least $^{1}/_{16}$-inch thick and use reinforcing mesh or UL 181-approved tape for all joints wider than $^{1}/_{8}$ inch or joints that may experience some movement. Silicone or siliconized acrylic-latex caulk is acceptable for sealing wood-to-wood joints in panned joist spaces that function as return ducts.

Joints should rely on mechanical fasteners to prevent joint movement or separation. Tape alone will not hold a joint together, and it will not resist the force of compacted insulation or joint movement. Aluminum foil tape or cloth duct tape are not good materials for duct sealing because their adhesive often fails after a short time.

3.4.3 Duct Insulation

Insulate forced-air ducts that run through unconditioned areas with foil-faced duct insulation with a minimum value of R-11. Ducts may be insulated with two-part foam products that meet the federal specification for duct insulation. If two-part foam is used, workers must ensure all duct seams are sealed to assure the air stream does not come in contact with the foam.

Do not apply duct insulation to ducts that will be surrounded by R-11 or more of loose-fill insulation. Before installing the loose-fill insulation, make sure to seal these ducts.

Do not insulate ducts that run through conditioned areas unless they cause overheating in winter or condensation in summer.

Follow these steps when installing duct insulation:

1. Perform necessary duct sealing before insulating ducts.
2. Insulate all exposed forced-air ducts in unconditioned areas, so no significant areas of bare duct are left un-insulated.
3. Fasten insulation mechanically, using stick pins,
twine, plastic straps, or other appropriate materials. Tape the joints in the insulation to prevent air convection, and apply mastic over the tape to increase the tape's longevity.

3.4.4 Measuring System Airflow

Furnace airflow significantly affects the temperature rise. Excessive airflow (low supply air temperature) may cause customer-comfort issues. Low airflow is a more common problem in forced-air duct systems.

Insufficient airflow may cause short cycling or, in severe cases, failure of the heat exchanger. The most common causes of low airflow are an oversized furnace, a dirty filter, a dirty A-coil, registers or grilles that are blocked, fuel input set too high, fan speed set too low/too high, supply ducts that are too small or are restricted, and inadequate or restricted return ducts. *Table 3.1* shows recommended minimum airflow for various forced air systems. When airflow is lower than the recommended minimum, the system is likely to have a temperature rise that is higher than the maximum specified by the manufacturer.

Table 3-1: Recommended Minimum Airflow *(in CFM)*

Furnace Size in kBtu	Natural Draft	Fan-Assisted Draft	Sealed Combustion
40	400	520	600
50	500	650	750
60	600	780	900
75	750	975	1,125
100	1,000	1,300	1,500
	Multiplier		
kBtu x	10	13	15
To calculate the estimated minimum airflow for a furnace, multiply the input kBtu by the multiplier for the type of furnace. (e.g., 40 x 15 = 600 CFM)			

Preparing to Measure Airflow

Sophisticated test instruments are not necessary to discover that filters, air-conditioning coils (A-coils), or blowers are packed with dirt or the branch duct to the master bedroom is disconnected. Diagnose these problems before measuring duct airflow. The following steps precede airflow measurements:

1. Ask the customer about comfort problems and temperature differences in various parts of the home.
2. Based on the customer's comments, look for disconnected or restricted ducts.
3. Inspect the filter(s), blower fan, and A-coil for dirt. Clean them if necessary. If the A-coil is not easily visible, a dirty blower fan is a fair indicator that the A-coil may also be dirty.

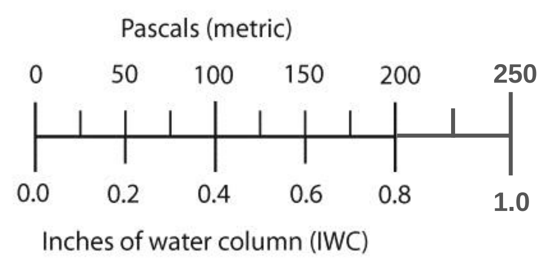
Flow-Plate Method for Measuring System Airflow

The flow-plate meter is a plate with holes and sampling tubes that work in conjunction with a digital manometer to measure the velocity and static pressures inside the ductwork. The manometer then converts these values into an estimate of the distribution airflow.

The flow-plate meter will contain metering plates that can be configured to fit inside all standard-size filter slots. Whenever possible, make sure the plate is not bigger than the return cutout in the furnace. See the instruction manual for the flow-plate meter for specific directions on its use.

Measuring External Static Pressure

Perform this test if initial temperature rise and CO test results are outside of manufacturer's specifications and additional investigation is needed. External static pressure (ESP) is the difference between pressures in the supply and return ductwork. ESP is the airflow resistance caused by items external to the furnace cabinet. The ESP test can be used to identify existing ductwork issues such as insufficiently sized ductwo



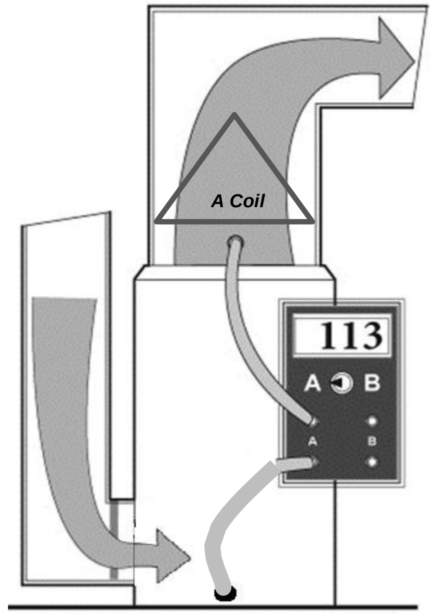
Pressure in two measurement systems: Technicians and engineers are both Pascals (metric) and inches of water column to measure duct pressures.

Testing for ESP also allows for estimation of airflow if the furnace manufacturer's fan tables for static pressure and airflow are available.

ESP equals the sum of the absolute values of the static pressures in the supply and return sides. For example, a supply-side static pressure of +30 Pascals and a return-side static pressure of -80 Pascals indicate an ESP of 110 Pascals (80 + 30 = 110). The supply-side static pressure will always be a positive number, and the return-side static pressure will always be a negative number. The larger the ESP, the lower the airflow at a given fan speed.

The ESP test requires a static-pressure probe, a pressure hose, and a digital manometer. Follow these steps to test the ESP of a forced-air heating system:

1. Install a clean furnace filter into the filter slot. If one is not available, remove the existing furnace filter if it is plugged or excessively dirty.
2. Drill one hole in the supply plenum, above the furnace cabinet and below the A-coil drain pan (if present). The hole must be large enough to accommodate a static-pressure probe. If the A-coil is mounted directly to the furnace, in order not to drill a hole in the coil or drain pan, drill a hole in the very top of the furnace cabinet. Be sure not to drill through a furnace baffle or heat exchanger. Ensure the hole goes through the insulation inside the furnace cabinet.



External static pressure (ESP): The positive and negative pressures created by the resistance of the supply and return ducts produces ESP. The measurement shown here simply adds the two static pressures without regard for their signs. As ESP increases, airflow decreases. Numbers shown here are for example only.

External Static Pressure

ESP (IWC)	0.3	0.4	0.5	0.6	0.7	0.8
CFM	995	945	895	840	760	670

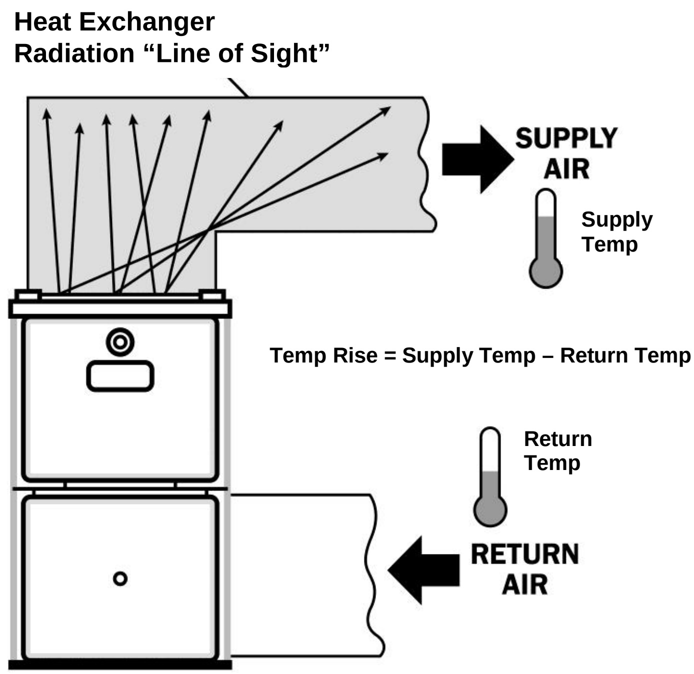
3. Drill one hole into the back of the blower cabinet. The hole must be large enough to accommodate a static-pressure probe. Be sure not to drill into wiring or other objects by removing the blower cabinet door to visually select a location free from obstacles. Ensure the hole goes through the insulation inside the blower cabinet.
4. Set the digital manometer to “PR/PR” mode, and attach a pressure hose to the Channel A input tap. (The “UNITS” button can be used on the monometer to measure Inches of Water Column).
5. Attach the static-pressure probe to the hose. Insert the probe into each of the holes and record the test result for each hole.
6. Add the absolute values of the two test results, treating each result as if it were a positive number. This sum is the ESP for the heating system.
7. The higher the ESP measurement, the lower the airflow will be (assuming no change in the air handler’s speed setting). The manufacturers’ maximum recommended ESP is usually 0.50 IWC for standard air handlers. As ESP increases above 0.50 IWC, the likelihood of insufficient airflow increases. A very high ESP (over 1.0 IWC) may indicate an oversized furnace, the presence of constricted or insufficient ductwork, a plugged A-coil or furnace filter, or other distribution-system issues.

Use the ESP test as a guide, along with customer conversations and the airflow and temperature-rise tests, in determining whether the heating system has sufficient airflow.

3.4.5 Measuring Temperature Rise

Temperature rise is the temperature difference between the supplied air and the return air. This test is critical in determining if the furnace is set up and operating properly. Perform the test after the furnace has reached steady state and the ductwork has heated up.

Measure the return temperature by inserting the thermometer in the return drop prior to the filter. Measure the supply temperature in a main duct within 6 feet of the supply plenum without being in the line of sight of the heat exchanger. When there are multiple main ducts, measure the temperature in each branch and use the highest reading.



3.4.6 Filters

Observe the following standards related to furnace filter installation.

1. Supply the customer with MERV 6 or higher furnace filters. Provide either:
   a. Six one- to two-inch replaceable filters (install one of them in the furnace); or
   b. One washable filter (installed); or
   c. One deep-pleated filter (installed).
2. Confirm filters are held firmly in place and provide complete coverage of the blower intake or the return register.
3. Ensure filters are easy to replace.
4. Confirm the heating system has a sealing filter cover, and install a new one if none exists. Construct the new filter-slot cover so it can be removed easily and safely. Confirm the filter is easy to access and replace. Magnetic filter covers are allowed only if they provide an adequate seal to the ductwork to prevent air leakage.

3.5 Boiler Replacement

Complete all tests on the Hot Water Boiler Replacement Check List and document results.

Follow these specifications when replacing boilers:

1. To size a replacement system accurately, consider the home's design-temperature heat loss, the room-by-room heat loss, and the home's existing radiation capacity. In situations of insufficient radiation capacity, the home may need more heat emitters to optimize the new system's efficiency and to heat all rooms adequately.
2. Flush the existing distribution system per manufacturer's instructions or until the water runs clean and is free of sediment. Verify proper pH and sediment values as provided by manufacturer. With a zoned system, flush each zone separately.
3. Install isolation valves at accessible points in the supply- and return-pipe connections and as near to the boiler as is convenient and practical to permit draining the boiler without emptying the system. These valves can also serve for filling the system and purging air from separate zones.
4. Locate new zone valves or zone circulating pumps near the boiler. Confirm each zone has its own shut-off valve.
5. Install a pressure-relief valve (PRV) per manufacturer's instructions. Confirm the PRV is rated and sized correctly for the boiler BTU input and maximum operating pressure.
6. Install an automatic fill valve, if none is present.
7. The feed-water (inlet) side of the pressure-reducing feed valve shall have a backflow preventer, with a shut-off valve installed upstream from the backflow preventer, and the boiler (outlet) side of the pressure-reducing feed valve also shall have a shut-off valve to allow for maintenance or replacement without draining the boiler system.
8. The backflow preventer drain shall face the floor.
9. The system shall have an adequately sized expansion tank on the supply side of the boiler. Install an expansion tank or fill the existing expansion tank and the system to the correct level.
10. Install the circulator pump near the downstream side of the expansion tank to prevent the suction side of the pump from depressurizing the piping.
11. Verify return-water temperature is appropriate:
    a. For oil boilers, verify return-water temperature is above 150° F.
    b. For non-condensing gas boilers, verify return-water temperature is above 130° F, to prevent acidic condensation within the boiler.

12. Install piping bypasses, mixing valves, primary-secondary piping, or other strategies as necessary to prevent condensation.
13. For condensing boilers, install condensation-resistant venting with condensation drains designed into the venting system per the manufacturer's specifications.
14. Insulate all pipes on the circulating loop between the boiler and an indirect domestic water heater.
15. When installed on a floor below grade, a new boiler shall be installed above known flood levels and as high as practical to avoid damage in case of flooding.
16. Inspect the chimney for deterioration and correct sizing. Repair and reline the chimney as necessary.
17. With standard-efficiency boilers, install a full-closure electric vent damper where feasible.

3.5.1 High-Efficiency (≥ 90%+) Boilers

High-efficiency boilers often present significant energy-saving opportunities as compared with standard-efficiency boilers. Similar to ≥90% efficient furnaces, high-efficiency boilers cause water vapor in the exhaust gases to condense, which releases extra heat and raises its efficiency potential above 90 percent. (High-efficiency systems are often referred to as "condensing" systems.)

To size a replacement system accurately, consider the home's design-temperature heat loss, the room-by-room heat loss, and the home's existing radiation capacity. In situations of insufficient radiation capacity, the home may need more heat emitters to optimize the new system's efficiency and to heat all rooms adequately.

With a high-efficiency boiler, the return water acts as a coolant for the exhaust gases. The lower the temperature of the return water, the more the exhaust gases cool — which in turn increases the amount of water that condenses out of the exhaust, and thus increases the boiler's efficiency. For this reason, lower return-water temperatures correlate with increased efficiencies.

Outside air temperature sensors are installed with a boiler to allow the boiler controls to sense the actual outside temperature. Outdoor reset is a control function allowing the boiler to adjust the supply-water temperature to the minimum needed to heat the building at a given outside temperature. When the boiler limits its heat output to the dwelling's actual need, the lower return-water temperature increases condensation and increases the boiler's efficiency.

High-efficiency boilers require regular maintenance. Some high-efficiency boilers are especially vulnerable to problems with the distribution water — namely, dirt/debris/sediment/rust in the water and/or an improper pH level, both of which can lead to plugged heat exchangers and other issues. Educate customers and make sure they understand the maintenance requirements.

Follow these additional instructions when installing high-efficiency boilers:

1. Verify flue-gas O_2 percent or CO_2 and CO ppm are within the manufacturer's ranges for both high and low fire.
2. Equip the boiler with an outside air temperature sensor installed on a north-facing exterior wall. Determine the outdoor temperature above which the boiler should not operate and set high temperature shutoff to match.
3. Program the modulating boiler's heating curve in line with the dwelling's heat loss, outdoor design temperatures and radiation capacity.
4. Ensure the chemistry of the distribution water meets manufacturer's specifications. Testing may include pH, hardness/total dissolved solids (TDS), or inhibitor treatment.

3.6 Hydronic Distribution Systems

Hydronic distribution systems consist of the supply and return piping, the circulator, expansion tank, air separator, air vents, and heat emitters. A properly designed and installed hydronic distribution system can operate for decades. Many systems; however, have installation flaws or need service.

Boiler piping and controls present many options for zoning, boiler staging, and energy-saving controls. Dividing homes into zones, with separate thermostats, can significantly improve energy efficiency over operating a single zone. Modern hydronic controls can provide hot water for heating to different zones at different times with varying heating loads in the zones.

Follow these instructions for hydronic distribution systems:

1. Inspect radiators. Repair or replace as necessary.
2. Bleed air from radiators and from the entire system.
3. Confirm the distribution system has no leaks.
4. Modify the distribution system as necessary to work properly with the replacement boiler.
5. The system shall have automatic and manual air-bleed valves to eliminate air from all high points in the distribution-piping system.
6. Extend new piping and radiators to conditioned areas, like additions and finished basements currently heated by space heaters.

Zone valves: A separate thermostat controls each zone valve. When a thermostat calls for heat, the boiler fires and the zone valve opens.

7. Install thermostatically controlled radiator valves on the major radiators; or zone controls; or outdoor reset and boiler controls to adjust supply-water temperature according to outdoor temperature, if feasible for the boiler system. Modulating pumps on multi-zoned systems may be considered.
8. Insulate all supply piping outside conditioned spaces. For hot-water systems, install 1½-inch fiberglass insulation on all pipes less than or equal to 1½ inches in diameter, and 2 inch fiberglass insulation on all pipes greater than 1½ inches in diameter. For steam systems, install 1½ inch fiberglass insulation on all pipes less than or equal to 1½ inches in diameter, and 3 inch fiberglass insulation on all pipes greater than 1½ inch in diameter.

3.7 Boiler Efficiency and Maintenance

Boilers can maintain good performance and efficiency for many years if they are regularly maintained and tuned-up. Boiler performance and efficiency improve after effective maintenance and tune-up procedures.

Modern high-efficiency boilers require annual maintenance to achieve optimum performance and life expectancy. For information about boiler installation, see *Boiler Replacement in Chapter 3 - Section 3.5.*

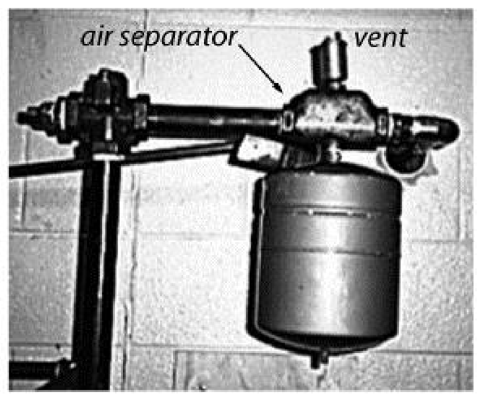
Boiler performance and efficiency deteriorate in more ways than in forced-air furnaces. Specifically these are:

1. Corrosion, scaling, and dirt on the water side of the heat exchanger.
2. Corrosion, dust, and dirt on the fire side of the heat exchanger.
3. Excess air during combustion from air leaks and incorrect fuel-air mixture.
4. Off-cycle air circulation through the firebox and heat exchanger, removing heat from stored water.

Consider the following maintenance and efficiency improvements for both hot water and steam boilers:

1. Check for leaks on the boiler, around its fittings, or on any of the distribution piping connected to the boiler.
2. On a steam boiler, inspect the water gauge glass for erosion, cracks, or drying. Damaged gauge glass on the boiler should be replaced in accordance with manufacturer specifications. Remove, clean, and replace the gauge glass when dirt or sediment is coating it and making it difficult to observe the water level of the boiler.
3. Clean noticeable dirt from the fireside of the heat exchanger.
4. Check doors and cleanout covers for air leakage. Replace gaskets, warped doors, or warped cleanout covers.
5. Drain water from the boiler drain until the water flows clean.

Safety Checks and Improvements



Expansion tank, air separator, and vent: Preventing excessive pressure and eliminating air from the systems are important for hydronic distribution systems.

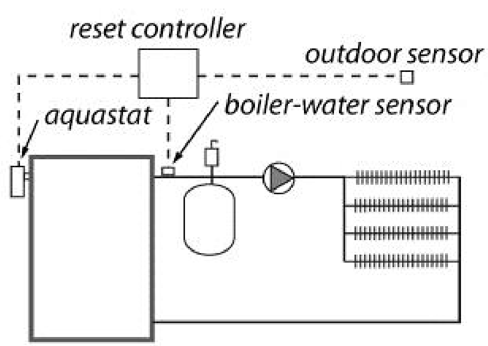
1. Confirm the existence of a 30 psi-rated pressure-relief valve. Replace a malfunctioning valve or add one if none exists. Note signs of leakage or discharges, and find out why the relief valve is discharging.
2. Make sure the expansion tank is not waterlogged or sized too small for the system. This could cause the pressure-relief valve to discharge. Test expansion tank for acceptable air pressure — usually 12 to 22 psi.

   Note: A hot-water boiler is recognized by its expansion tank, located somewhere above the boiler. The expansion tank provides an air cushion to allow the system's water to expand and contract as it is heated and cooled without creating excessive pressure in the boiler piping, and discharging through the pressure-relief valve.
3. If rust is observed in the venting, verify return water temperature is above 130° F for gas and above 150° F for oil, to prevent acidic condensation.
4. Verify the system does not cycle on high limit.
5. Lubricate circulator pump(s) if necessary.

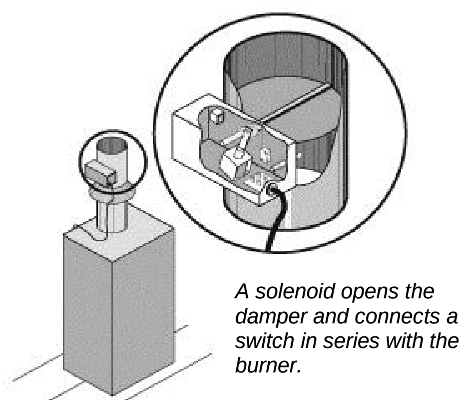
Efficiency Improvements

1. Repair water leaks in the system.
2. Remove corrosion, dust, and dirt on the fireside of the heat exchanger.
3. Check for excess air during combustion from air leaks and incorrect fuel-air mixture.
4. Confirm the boiler does not have low-limit control for maintaining a minimum boiler-water temperature, unless the boiler is heating domestic water in addition to space heating.
5. Bleed air from radiators and piping through air vents on piping or radiators.
6. Consider installing outdoor reset controllers on non-high efficiency boilers to regulate water temperature, depending on outdoor temperature.
7. After control improvements like two-stage thermostats or reset controllers, verify return-water temperature is high enough to prevent condensation and corrosion in the chimney s noted previously.
8. Vacuum and clean fins of fin-tube convectors if dust and dirt is present.
9. Consider installing full-closure electric vent dampers on natural-draft gas- and oil-fired high-mass boilers.

Purging air: Trapped air collects at the hot-water system's highest parts. Bleeding air from radiators fills the radiator and gives it more heating surface area.



Reset controller: The circulating-water temperature is controlled by the reset controller according to the outdoor temperature.



Vent dampers: Electric vent dampers close the chimney when the burner isn't firing, preventing circulating air from carrying the boiler's stored heat up the chimney.

3.8 Gas-Fired Heating Systems

3.8.1 Gas-Fired Heating-System Installation

The general procedures outlined in *General Heating-System Replacement in Chapter 3 – Section 3.2*, should be followed. Complete all tests on the Replacement Gas Furnace Check List and document results.

When replacing a gas-fired heating system:

1. Confirm the clearances to nearby combustibles of the heating unit and its vent connector conform to NFPA 54.
2. Clock the gas meter if necessary to troubleshoot oxygen, flue-gas temperature, carbon monoxide, or temperature-rise problems, and to verify the actual gas input matches with the nameplate input rating. Adjust gas input if necessary. See *Measuring BTU Input on Natural-Gas Appliances in Chapter 3 – Section 3.8.3.*
3. Check the input gas pressure on the furnace when all gas-fired appliances are operating in the house to ensure no drop-off in required gas pressure. If the input is significantly different than the rating on the nameplate, all other variables above can be affected.
4. Measure manifold gas pressure to ensure it stays within the manufacturer's specified range. Adjust the fuel-air mixture for the lowest CO output and maximum SSE.
5. Follow manufacturer's venting instructions, along with the NFPA 54 to establish a proper venting system.
6. Follow manufacturer's instructions for proper removal of condensate. See *Condensate Removal in Chapter 3 – Section 3.8.2*.
7. Install a proper sediment trap on the gas line, if none exists.
8. When fuel switching from oil to gas, place the old oil tank out of service in accordance with Wisconsin Administrative Code ATCP 93.315.

3.8.2 Condensate Removal

Condensate is routed away from the furnace in one of two ways:

1. Running condensate tubing or piping directly from the furnace to an appropriate drain (Preferred Method); or
2. Pumping the condensate from the furnace to an appropriate drain using an electric **condensate pump**.

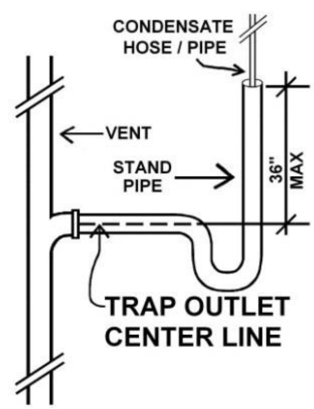
Whenever feasible, pipe directly from the furnace to the floor drain, without installing a condensate pump. Mechanically fasten the piping, either to the floor-drain strainer or to the floor itself. Ensure the piping will not pose a tripping hazard to the occupants. Installing a "trip strip," with the customer's approval, may be useful to prevent occupants from tripping over the piping.

Sometimes, a direct-piping strategy will not be feasible. There may not be a drain near the furnace, or perhaps the piping would pose a tripping hazard to the occupants. In these situations, installing a condensate pump is likely a better option. See the next section for information about condensate pumps.

Condensate Pumps

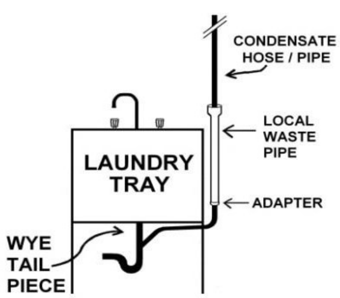
A condensate pump is installed when direct piping to an approved drain is not feasible. Condensate pumps may be installed using existing receptacles, new ground-fault circuit interrupter (GFCI) receptacles, or directly wired in accordance with pump manufacturer's requirements. Inspect the entire condensate system for leaks after installation. Insulate the condensate drain system when it is located in an unconditioned area or has the potential to form condensation. If a condensate pump is installed in a finished area, a secondary drain pan should be installed with a safety feature to disable the heating system if the pump fails. Condensate is a slightly acidic byproduct of combustion. Plumbing code requires it to be drained to the sanitary sewer system, and not to the ground or to a sump pump. Code allows condensate to go to a floor drain, a stand pipe, or an indirect or local waste pipe served by a stand pipe or the laundry tray tail piece. An air gap is required where the condensate line enters the receptor. The condensate line cannot be go directly into any drainpipe. See SPS 382.33 for Wisconsin code provisions regarding condensate drains.

Floor drain: The floor drain is the most common method for discharging condensate. Condensate lines that run to the drain must be secured to the floor to keep them in place. This method works best when the drain is not in a typical path of foot traffic.



STAND PIPE

Stand pipe: The laundry stand pipe is often the best place to discharge condensate. If the opening is not large enough for the washing machine hose and the condensate line, an adapter can be added to enlarge the top of the pipe. A stand pipe cannot exceed 36 inches in height above the centerline of the horizontal drainpipe. If an existing standpipe is not an option, a new stand pipe, trapped and vented, is acceptable. This option should be the last choice, as the trap can dry out if the heating system does not discharge condensate over an extended time. If a washing machine could be discharged into the stand pipe, extend the standpipe at least 18 inches above the centerline of the horizontal drainpipe.

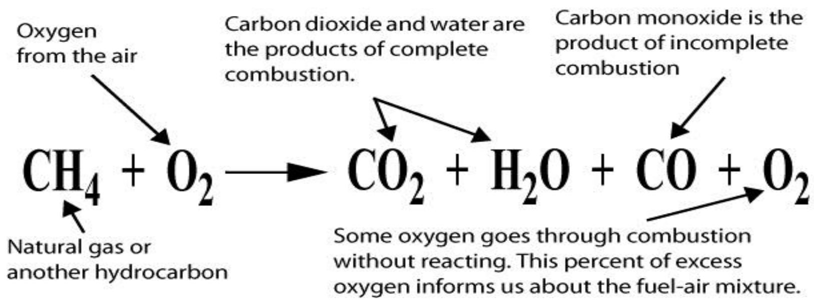


Indirect or local wastepipe: A vertical pipe that uses the trap of a stand pipe or laundry tailpiece is considered an indirect or local wastepipe. It needs to be higher than the flood line of the laundry tray or stand pipe. This method can also be used if the existing standpipe is full of other hoses.

3.8.3 Testing and Servicing Gas-Fired Systems

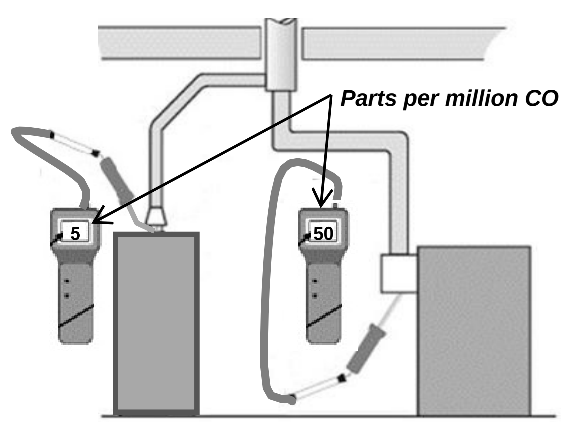
Gas burners should be cleaned and tuned every two to four years. Sometimes a maintenance schedule will be posted on an existing heating system, allowing assessment of the heating-system maintenance history (or lack thereof).

The goals of these service measures are to reduce CO, to optimize fuel-air mixture, and to confirm the operation of safety controls. Complete all tests on the Heating System Repair or Clean and Tune Check List and document results.

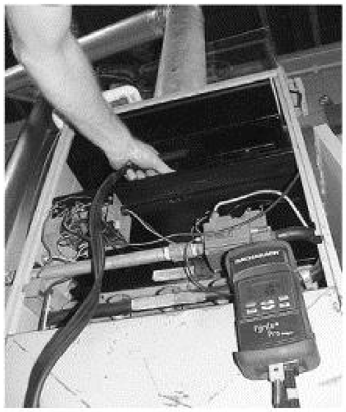


Perform the following inspection and maintenance procedures, as necessary, on gas-fired furnaces, boilers, water heaters, and space heaters:

1. Inspect for soot, melted wire insulation, melted grommets, and rust in the burner and manifold area outside the firebox. These all are indicators of flame rollout, combustion-gas spillage, and CO production.
2. Inspect the burners for dust, debris, misalignment, flame impingement, and other flame-interference problems. Clean, vacuum, and adjust as needed.
3. Inspect the heat exchanger for leaks.
4. Verify heating system wiring connections are enclosed in covered electrical boxes.
5. Determine the pilot is burning (if equipped) and main burner ignition is satisfactory.
6. Sample the undiluted combustion gases with a calibrated flue-gas analyzer and record steady-state efficiency, O_2 percentage, CO ppm (as-measured), and flue-gas temperature.



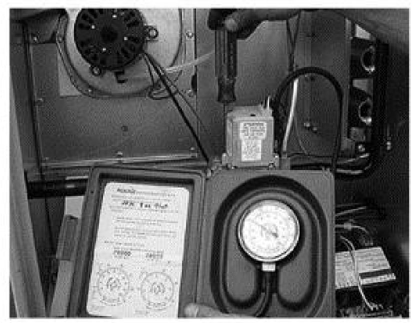
Sampling combustion gases: Sample combustion gases at the exhaust vent of the appliance before dilution air mixes with the gases.



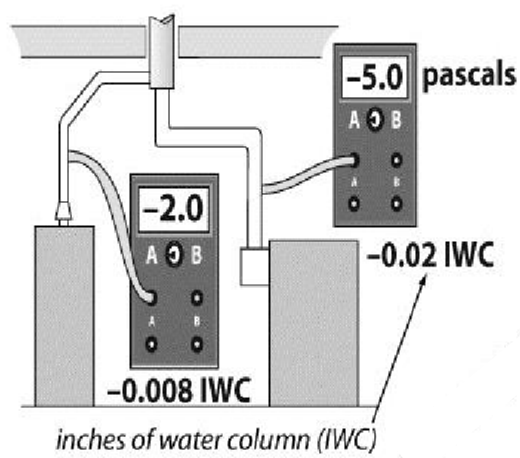
Testing older furnaces: Insert the probe into the draft diverter near the exhaust ports of the heat exchanger.

Testing 80+ furnaces: Drill a quarter-inch hole in the metal vent connector to sample combustion gases.

7. Clock the natural-gas meter, with all other gas appliances off, to confirm the input BTUs to the furnace or boiler match with the nameplate rating. Adjust gas pressure if necessary. See *Measuring BTU Input on Natural Gas Appliances in Chapter 3 – Section 3.8.3* for clocking the meter.
8. Clean the air handler ("squirrel cage") and the air-handler cabinet. Adjust the air handler's speed setting, if necessary, to ensure adequate airflow and to ensure temperature rise is within the manufacturer's specifications.
9. Test pilot-safety control for complete gas-valve shutoff when pilot is extinguished.
10. When testing is complete, seal all test holes.
11. Verify the thermostat's heat-anticipator setting matches the measured current in the 24-volt control circuit.
12. Check venting system for proper size and pitch.
13. Check venting system for obstructions, blockages, or leaks.
14. Measure chimney draft downstream of the draft diverter and check for spillage.
15. Measure gas input, and observe flame characteristics if soot, CO, or other combustion problems are present.



Adjusting gas pressure: Adjusting gas pressure is the only way to change the fuel-air mixture.



Measuring draft: Measuring chimney draft downstream from the draft diverter.

A common furnace-efficiency problem is low fuel input and high O_2 percentage, resulting in poor heat transfer. This condition will be detected by combustion testing and clocking the natural-gas meter. See the standards for O_2 percentage and flue-gas temperature in *Table 3-2*.

Flue-gas temperature is another important indicator of furnace performance. A low flue-gas temperature usually indicates efficient performance, since less of the heat is leaving the building. If the flue-gas temperature is too low in older furnaces or 80+ furnaces; however, acidic condensation will form in the vent. This acidic condensation can rust metal vents and damage masonry chimneys.

Adjust gas pressure and airflow in order to optimize gas input, O_2 percentage, flue-gas temperature, and SSE. These adjustments are best made while monitoring the exhaust gas with the combustion analyzer.

Table 3-2: Typical Ranges for Gas Burning Appliances

Performance Indicator	SSE 80+	SSE 90+
Carbon monoxide (CO) (ppm) as-measured *OR*	≤ 100	≤ 100
Carbon monoxide (CO) (ppm) air-free	≤ 200	≤ 200
Stack temperature (°F)	325° - 450°	90° - 120°
Temperature rise (°F)	40° - 70°	30° - 70°
Oxygen (O_2)	4-9%	4-9%
Gas pressure output at manifold - Inches of Water Column (IWC)	3.2 – 3.9	3.2 – 3.9
Propane pressure output at manifold (IWC)	10 – 11	10 – 11
Steady state efficiency (SSE)	82 – 86%	92 – 97%
Supply temperature (°F)	120° - 140°	95° - 140°

Proceed with burner maintenance and adjustment when any of the following are present:

1. CO is greater than 100 ppm as measured or 200 ppm air-free
2. Visual indicators of soot or flame roll-out exist
3. Burners are visibly dirty

Troubleshooting CO

CO Exceeds Limit in One Chamber

1. Open the primary air shutter of the burner where CO is above acceptable limits.
2. Clean that burner and/or pilot assemblies.
3. Align the burner and/or pilot assembly to eliminate impingement
4. Check orifice size and alignment.
5. Check for flame movement and cracks in the heat exchanger.

CO Exceeds Limit in Two Chambers

1. Confirm combustion air source.
2. Check venting system and heat exchanger for blockages.
3. Open primary air shutter on each burner.
4. Clean burners and/or pilot assembly
5. Check orifice size and gas pressure.
6. Measure the appliance input and adjust if necessary.

Carbon Build-up in Heat Exchanger

1. Clean out carbon build-up.
2. Clean all other combustion surfaces including burners, pilot assembly, orifice, and baffles.
3. Inspect heat exchanger for cracks.
4. Reassemble the furnace:
   a. Set primary air openings.
   b. Check gas pressure and orifice size.
   c. Align, position, and level burners.
5. Check venting system and heat exchanger for blockages.
6. Measure the appliance input and adjust if necessary.

Procedures Fail to Reduce CO Below Limit

Re-check the Following Upon:

1. Primary air adjustment.
2. Burner level, alignment, and position.
3. Combustion air source.
4. Gas pressure is correct for type of fuel.
5. Appliance input is altitude adjusted.
6. Venting system is free of obstructions.
7. Heat exchanger is intact.
8. No flame impingement present

Table 3-3: Combustion Problems and Possible Solutions

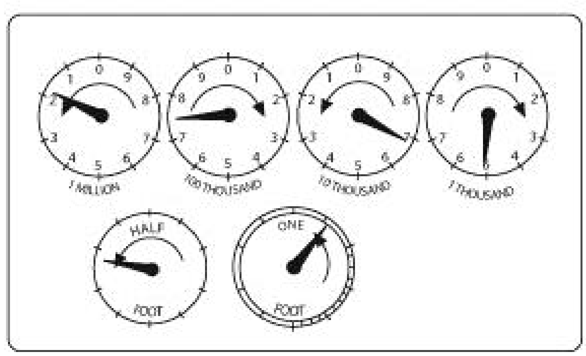
Problem	Possible Causes and Solutions
Weak draft with CAZ depressurization	Return duct leaks, clothes dryer, exhaust fans, other chimneys. Seal return leaks. Provide make-up air.
Weak draft with no CAZ depressurization	Chimney blocked or leaky or else CAZ are too airtight.
Carbon monoxide	Mixture too rich or too lean. Adjust gas pressure. Check chimney and combustion air for code compliance.
Stack temperature or temperature rise too high or low	Adjust fan speed or gas pressure. Improve ducts to increase airflow.
Oxygen too high or low	Adjust gas pressure, but don't increase CO level.

Gas-burner maintenance includes the following measures:

1. Remedy the causes of CO and soot. These causes may include over-firing, closed primary air intake, flame impingement, and lack of combustion air.
2. Remove dirt, rust, and other debris that may be interfering with the burners. Clean the heat exchanger, if necessary.
3. Take action to improve draft, if inadequate because of improper venting, obstructed chimney, leaky chimney, or depressurization. See *Improving Inadequate Draft in Chapter 3 – Section 3.13.1*.
4. Seal leaks in vent connectors and chimneys.
5. Adjust gas input if combustion testing or clocking the gas meter indicates over-firing or under-firing.

Measuring BTU Input on Natural-Gas Appliances

1. Turn off gas supply to all gas-combustion appliances not being tested (such as heating systems, water heaters, dryers, cook stoves, space heaters, etc.) that are connected to the meter being timed.
2. Fire the appliance being tested, and watch the dials of the gas meter.
3. Carefully count how long it takes for one revolution of the ½-, 1-, or



Gas meter dial: Use the number of seconds per revolution of the one-foot dial and the table on the following page to find the appliance's input.

2-cubic-foot dial. Find that number of seconds in the columns marked “Seconds per Revolution” in *Table 3-4*. Follow that row across to the right to the correct column for the ½-, 1-, or 2-cubic foot dial. Multiply the number in the table by 1000. Record the input in thousands of BTUs per hour. *For gauging a ¼-cubic-foot dial, count how long it takes for 4 revolutions. Then, use the 1-cubic-foot column to determine the input.*

4. If the measured input is higher or lower than input on the nameplate by more than 10 percent, adjust gas pressure up or down, within the ranges in *Table 3-3*, until the approximately correct input is achieved. **CAUTION:** Consult with fuel supplier before adjusting pressure at meter.
5. For LP gas, determine the orifice size. From Table E.1.1 of the National Fuel Gas Code, find the input BTU value that corresponds with the orifice size. Multiply the listed BTU value by the number of orifices to get the input BTU for the heating system.
6. If the measured input is still out of range after adjusting gas pressure to these limits, replace the existing orifices with larger or smaller orifices sized to give the correct input. Any changes done to orifices must follow manufacturer’s instructions.

Table 3-4: Input in Thousands of Btu/hr for 1000 Btu/cu. ft. Gas

Seconds per Revolution	Size of Meter Dial			Seconds per Revolution	Size of Meter Dial			Seconds per Revolution	Size of Meter Dial		
	½ cu. ft.	1 cu. ft.	2 cu. ft.		½ cu. ft.	1 cu. ft.	2 cu. ft.		½ cu. ft.	1 cu. ft.	2 cu. ft.
15	120	240	480	40	45	90	180	70	26	51	103
16	112	225	450	41	44	88	176	72	25	50	100
17	106	212	424	42	43	86	172	74	24	48	97
18	100	200	400	43	42	84	167	76	24	47	95
19	95	189	379	44	41	82	164	78	23	46	92
20	90	180	360	45	40	80	160	80	22	45	90
21	86	171	343	46	39	78	157	82	22	44	88
22	82	164	327	47	38	77	153	84	21	43	86
23	78	157	313	48	37	75	150	86	21	42	84
24	75	150	300	49	37	73	147	88	20	41	82
25	72	144	288	50	36	72	144	90	20	40	80
26	69	138	277	51	35	71	141	94	19	38	76
27	67	133	267	52	35	69	138	98	18	37	74
28	64	129	257	53	34	68	136	100	18	36	72
29	62	124	248	54	33	67	133	104	17	35	69
30	60	120	240	55	33	65	131	108	17	33	67
31	58	116	232	56	32	64	129	112	16	32	64
32	56	113	225	57	32	63	126	116	15	31	62
33	55	109	218	58	31	62	124	120	15	30	60
34	53	106	212	59	30	61	122	130	14	28	55
35	51	103	206	60	30	60	120	140	13	26	51
36	50	100	200	62	29	58	116	150	12	24	48
37	49	97	195	64	29	56	112	160	11	22	45
38	47	95	189	66	29	54	109	170	11	21	42
39	46	92	185	68	28	53	106	180	10	20	40

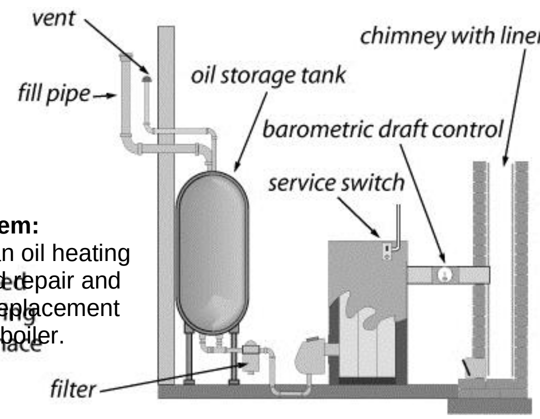
3.8.4 Leak-Testing Gas Piping

For information on leak-testing gas piping, *see Leak-Testing Gas Piping in Chapter 5 – Section 5.4.5*.

3.9 Oil-Fired Heating Systems

3.9.1 Oil-Fired Heating-System Installation

The general procedures outlined in *General Heating System Replacement in Chapter 3 - Section 3.2* should be followed when replacing an oil heating system. Complete all tests on the Oil Replacement Furnace Check List and document results.



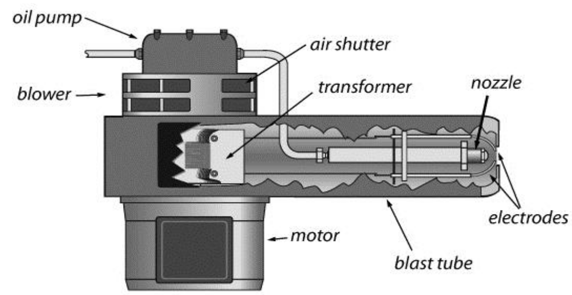
Oil heating system: Components of an oil heating system may need repair and cleaning during replacement of the furnace or boiler.

When replacing an oil furnace:

1. Properly size the nozzle based on the post-weatherization conditions, using REScheck®, Manual J, or an equivalent industry-accepted sizing formula. Document the nozzle size on the inside of the furnace cabinet, next to the furnace nameplate.
2. Examine the existing chimney and vent connector for suitability as venting for the new appliance. The vent connector may need to be resized, and the chimney may need to be relined.
3. Confirm the clearances to nearby combustibles of the heating unit and its vent connector conform to NFPA 31.
4. Test oil pressure, and verify it complies with the manufacturer's specifications.
5. Test control circuit amperage and adjust the thermostat's heat anticipator to match.
6. Test smoke number to confirm it meets manufacturer's specifications. See *Table 3-5.* Install a new fuel filter, and purge the fuel lines.
7. Verify the chimney operates safely and in accordance with NFPA 211.
8. Confirm the tank and oil lines comply with NFPA 31.

3.9.2 Testing and Servicing Oil-Fired Systems

Oil burners require annual maintenance to retain their operational safety and combustion efficiency. Testing for steady-state efficiency, draft, carbon monoxide, and smoke should be used to guide and evaluate maintenance. These clean-and-tune procedures pertain to oil-fired furnaces, boilers, and water heaters.



Oil burner operation: For continual and complete burning of the oil, oil is pumped through the nozzle to create a specific spray pattern that is ignited by properly spaced electrodes carrying 10,000 volts from the transformer.

Oil-Burner Inspection and Testing

Evaluate oil-burner operation by visually inspecting and combustion testing the system. An oil burner passing visual inspection and giving good test results may need minimal maintenance. If the test results are fair, adjustments may be necessary. Unsatisfactory test results may indicate the need to replace the burner or the entire heating unit.

Follow these steps to improve oil-burner safety and efficiency:

1. Inspect burner and appliance for signs of soot, overheating, fire hazards, corrosion, or wiring problems.
2. Equip all oil-fired heating systems with a barometric draft control.
3. Confirm the oil heating system has a dedicated electrical circuit.
4. Enclose all 120-volt wiring connections in covered electrical boxes.
5. Inspect fuel lines and storage tanks for leaks.
6. Inspect the heat exchanger and combustion chamber for cracks, corrosion, or soot buildup.
7. Check to see if the flame ignition is instantaneous or delayed. The flame ignition should be instantaneous, except for pre-purge units where the blower runs for a while before ignition.
8. Sample undiluted flue gases with a smoke tester, following the smoke-tester instructions. Compare the smoke smudge left by the gases on the filter paper with the manufacturer's smoke-spot scale to determine smoke number. *With a smoke number of two or higher, do not use the electronic combustion analyzer.*
9. Analyze the flue gas for O_2 percentage, temperature, CO ppm, and steady-state efficiency (SSE). Sample undiluted flue gases between the barometric draft control and the appliance. Adjust fuel-air mixture and airflow to conform to standards in *Table 3-5*.

10. Measure flue draft between the appliance and barometric draft control and over-fire draft at an opening to the firebox.

11. Measure high-limit shut-off temperature, and adjust or replace the high-limit control if the shut-off temperature is more than 200° F for furnaces or 180° F for hot-water boilers.

12. Measure the oil-pump pressure, and adjust to manufacturer's specifications if necessary.

13. Measure transformer voltage, and replace transformer if not within the allowable range.

14. Ensure barometric draft controls are mounted plumb and level, and the damper swings freely.

15. Time the CAD cell control or stack control to verify that the burner will shut off, within the time frame per manufacturer's specifications, when the CAD cell is blocked from seeing the flame.

Table 3-5: Typical Ranges for Oil Burning Appliances

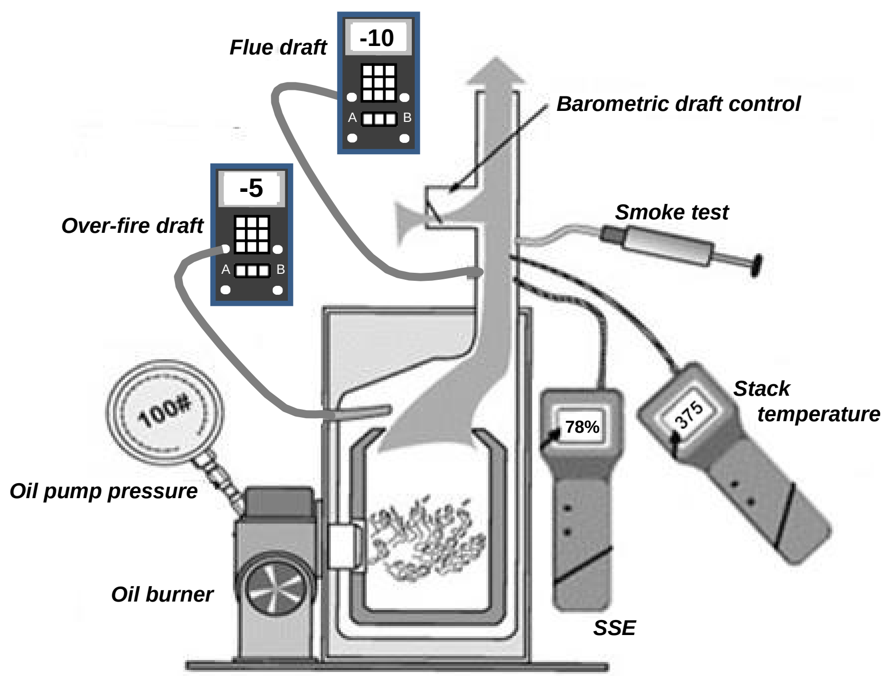
Performance Indicator	Non-Flame Retention	Flame Retention
Carbon monoxide (CO) (ppm) in flue gas	≤ 100 as-measured / 200 ppm air-free	≤ 100 as-measured / 200 ppm air-free
Stack temperature (°F)	325° - 550°	300° - 450°
Oxygen (O_2)	6-9%	5-9%
Smoke number (1-9)	≤ 2	≤ 1
Excess air (%)	≥ 80%	≥ 35%
Oil pressure pounds per square inch (psi)	≥ 100	100 -150
Over-fire draft (Inches of Water Column - IWC negative)	.02 IWC or 5 Pa	.02 IWC or 5 Pa
Flue draft (IWC negative)	.04 -.01 IWC or 10-15Pascals	.04 -.01 IWC or 10-15Pascals
Steady state efficiency (SSE)	≥ 75%	≥ 80%

Oil-Burner Maintenance and Adjustment

After evaluating the oil burner's initial operation, perform the following maintenance tasks as needed to optimize safety and efficiency:

1. Verify correct flame-sensor operation.
2. Replace the burner nozzle after matching the new nozzle's size to the home's post-weatherization heat-load requirements.
3. Clean the burner's blower wheel.
4. Replace oil filter(s).
5. Clean or replace air filter. See *Filters in Section 3.4.6* for guidance on providing furnace filters.
6. Remove soot and sludge from combustion chamber.

7. Remove soot from Heat exchanger surfaces.
8. Clean dust, dirt, and grease from the burner assembly.
9. Ensure the oil pump is set to the correct pressure.
10. Adjust barometric damper for a negative over fire draft of 5 Pascals or 0.02 IWC, per manufacturer's specifications.
11. Adjust gap between electrodes and their position in burner tube, per manufacturer's specifications.
12. Repair the ceramic combustion chamber, or replace it if necessary.
13. Inspect and clean the end of the burner-tube assembly. Replace flame-retention head if damaged.
14. Inspect and clean the transformer contacts to remove any corrosion.
15. Adjust air shutter to achieve O_2 and smoke values, specified in *Table 3-5*.



Measuring oil-burner performance: To measure oil-burning performance indicators, a manometer, flue-gas analyzer, smoke tester, and pressure gauge are required.

After these maintenance procedures, perform the diagnostic tests described previously to evaluate improvement made by the maintenance procedures and to determine if fine-tuning is required.

3.10 Electric Furnaces and Electric Baseboard Heat

In Wisconsin, electric baseboard heat is much more common than electric furnaces. Due to the high cost of electricity, these systems may be good candidates for fuel switching.

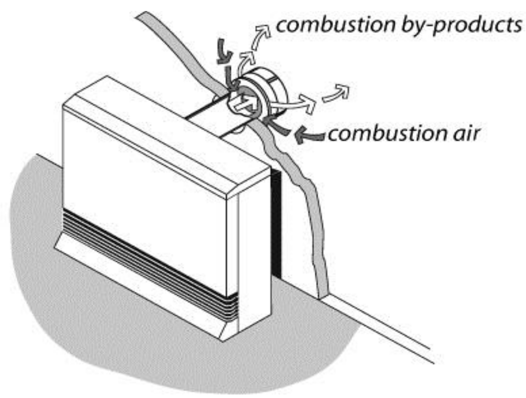
Caution: Disconnect power from electric furnaces before performing any maintenance.

1. Check or clean and lubricate the following components: thermostat, blower, housing around electric element, and baseboard fins.
2. Clean or replace all filters.
3. Take extra care in duct sealing and in duct-airflow improvements for electric furnaces because of the high cost of electricity.
4. Verify safety limits and temperature rise conform to manufacturer's specifications.

3.11 Replacing Space Heaters

When replacing a space heater:

1. Follow the manufacturer's venting instructions carefully. Do not vent sealed-combustion, induced-draft space heaters into naturally drafting chimneys.
2. If the space heater will sit on a carpeted floor, provide a fire-rated floor protector, sized to the width and length of the space heater, as a base.
3. Locate space heater away from traffic, draperies, and furniture.
4. Space heaters require a properly grounded duplex receptacle for electrical service.



Sealed combustion space heater: A sealed combustion space heater draws combustion air in and exhausts combustion by-products using a draft fan.

Inform the customer of the following operating instructions:

1. Do not store any objects near the space heater that would restrict airflow around it.
2. Do not use the space heater to dry clothes or for any purpose other than heating the home.
3. Do not allow anyone to lean or sit on the space heater.
4. Do not spray aerosols near the space heater. Many aerosols are flammable or can cause corrosion to the space heater's heat exchanger.

Space heater controls: Many modern energy-efficient space heaters have programmable thermostats as standard features.

3.12 Replacing Wood Stoves

Wood stoves with a crack or hole in the firebox should be replaced. Units that do not meet clearances and cannot be corrected should be considered for replacement. All replacement wood stoves must meet applicable local codes and EPA requirements. Installations must conform to the NFPA 211.

When replacing a wood stove:

1. Install the stove to meet manufacturer's specifications.
2. Verify the replacement stove is certified to meet EPA emission standards or local standards, whichever are stricter.
3. Confirm the installed unit is certified and labeled by:
   a. National Fire Protection Association under 211-1996
   b. Other equivalent listing organization
4. Visually inspect the chimney for safe operation by referring to NFPA 211.
5. Provide all customers with in-home operation instructions, to include proper wood-burning practices; safety information; and education about proper maintenance, such as stack thermometers and the need for fire extinguishers.
6. Educate the customers about the potential impact of exhaust ventilation and/or forced-air distribution on the wood heater's operation.

Install make-up air if the building is tightened below the Depressurization Limit CFM_{50}.

3.13 Venting Combustion Gases

Proper venting is essential to the operation, efficiency, safety, and durability of combustion heaters. The National Fire Protection Association (NFPA) and the International Code Council (ICC) are the authorities on material-choice, sizing, and clearances for chimneys and vent connectors, as well as for combustion air. The information in this venting section is based on the following NFPA and ICC documents:

- ✓ The International Fuel Gas Code (IFGC) (ICC)
- ✓ NFPA 31: Standard for the Installation of Oil-Burning Equipment
- ✓ NFPA 211: Standard for Chimneys, Fireplaces, Vents, and Solid-Fuel- Burning Appliances

Table 3-6: Guide to Venting Standards

Topic	Code Reference
Venting sizing	IFGC, Section 504
Clearances	IFGC, Section 308 and Tables 308.21 NFPA 31, Section 4-4.1.1 and Tables 4-4.1.1 and 4-4.1.2 NFPA 211, Sections 6.5, 4.3, 5
Combustion air	IFGC, Section 304 NFPA 31, Section 1-9; NFPA 211, Section 8.5 and 9.3

3.13.1 Improving Inadequate Draft

If measured draft is below the minimum worst-case requirement, investigate the reason for the weak draft. Open a window, exterior door, or interior door that is below the level of the heating appliance to observe whether the addition of make-up air will improve draft. If the added air strengthens draft, then the problem is usually depressurization. If opening a window has no effect, inspect the chimney. The chimney could be blocked or excessively leaky.

Chimney Improvements to Solve Draft Problems

Consider the following chimney improvements when attempting to improve worst-case draft:

1. Remove chimney obstructions.
2. Repair disconnections or leaks at joints and where the vent connector joins a masonry chimney.
3. Measure the size of the vent connector and chimney and compare with vent-sizing information listed in Section 504 of the International Fuel Gas Code. A vent connector or chimney liner, either too large or too small, can result in poor draft.
4. Increase the pitch of horizontal sections of vent, to facilitate the flue gases' movement toward the chimney.
5. Extend the flue's roof-jack. This option may be especially useful when the appliance's exhaust stack is short — for example, in a mobile home, or in a ranch home on a slab.
6. If wind is causing erratic draft, consider installing a wind-dampening chimney cap.

If the masonry chimney is deteriorated, consider installing a new chimney liner.

Duct Improvements to Solve Draft Problems

Consider the following duct and airflow improvements when attempt to improve worst-case draft:

1. Seal/remove any return grilles in the CAZ.

2. Install a sealing filter cover.
3. Seal return-duct leaks in the CAZ, using the diagnostic workbook to guide duct-sealing decision-making.
4. Isolate the furnace from its return registers by air sealing.
5. Install make-up air to the CAZ. Open a nearby window, exterior door, or interior door to observe whether the addition of make-up air will improve draft. If the open window or door improves draft to an acceptable level, measure the size of the opening, and install make-up air accordingly.

Table 3-7: Draft Problems and Solutions

Problem	Possible Solutions
Adequate draft never established	Remove chimney blockage, seal chimney air leaks, or provide additional combustion air as necessary.
Blower activation weakens draft	Seal leaks in the furnace and in nearby return ducts. Isolate the furnace from nearby return registers.
Exhaust fans weakens draft	Provide make-up or combustion air if opening a door or window to outdoors strengthens draft during testing.
Closing interior doors during blower operation weakens draft	Add return ducts, grills between rooms, or jumper ducts.

3.14 Combustion Air

A combustion-appliance zone is classified as either an **unconfined space** or as a **confined space as defined by the IFGC**. An unconfined space is a CAZ connected to enough building air leakage to provide combustion air. A confined space is a CAZ with sheeted walls and ceiling and a closed door that form an air barrier between the appliance and other indoor spaces.

For confined spaces, the IFGC prescribes additional combustion air from outside the CAZ. Combustion air is supplied to the combustion-appliance zone in four ways.

1. To an unconfined space through leaks within the building
2. To a confined space through an intentional opening or openings between the CAZ and other indoor areas where air transfers in to replenish combustion air
3. To a confined space through an intentional opening or openings between the CAZ and outdoors or ventilated intermediate zones like attics and crawl spaces
4. Directly from the outdoors to the confined or airtight CAZ through a duct. Appliances with their own direct combustion-air ducts are called **sealed-combustion** or **direct-vent** appliances.

Table 3-8: CFM Air Requirements for Combustion Furnaces or Boilers

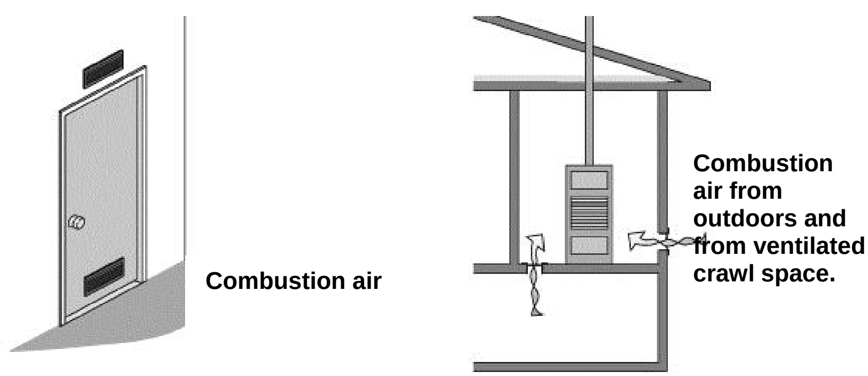
Appliance	Combustion Air (CFM)	Dilution Air (CFM)
Conventional Oil	38	195
Flame-Retention Oil	25	195
High-Efficiency Oil	22	-
Conventional Atmospheric Gas	30	143
Fan-Assisted Gas	26	-
Condensing Gas	17	-
Fireplace (no doors)	100-600	-
Airtight Wood Stove	10-50	-
A.C.S. Hayden, Residential Combustion Appliances: Venting and Indoor Air Quality Solid Fuels Encyclopedia		

3.14.1 Unconfined-Space Combustion Air

Combustion appliances located in most basements, attics, and crawl spaces get adequate combustion air from leaks in the building shell. Even when a combustion appliance is located within the home's living space, it usually gets adequate combustion air from air leaks, unless the house is airtight or the combustion zone is depressurized.

3.14.2 Confined-Space Combustion Air

A confined space is defined by the IFGC as a room containing one or more combustion appliances and which has less than 50 cubic feet of volume for every 1,000 BTUs per hour (BTUH) of appliance input.



Passive combustion-air options: Combustion air can be supplied from adjacent indoor spaces or from outdoors. Beware of passive combustion-air vents into the attic that could depressurize and combustion zone or allow moist air to travel into the attic.

If a small mechanical room is connected to adjacent spaces through large air passages like floor-joist spaces, however, the CAZ may not need additional combustion air, even with sheeted walls and a door separating it from other indoor spaces. The extent of the connection between the CAZ and other spaces can be confirmed by worst-case draft testing or blower-door testing.

On the other hand, if the home is unusually airtight, the CAZ may not be able to obtain adequate combustion air, even when the CAZ is larger than the minimum confined-space room volume, defined above.

In confined spaces or airtight homes where outdoor combustion air is needed, the best strategy is a single-vent opening installed as low in the CAZ as is practical. A combustion-air vent into an attic may depressurize the combustion zone or dump warm, moist air into the attic. Instead, connect the combustion zone directly to the outdoors or to a ventilated crawl space through a single low vent, if possible.

Choose an outdoor location that is sheltered, where the wall containing the vent is not parallel to prevailing winds. Wind blowing parallel to an exterior wall or at a right angle to the vent opening tends to de-pressurize both the opening and the CAZ connected to it. Indoors, locate combustion air vents away from water pipes to prevent the pipes from freezing.

3.14.3 Net-Free Area

Net-free area is the surface area of venting that remains open after subtracting for the blocking effect of louvers and grilles. Metal grilles and louvers are assumed to reduce the size of the vent opening to 75 percent of the original surface area. Wooden grilles and louvers are more restrictive, and they are assumed to reduce the net free area to 25 percent of the original surface area.

Manufacturers often provide specifications about the net-free area through their grilles and louvers. When this information is available, use it to calculate the size of opening required to provide the net free area necessary. When these specifications are not available, use the assumptions listed above.

For example, calculate a 10 inch by 10-inch opening (100 square inches) with a metal grille attached as having 75 square inches of net free area. With a wooden louver installed, to calculate the same opening use 25 square inches of net-free area.

When sizing vent openings, always account for the reduction in the net-free area that will occur due to the installation of grilles and louvers.

3.14.4 Sizing Combustion-Air Openings

Table 3-9 summarizes the required ratios of combustion-air net free area to appliance input (BTUH).

Here is an example of sizing two direct combustion-air openings to adjacent indoor space: The furnace and water heater are located in a confined space. The furnace has an input rating of 100,000 BTUH. The water heater has an input rating of 50,000 BTUH. Combined, the two appliances have an input rating of 150,000 BTUH. Therefore, each opening must have at least 150 square inches of net free area of venting between the mechanical room and adjacent indoor space (150,000 ÷ 1,000 = 150). There are two openings, so the CAZ will have a total of 300 square inches of net-free area of venting.

Table 3-9: Combustion Air Openings: Location and Size

Location	Dimensions
Two direct openings to adjacent indoor space	Minimum area each: 100 in^2 1 in^2 per 1000 BTUH each combined rooms volumes must be ≥S 50 ft^3 per 1000 BTUH
Two direct openings or vertical ducts to outdoors	Each vent should have 1 in^2 for each 4,000 BTUH
Two horizontal ducts to outdoors	Each vent should have 1 in^2 for each 2,000 BTUH
Single direct or ducted vent to outdoors	Single vent should have 1 in^2 for each 3,000 BTUH
From the *International Fuel Gas Code (IFCG).*	

If the same CAZ were ducted to the outdoors with a single opening, the requirement for the net-free area of venting would decrease to 50 square inches (150,000 ÷ 3,000 = 50 sq. in.).

When installing two combustion-air openings, the IFGC usually requires one opening commences 12 inches from the ceiling and one opening 12 inches from the floor. See IFGC 2012, Section 304.5 for a full breakdown of combustion-air requirements.

3.15 Thermostats

Set the thermostat's heat anticipator to the amperage measured in the control circuit, or follow the thermostat-manufacturer's instructions for adjusting cycle length.

3.15.1 Programmable Thermostats

A programmable thermostat may be a big energy saver if the occupants understand how to operate the thermostat. If the existing thermostat will be replaced as a part of the weatherization work, discuss this option with the occupant. If the occupant is willing to use a programmable thermostat, proceed with the installation. Educate the occupant on the use of the thermostat, and leave a copy of manufacturer's directions with them.

Final Inspection and Quality Assurance Standards

Heating system work shall meet the following standards.

Required Outcomes		
	Replacements	**Clean and Tune**
All Fuels and Types	1. The carbon monoxide concentration in the undiluted flue gas does not exceed 100 ppm as-measured or 200 ppm air-free, *or* is within manufacturer's specifications.	1. The carbon monoxide concentration in the undiluted flue gas does not exceed 100 ppm as-measured or 200 ppm air-free, *or* is within manufacturer's specifications.
Gas Systems	2. Test and set the gas pressure within the manufacturer's specifications.	2. Test and set the gas pressure within the manufacturer's specifications
Oil Systems	3. The smoke test: ≤ 1 for flame retention burner systems and ≤ 2 for non-flame retention burner systems using a smoke-spot scale	3. The smoke test: ≤1 for flame retention burner systems and ≤2 for non-flame retention burner systems using a smoke-spot scale.
Forced-Air	4. The temperature rise is within the manufacturer's specification.	4. The temperature rise is within the manufacturer's specification.
All Boilers	5. O_2 and CO (or CO_2) values are within manufacturer's specified range. 6. Non-condensing boiler: The stack temperature is at least 300° F to minimize condensation in the chimney.	5. O_2 and CO (or CO_2) values are within manufacturer's specified range. 6. Non-condensing boiler: The stack temperature is at least 300° F to minimize condensation in the chimney.
≥ 90% Boilers	7. Outside air temperature sensor is installed on a north-facing exterior wall. 8. Heating curve is programmed in line with the dwelling's heat loss and radiation capacity.	7. Outside air temperature sensor is installed on a north-facing exterior wall. 8. Heating curve is programmed in line with the dwelling's heat loss and radiation capacity.

Heating Systems – General

1. Heating System Check List is complete, in file;
2. Condensate Line:
    a. Drains properly and is secured to floor drain.
    b. Does not present a tripping hazard.
    c. Pump installed only when needed.
3. No fuel leaks.
4. Oil systems have a new oil filter.
5. There are no pre-existing unvented space heaters remaining in place.

Required Testing		
	Replacements	**Clean and Tune**
All Fuels and Types	1. Measure the steady-state efficiency (SSE).	1. Measure the steady-state efficiency (SSE).
	2. Measure oxygen (O_2) levels. See Table 3-2, Typical Ranges for Gas-Burning Equipment.	2. Measure oxygen (O_2) levels. See Table 3-2, Typical Ranges for Gas-Burning Equipment.
	3. Measure the stack temperature (T-Stack).	3. Measure the stack temperature (T-Stack).
Forced-Air	4. Measure the airflow of the furnace air handler. Use a flow plate or the manufacturer's fan-flow tables to calculate airflow.	4. Measure the airflow of the furnace air handler. Use a flow plate or the manufacturer's fan-flow tables to calculate airflow.
All Boilers	5. Measure the supply and return water temperatures.	5. Measure the supply and return water temperatures.

New Heating Systems

1. Heating system is properly sized and adequately heats the building.
    a. Sizing calculation is in the customer file that accurately reflects the heat loss of the post-weatherization building.
    b. Distribution system is adequate for the properly sized furnace.
2. Heating system has proper venting.
    a. Meets manufacturer's and code requirements.
    b. Proper clearances from windows, doors, and 3 feet from a gas meter, regulator, and vent outlet.
3. System is raised off the floor by durable materials.
    a. For basements with known water problems, the height is based on typical high water marks noted in the CAZ or based on customer input.
4. Heating system equipment meets specification requirements.
5. Building permit obtained as required.
6. Installation meets code requirements.
7. System is on a dedicated electrical circuit.
    a. Service disconnect is present or within line-of-sight at service panel.
    b. Circuit is properly sized or a fuse or breaker is installed to protect the system.
8. The warranty and/or manual booklet is posted on or near the furnace.
9. Installed wood systems or stoves comply with NFPA 211 or EPA (per label).

Forced-Air Distribution

1. Filter/compartment
    a. Is properly sealed, tight cover fit, and the filter seals to the filter rack.
    b. Allows for easy filter replacement.
    c. Filter is MERV 6 or better.
    d. One cleanable filter, six disposable 1- to 2-inch filters included, or one 3-inch filter installed.
2. Distribution within the CAZ and living areas are sealed based on worst-case depressurization testing. The distribution system does not excessively depressurize the CAZ, (>1 Pascal, based on warnings in the diagnostic workbook when Category I appliances are present).
3. Adequate heat and return air is provided in the living areas.

4. New supply and return ducts are the proper size for efficient operation of the heating system.
5. Duct joints are properly attached and secured.
6. Ducts are properly supported.
7. Metal ducts are sealed with a UL181 rated material like mastic, tape or caulk.
8. Distribution work in unheated areas is insulated to minimum of R-11.
9. Insulation meets material specifications and is not compressed.
10. Fiberglass insulation is installed with mechanical fasteners.
11. Registers are properly functioning for their intended purpose.
12. There are no return grills in the CAZ.
13. New supply ducts have dampers.
14. Mobile home return air system is centralized through living space.
15. Back-draft dampers are installed between a wood furnace plenum and another forced air system.

Boilers

1. Boiler size is properly calculated and includes domestic hot water when applicable.
2. Existing radiators and other terminal devices are the appropriate size and quantity for the spaces they heat.
3. Heating System Check List is complete and in file.
4. Replacement units are rated for the application.
5. The existing feed water and distribution system works properly with a new boiler.
6. Distribution system was properly flushed.
7. Boiler controls, auto fill valve, zone valve, and expansion tank are present and functioning as designed and outdoor air temperature sensor is installed.
8. Existing boiler or distribution is adjusted or modified properly.
9. Radiators are bled and there no air is in the system.
10. Pressure relief valve has been documented as opened; closes without leaking.
11. Three- and four-unit buildings only. Boiler registration number is posted with current state certified inspection.

Hot-Water Space-Heating Distribution

1. Pipes are insulated in unheated areas.
2. Insulation seams are tightly fitted and secured.
3. No leaks in the system.

Thermostats

1. Installed thermostat functions properly with the installed heating system and meets household needs.
2. Customer is educated and understands how to operate programmable thermostat.
3. Thermostat is in a location that allows the heating system to operate properly to heat the space.
4. Thermostat is installed on an interior wall but not near a supply register.

Additional Considerations

Under certain circumstances, the following items may be necessary to verify other tests results are correct or for troubleshooting various problems.

1. Airflow through the flow meter is consistent with flow rate listed in Table 3-1 and the manufacturer's fan tables.

Additional Tests		
	Replacements	**Clean and Tune**
All Systems	1. Confirm excess air (EA) is adequate.	1. Confirm excess air (EA) is adequate.
Natural Gas Systems	2. Measure the input by "clocking the meter" to determine the input of a natural gas appliance. Input is typically within 10% of the appliance rating.	2. Measure the input by "clocking the meter" to determine the input of a natural gas appliance. Input is typically within 10% of the appliance rating.
Oil Systems	3. Check oil pump pressure.	3. Check oil pump pressure.
Forced-Air	4. Measure external static pressure (ESP).	4. Measure external static pressure (ESP).

Chapter 4: Base Load Measures

Base load measures are energy-conservation measures that affect non-space heating energy usage. These measures may include, but are not limited to:

1. Water heater replacement
2. Domestic hot water treatments
3. Refrigerator and freezer replacement or removal
4. Lighting retrofits

4.1 Water Heater Replacement

Energy conservation water heater replacements typically occur by completing conversions to natural gas from another fuel type or by replacing the existing inefficient water heater.

Observe the following standards for all water heater replacements or removals:

1. Remove existing water heater and dispose of properly.
2. Size the replacement water heater properly, based upon the number of people in the building.

Observe the following standards for water heater installations:

1. Install water heater per manufacturer's instructions on a level and stable location. Provide strapping to secure the water heater, if needed.
2. Install a temperature and pressure-relief (TPR) valve with piping as required by code or local jurisdiction.
3. Ensure venting meets NFPA 54 for gas units.
4. Install a dedicated shut-off valve on the inlet side for future servicing, if none exists.
5. Ensure water lines do not leak after connection to water heater.
6. Fill tank with water before turning water heater on.
7. Measure and adjust temperature settings to 120° F. Check delivered temperature and adjust as necessary.
8. Affix a tag to the water heater identifying whom the customer should call for warranty service. Display the tag prominently, and confirm that it includes the service provider's name, address and telephone number.

4.1.1 ENERGY STAR® Gas Power-Vented Water Heater Installations

1. Follow the manufacturer's instructions to ensure proper venting of the new water heater.
2. If an existing outlet does not exist, install a GFCI outlet for electrical connection.

3. Confirm no gas leaks exist in any of the gas piping.
4. Install a proper sediment trap on gas line, if none exists.
5. Ensure bonding of Corrugated Stainless Steel Tubing (CSST) gas piping system meets NFPA 54.
6. Install properly sized gas piping.
7. A UL-listed appliance connector may be used to connect gas valve to gas piping.
8. Measure and adjust gas pressure to meet manufacturer's instructions.
9. Follow manufacturer's instructions for the proper removal of condensate.
10. Test for carbon monoxide (CO) level in the exhaust vent to confirm the CO level is less than 100 ppm as-measured or 200 ppm airfree (or meets manufacturer's specifications, if they are different).

4.2 Domestic Hot Water Treatments

4.2.1 Water Saving Showerheads and Aerators

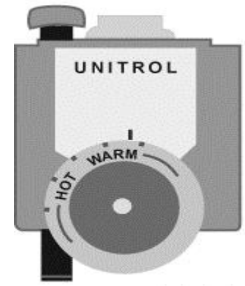
1. Remove and replace existing showerheads and aerators rated or tested above 1. 5 gallons per minute, and recycle replaced items appropriately.
2. Install new showerheads using thread-seal tape or other pipe sealant to prevent leakage. Avoid over-tightening the new showerhead.
3. Protect the curved chrome showerhead nipple from damage during installation, using cloth or leather between the jaws of the pipe wrench or pliers.
4. When replacing faucet aerators, be careful to avoid scratching or deforming them.
5. Be cautious when significant deposits exist on the devices as this could lead to fixture damage and additional costs.

4.2.2 Water Heater Pipe Insulation

1. **FOR MOBILE HOMES ONLY:** For water heaters located in a closet with exterior access, insulate all water piping in the closet.
2. Insulate all pipes on the circulating loop between a boiler and an indirect domestic hot water storage tank.
3. Use properly-sized pipe insulation rated at R-2 or better. Insulate elbows, unions, and other fittings to the same thickness the straight pipe runs are insulated.
4. Keep pipe insulation at least six inches away from combustion vent pipe, unless the insulation has a fire-safety rating for closer clearance.
5. Secure seams, joints, and ends of pipe sleeves.

4.2.3 Setting or Reducing Water Temperature

1. Measure the hot water temperature at the faucet nearest to the water heater, and set or reduce the water heater temperature to 120° F, with customer permission.
2. Mark the current setting on the thermostat, and move the control to a lower temperature. Note the difference between electric and gas controls shown here.
3. On electric water heaters, set the upper thermostat and lower thermostat to the same temperature. Shut off power to the water heater before opening thermostat access panels.



Gas water heater control

Electric water heater control

4.3 Refrigerator or Freezer Replacement and Removal

Prior to installing a replacement unit:

1. Install replacement units only in locations allowed per manufacturer's instructions. Units can be installed in a non-conditioned space if allowed by the manufacturer.
2. Confirm the replacement unit will fit in the existing opening without modifications. Modify the opening only with agency and customer approval.
3. Verify door openings are wide enough to accommodate a new unit installation.
4. For units that do not meet Wisconsin Weatherization Program replacement guidelines, confirm the required waiver documentation is in the customer file.

When replacing a refrigerator or freezer:

1. Install the replacement unit level for proper operation. Raise the front of a refrigerator slightly to allow the doors to close slowly and without assistance or with limited assistance from the customer.
2. Unless limited by the existing installation space, install all the parts and trim per the manufacturer's instructions.
3. Plug the unit into the nearest receptacle to confirm the unit functions. Do not plug into an extension cord. The outlet should not be on a ground fault interrupter circuit.
4. Change the swing on doors, if necessary to meet the needs of the customer.
5. Verify the doors are properly aligned and seal tightly with a positive gasket seal.
6. De-manufacture and properly dispose of existing units being removed or replaced. Do not disable the existing unit until you install the replacement and confirm it works properly.

4.4 Lighting

Compact fluorescent lamps (CFLs) and Light Emitting Diode (LED) bulbs typically use 75 percent less electricity than a standard incandescent bulb. To prevent customer removal and promote efficiency, replacement CFL and LED bulbs should be selected to provide light output (lumen, efficacy, and color) equivalent to existing incandescent bulbs.

Spiral-style CFL

Globe-style LED

Halogen torchiere lamps pose a health and safety risk due to the heat generated by the halogen bulb. Replacing these lamps with a fluorescent or LED model eliminates the health and safety risk and reduces electrical usage.

Torchiere-style CFL

When replacing lighting:

1. Demonstrate CFL and LED lighting. Explain the related electric savings potential for customers unsure about replacing incandescent bulbs with CFLs or LEDs.
2. Select replacement CFL or LED bulbs with wattage that matches the lumen output and functionality of the existing incandescent bulb. Confirm customer satisfaction for task lighting and background lighting.
3. Install all CFLs or LEDs. CFLs or LEDs shall not be left for the customer to install.
4. Install CFLs by grasping the plastic base, never by the glass tubing.
5. Turn on each CFL or LED lighting replacement after installation to confirm it works properly.
6. Replace halogen torchiere lamps with fluorescent or LED torchiere lamps when appropriate, and remove halogen torchiere lamps from residence. Properly dispose of halogen torchiere lamps.
7. Existing CFLs shall not be replaced with LEDs.
8. Provide CFL disposal and clean up instructions to customers.

If a CFL breaks, take care in cleaning up. Even though the amount of mercury is very small, EPA recommends the following steps:

1. Open nearby windows to disperse any vapors and leave the room for 15 minutes.
2. Carefully scoop up the fragments and powder with stiff paper or cardboard and seal them in a plastic bag.
3. Wipe the area clean with damp paper towels and place in the plastic bag.
4. Do not use a vacuum or broom to clean up the broken bulb on hard surfaces.

5. Place all clean up materials in a sealed plastic bag.
6. Place the bag in a second sealed plastic bag and place it in an outdoor trash container. Note: Broken and unbroken CFLs should be taken to a recycling center if possible.
7. Wash your hands after disposing of the bag.

If a fluorescent bulb breaks on a rug or carpet, do your best to remove all visible materials using the steps above. Use sticky tape such as duct tape to help pick up the small pieces and powder. If you need to vacuum, once all visible materials have been removed, remove the vacuum bag (or empty and wipe the canister) and place the bag or vacuum debris in two sealed plastic bags and dispose of at your local hazardous waste site.

Final Inspection and Quality Assurance Standards

Acceptable installations shall meet the following standards.

Water Heater Replacement

1. Replacement is ENERGY STAR rated where applicable and meets the required Energy Factor (EF) or Uniform Energy Factor (UEF).
2. Follows Wisconsin Weatherization Program protocol for water heater replacement and was properly modeled with the energy audit.
3. Unit is properly sized for the household.
4. Follows manufacturer's instructions for installation including venting, pressure relief, drain tube, and electrical connection.
5. New outlet (receptacle) is GFCI as required by code.
6. Temperature measured is 120-125° F, unless an owner request for a higher temperature is documented. Do not set the water heater temperature below 120° F.
7. Replacement unit is not leaking or back drafting.

Water-Saving Devices

1. Installation follows Wisconsin Weatherization Program policies and protocol.
2. New aerators and showerheads do not leak.
3. Recycle or properly dispose of replaced showerheads and faucet aerators.

Refrigerators

1. Installation meets the manufacturer's instructions.
2. All parts and trim are present and installed as designed.
3. Unit is properly sized for the household.
4. Doors are properly aligned and there is a positive gasket seal.
5. The new refrigerator is installed as close to level as possible.
6. The unit consuming the most electricity (pre-weatherization) was replaced.
7. The refrigerator replaced was removed from the dwelling and disposed of properly.
8. Replacement refrigerator follows Wisconsin Weatherization Program policies and protocol.
9. The customer file contains a waiver for any unit that falls outside of replacement guidelines.

Freezers

1. Installation meets the manufacturer's instructions.
   a. Unit is not installed in a non-conditioned space (garage, porch) unless allowed by the manufacturer.
2. All parts and trim are present and installed as designed.
3. Replacement freezer size is equal to or less than unit or units replaced.
4. Lid is properly aligned and there is a positive gasket seal.
5. The unit consuming the most electricity (pre-weatherization) was replaced.
6. The freezer replaced was removed from the building and disposed of properly.
7. Replacement freezer follows Wisconsin Weatherization Program policies and protocol.
8. Additional functional units were removed and bounty offered per program policy with owner's permission.

Lighting: CFLs and LEDs

1. Follows Wisconsin Weatherization Program protocol and policies.
2. Replacement bulbs are appropriate for the intended use.
3. No uninstalled CFLs or LEDs were left at job site.
4. All halogen torchiere lamps were replaced.

Chapter 5: Health and Safety

This chapter addresses some of the most pressing health and safety hazards household's face, as well as those faced by weatherization professionals while auditing, installing measures, or inspecting completed work. When serious safety problems are discovered in a home, field staff should inform an immediate supervisor and the customer about the hazards. Major hazards and potentially life-threatening conditions should be corrected prior to weatherization work beginning, unless the installers are making the corrections as part of their work.

See *Health and Safety Inspection Check List* and the *Release of Liability Form* located via link on the Home Energy Plus website linked below:
http://homeenergyplus.wi.gov/category.asp?linkcatid=494andlinkid=122andlocid=25

Weatherization workers should be aware of the potential causes of on-site injuries and how awareness and precautions can reduce them. Examples of potential causes include, but are not limited to:

- ✓ Slips, trips, and falls
- ✓ Extreme temperatures
- ✓ Improper tool use
- ✓ Combustibles (materials or gases)

If an emergency occurs in the field, follow the agency safety policy or dial 911. When working, weatherization professionals must follow all applicable health and safety protocols per Occupational Safety and Health Administration (OSHA) and/or the local jurisdiction having authority.

Before beginning work, assess work areas for health and safety hazards to the workers and to the customer. Resolve any hazards either before work begins or during the work process. If hazards cannot be resolved, the home may require deferral until the hazards are addressed.

Inspect all tools for safety, and use them in accordance with manufacturer's specifications.

5.1 Personal Protective Equipment

On almost a daily basis, weatherization workers find themselves in situations that necessitate the use of personal protective equipment (PPE). The employer is required to provide workers with proper PPE needed to complete their jobs.

Examples of such PPE include, but are not limited to:

- ✓ Disposable coverall garments
- ✓ NIOSH approved respirators with annual fit test (and medical documentation, if required).
- ✓ Eye and face protection
- ✓ Confined-space supplied air and ventilation
- ✓ Hearing protection
- ✓ Fall protection

5.2 Safety Data Sheet (SDS)

The SDS for a product or material contains data about material specifications and safety information. This includes information about:

1. Product and company/manufacturer
2. Hazards identification
3. Composition and ingredients
4. First-aid
5. Firefighting
6. Accidental release
7. Handling and storage
8. Exposure controls and personal protection
9. Physical and chemical properties
10. Chemical stability and reactivity
11. Toxicological effects
12. Ecological information
13. Disposal
14. Transport considerations
15. Regulatory information
16. Other

All SDS for weatherization products can be accessed through the Home Energy Plus Training and Technical Assistance website. When possible, materials that create long-term health risks for the customer and workers should be replaced with materials that present less risk.

5.3 Confined Spaces

Weatherization professionals commonly work in small spaces such as crawl spaces and attics that can be defined by OSHA as a confined space. A confined space is large enough and so configured that an employee can bodily enter and perform assigned work, but has limited or restricted means for entry or exit, and is not designed for continuous employee occupancy.

All work performed within a confined space shall be performed in accordance to OSHA standard 29 CFR Part 1926 Final Rule.

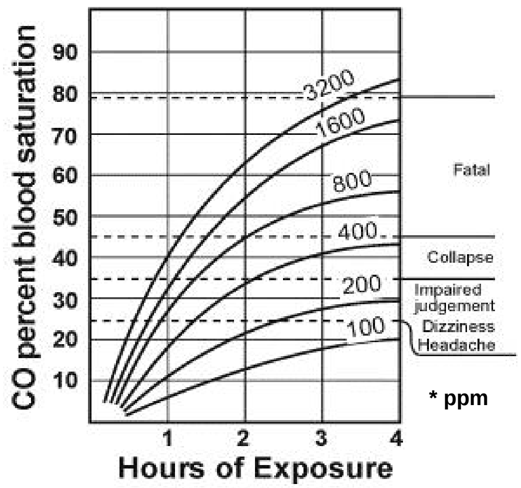
5.4 Source Pollutant Control

The control of pollutants at the source is always the best solution, especially in homes with a lower measured CFM_{50} reading. Whole-building mechanical ventilation helps remove and dilute low levels of pollutants. Technicians should be mindful of pollutant sources and exposures while performing weatherization.

The customer has significant control over the introduction and spread of many home pollutants. Always provide education to customer about corrective actions they can take to minimize pollutants in their homes.

5.4.1 Carbon Monoxide (CO)

The EPA's suggested maximum eight-hour exposure limit for CO is nine parts per million (ppm) in room air. CO at or above nine ppm is often linked to malfunctioning combustion appliances within the living space. Technicians are required to wear personal CO monitors while performing combustion safety testing.



Effects of CO: This graph's curves represent different exposure levels in parts per million (ppm).

Sources of Carbon Monoxide

CO pollution is often linked to unvented combustion appliances, back-drafting combustion appliances, gas ranges, charcoal grills, and motor vehicles idling in attached garages or near the home.

Testing for Carbon Monoxide

The most common CO testing instrument is an electronic sensor with a digital readout in parts per million (ppm). The readings will be either *AS MEASURED* or *AIR FREE.* Follow the manufacturer's recommendations on zeroing the meter — usually by exposing the meter to outside air. CO testing equipment typically requires recalibration every six months, using factory-specified procedures.

A CO test is normally completed in the appliance exhaust flue or at the exhaust port of the heat exchanger. Elevated CO can be caused by any of the following:

1. Over firing of an appliance — too much combustion fuel is supplied to the appliance. A low O_2 percentage on a combustion analyzer indicates the appliance may be over firing. Technicians may determine if the appliance is over firing by clocking the gas meter.

2. Inadequate combustion air — occurs when a combustion appliance is lacking sufficient combustion air.

3. Back drafting/spillage of combustion gases suppressing the flame.
4. Flame interference by an object (a pan over a gas burner on a range top, for example).
5. Misalignment of the burner.

Appliance service technicians should strive to identify and correct these problems.

5.4.2 Gas Range and Oven Safety

Range-Top Burners

Inspect ranges prior to testing ovens for carbon monoxide levels. Range-top burners that are dirty or mis-aligned may cause generation of excessive CO. Damaged burners or stove grates, or foil burner liners that interfere with the flame pattern, may cause the burner to create a yellow or orange flame. In this condition, the burner is likely generating high volumes of carbon monoxide. If any of these conditions are observed, advise residents that the range should be cleaned or repaired, to reduce the generation of CO and improve their indoor air quality.

Testing Gas Ovens

When completing oven testing:

1. Test ovens for *AIR FREE* carbon monoxide levels.
2. Remove any items stored in the oven and any foil coverings before turning the oven on.
3. Verify self-cleaning features are deactivated.
4. Insert the testing probe into the vent sleeve to sample pre-dilution-air exhaust gases.
5. Turn the oven on to its highest temperature setting and allow the oven to run continuously for 10 minutes.
6. Measure the oven during warm-up, and record the measurement at peak (after 10 minutes of run-time). Confirm the oven is firing when the measurements are taken.
7. Test the ambient air in the kitchen to verify the CO level is below 35 PPM.

Table 5-2: Action Levels for Range Ovens

Air Free CO PPM	Measuring Time	Action
< 800 PPM	After 10 minutes	Should be cleaned by customer to prevent possible CO problems.
> 800 PPM, <1000 PPM	After 10 minutes	Advise customer to have appliance serviced
>1000 PPM	After 10 minutes	Advise customer the oven should not be used and they should replace appliance.

5.4.3 Carbon Monoxide (CO) Alarms

Follow these instructions when installing CO alarms:

1. Install according to the manufacturer's instructions.
2. Educate the customer about the purpose and features of the alarms including what to do if an alarm sounds.
3. Leave instructions with the customer, and educate the customer about battery replacement, if applicable.

Do not install CO alarms:

- ✓ In a room that may get too hot or cold for the alarm to function properly.
- ✓ Within 5 feet of a combustion appliance, vent, or chimney.
- ✓ Within 5 feet of a storage area for vapor-producing chemicals.
- ✓ Within 12 inches of exterior doors and windows.
- ✓ Inside of a furnace closet or room.
- ✓ With an electrical connection to a switched circuit.
- ✓ With a connection to a ground-fault interrupter circuit (GFCI).
- ✓ Behind furniture or appliances.

The manufacturer's instructions may specify stricter standards than these. If a conflict exists, follow the stricter specification.

5.4.4 Smoke Alarms

Follow these instructions when installing smoke alarms:

1. Install according to the manufacturer's instructions.
2. Educate the customer about the purpose and features of the alarms including what to do if an alarm sounds.
3. Leave instructions with the customer, and educate the customer about battery replacement (if applicable).

Do not install smoke alarms:

- ✓ Within 12 inches of exterior doors and windows.
- ✓ On a switched circuit, if hard-wired.
- ✓ On a ground-fault interrupter circuit (GFCI).

The manufacturer's instructions may specify stricter standards than these. If a conflict exists, follow the stricter specification.

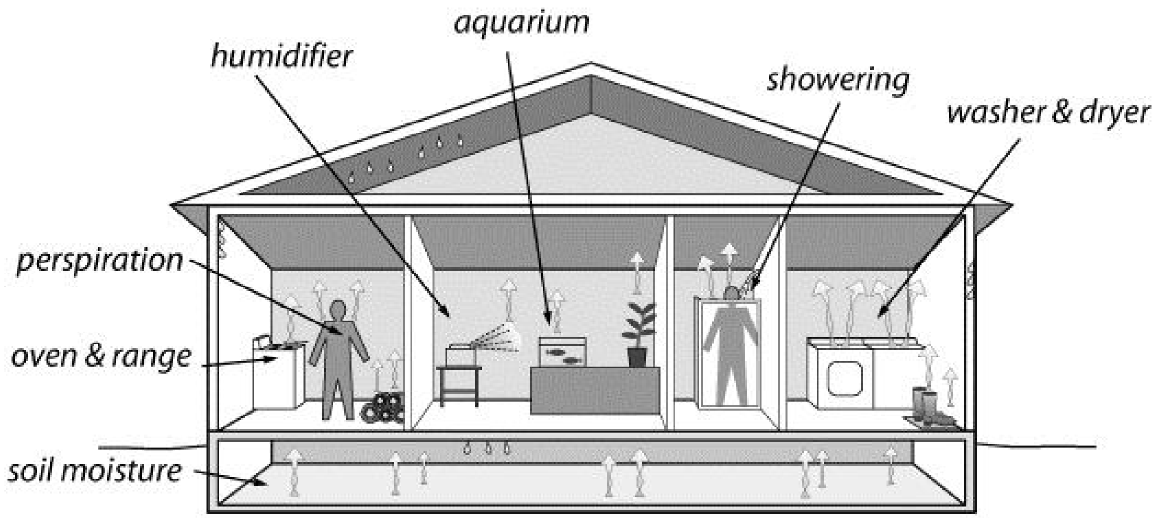
5.4.5 Leak-Testing Gas Piping

Natural gas and LPG piping systems may leak at their joints and valves. Leaks can be located with an electronic combustible gas detector (CGD), often called a gas sniffer. A gas sniffer will find all significant gas leaks, if used properly. Remember, natural gas is lighter than air and rises from a leak, while propane falls, position the sensor accordingly. The CGD shall have a variable tick rate or changing tone based on gas concentration levels. The CGD shall have a digital display of percentage of Lower Explosive Limit (LEL) and/or provide an alarm when detecting combustible gas concentrations exceeding 10% of the LEL.
When major gas leaks are identified, cease testing immediately, inform the customer, evacuate the building, and contact the appropriate authority.

Test for gas leaks by following these steps:

Combustible gas detector: These electronic combustible gas detectors are a fast and convenient way to find gas leaks.

1. Inspect all piping from the meter or tank to all connected appliances using a combustible gas detector. Include connections to all gas appliances and gas stove valves. No verified gas leaks are allowed in the building or on the customer side of the meter or propane tank at the completion of weatherization work.
2. If the detector identifies a leak, verify the leak with a non-corrosive bubbling liquid designed for finding gas leaks.
3. Repair all gas leaks verified with bubbling liquid.
4. Replace kinked or corroded flexible gas connectors.



Moisture sources: Household moisture can often be controlled at the source by informed and motivated customers. Indoor relative humidity should be between 30-50 percent.

5.4.6 Moisture Problems

Water and water vapor damages building materials by promoting mold and rot, dissolving glues and mortar, corroding metal, and nurturing pests like termites and dust mites. These pests, in turn, cause many cases of respiratory distress.

Water and moisture reduces the thermal resistance of insulation and other building materials. The most common sources of moisture are leaky roofs and damp foundations and basement floors. Other critical moisture sources include unvented dryers, showers, cooking appliances, and unvented gas appliances like ranges or decorative fireplaces.

Identifying and reducing sources of bulk/liquid moisture is the first priority for solving moisture problems. The next priority is to install or repair air and vapor barriers to prevent moisture from migrating into and through building cavities. Local exhaust fans located in the kitchen and bathrooms will remove high levels of moisture and other pollutants at the source.

Table 5-3: Moisture Sources and their Potential Contributions

Moisture Source	Potential Amount Pints
Ground Moisture	0-105 per day
Seasonal evaporation from materials	6-19 per day
Dryers venting indoors	4-6 per load
Dishwashing	1-2 per day
Cooking (meals for four)	2-4 per day
Showering	0.5 per shower

Relative humidity (RH) is a measurement of the degree to which air is saturated with moisture. Air at 100 percent RH is completely saturated. Home air below 30 percent RH is uncomfortably dry for many people. Air above 50 percent RH is likely to cause condensation on cold interior surfaces and in building cavities when outdoor weather is cold.

Symptoms of Moisture Problems

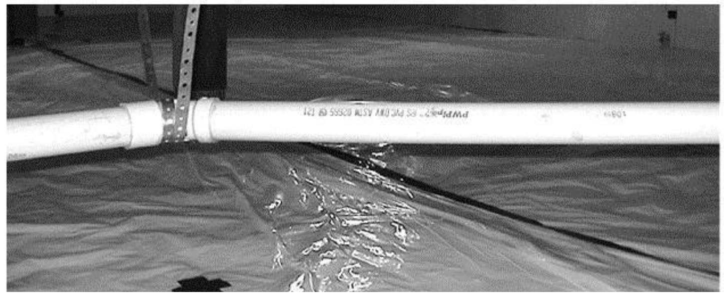
Condensation on windows, walls, and other surfaces may signal high RH and the need to find and reduce moisture sources. During very cold weather or rapid weather changes, condensation may occur. This occasional condensation is not a major concern. However, if window condensation is a persistent problem, reduce moisture sources, add insulation, or consider other remedies that lead to warmer interior surfaces. The colder the outdoor temperature, the more likely condensation will occur. Adding insulation helps eliminate cold areas where water vapor condenses.

Moisture problems arise when the moisture content of building materials reaches a threshold that allows pests like termites, dust mites, rot, and fungus to thrive. Asthma, bronchitis, and other respiratory ailments can be exacerbated by moisture problems because mold, mildew, and dust mites are potent allergens. The level of moisture problem can be determined by the current state of the existing building materials. The following are examples how moisture affects building materials:

1. Rot and wood decay indicate advanced moisture damage. Unlike surface mold and mildew, wood decay fungi penetrate, soften, and weaken wood.
2. Peeling, blistering, or cracking paint may indicate moisture is moving through a wall, damaging the paint and possibly the building materials underneath.
3. Corrosion, oxidation, and rust on metal are unmistakable signs moisture is at work. Deformed wooden surfaces may appear as damp wood swells and then warps and cracks as it dries.
4. Concrete and masonry efflorescence often indicates excess moisture at the home's foundation. Efflorescence is a white, crystalline deposit left by water that moves through masonry leaving behind minerals from mortar or the soil as it evaporates.

5.4.7 Foundation Moisture Control

Moisture and pollutants entering the home through foundations, basements and crawl spaces can be a substantial contributor to indoor humidity even when no wet areas are apparent and affect the indoor air quality. The pollutants and moisture can move easily through the home, driven by stack effect and by wicking of the moisture into permeable wood and concrete.



A well-sealed crawl space: The dirt floor in this crawl space is covered with a well-sealed cross-linked polyethylene ground moisture barrier.

Ground Moisture Barriers

Air, moisture, and pollutants can move through soil and into crawl spaces and dirt-floor basements. Even soil that seems dry at the surface can release a lot of moisture into the home.

Follow these instructions when installing a ground-moisture barrier to control the movement of moisture and soil gases:

1. Inspect all plumbing for leaks and repair any leaks found before installing the ground moisture barrier.
2. Cover the ground completely with an airtight barrier, such as 6-mil plastic or cross-laminated polyethylene.
3. Overlap seams a minimum of 12 inches using a “reverse shingle” or “upslope lapping” technique (e.g., overlapping so water leaking through the foundation will not flow in between the layers of poly at the seams).
4. Run the barrier up the foundation wall at least 6 inches and secure it, or attach it to the mudsill if termites are not a problem in the area. Air seal edges to the foundation.
5. Seal seams and around penetrations with adhesive to create an airtight seal. It may be easier to assemble sheets and seal the seams outside of the crawl space. When the sealing compound sets up, the barrier should be a continuous sheet.

Caution: Moisture barriers are typically for use in crawl spaces. Use in basements should be limited to basements with dirt floors and limited access. When the ground-moisture barrier is installed in a little-used basement, install walk boards to prevent the customer from slipping. Address any problems, such as plumbing leaks, prior to installing the barrier, to prevent water from pooling on top of the barrier.

Open Block Cores

Pollutants and moisture are often found in the bottom of concrete block foundations. When the top of the wall is not sealed or capped, the pollutants and moisture are pulled up into the home due to stack effect and convective lopping inside the open cores of the wall. Cap the open cores at the top of the foundation wall using rigid material and air-seal around the perimeter of the cap. Treating block cores in this fashion can limit the entrance of moisture and pollutants into the home.

5.5 Lead Paint and Lead-safe Work

Lead dust can damage the neurological systems of persons who ingest it. Children are more vulnerable than adults because of their rapid brain development and common hand-to-mouth behavior. Lead paint was commonly used in homes built before it was outlawed in 1978. Technicians working on these older homes should either assume the presence of lead paint; or, if they believe no lead paint is present, perform tests to rule out its presence.

Lead-safe work practices are used by weatherization professionals when they suspect or confirm the presence of lead paint.
Lead-safe work focuses on rigorous dust-prevention and housekeeping precautions. These practices are required when workers will disturb painted surfaces by cutting, scraping, drilling, or other dust-creating activities. All weatherization field workers must be trained in Lead-safe work practices.

Wall-blowing tent: This tent protects the customer and their belongings from insulation and paint dust.

Lead Safe Renovator requirements apply in pre-1978 housing when more than 6 square feet of interior painted surface per room or more than 20 square feet of exterior painted surface will be disturbed, or any time windows will be replaced or demolished. See the Wisconsin Weatherization Program Manual for specific policies and guidance regarding Lead Safe Renovator requirements and minimum standards for lead-safe weatherization.

Weatherization activities that could disturb lead paint and create lead dust include, but are not limited to, the following:

1. Removing siding for installing insulation.
2. Drilling holes in the interior or exterior of the home for installing insulation.
3. Removing trim or cutting through walls or ceilings.
4. Weather-stripping, repairing, or replacing doors.
5. Glazing, weather-stripping, or replacing windows.

When engaging in the above activities, take the following precautions:

1. Tent off the work area by taping a continuous sheet of plastic from floor to ceiling.
2. To protect installers from breathing dust, use appropriate personal protective equipment, such as fit-tested respirators, and coveralls, etc.
3. Confine the work area within the home to the smallest-possible floor area. Seal this area off carefully with floor-to-ceiling barriers made of disposable plastic sheeting, sealed at floor and ceiling with zip poles or tape.
4. Cover furniture and carpet in the work area with disposable plastic sheeting.
5. Spray water on the painted surfaces to keep dust out of the air when drilling, cutting, or scraping painted surfaces.
6. Use a dust-containment system with a HEPA vacuum when drilling holes indoors.
7. Clean up as work is performed. Vacuum affected areas with a HEPA vacuum and wet-mop these surfaces daily. Do not use the customer's cleaning tools. Do not leave the customer with lead dust to clean up.
8. Avoid taking lead dust home by not contaminating clothing, shoes, or tools. Wear boot covers while in the work area and remove them to avoid tracking debris from the work area to other parts of the house. Wear disposable coveralls, or vacuum cloth coveralls with a HEPA vacuum before leaving the work area.
9. Wash hands and face thoroughly before eating, drinking, or quitting for the day.
10. Keep customer and pets away from the work area.

Lead-safe drilling: Using a shrouded drill with a HEPA vacuum removes dust where it is generated.

5.6 Asbestos

Air-borne asbestos fibers can be dangerous, even when they are not visible to the naked eye. Exposure to asbestos can lead to a host of health problems — including, but not limited to:

1. Lung cancer
2. Mesothelioma, a rare form of cancer found in the thin lining of the lung, chest, abdomen, and heart
3. Asbestosis, a serious progressive, long-term, non-cancer disease of the lungs

Disease symptoms may take many years, or decades, to develop after exposure to asbestos. Being a smoker greatly increases the odds exposure to asbestos will lead to disease.

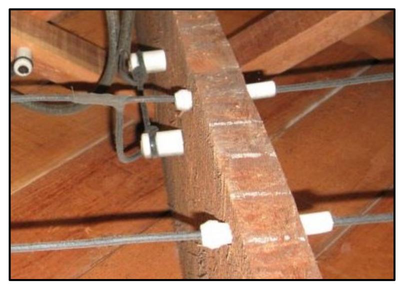
According to Wisconsin Department of Health Services, workers may assume asbestos is not present in wood, metal, glass, and fiberglass. All other building materials; however, should be presumed to contain asbestos, unless proven otherwise through bulk sampling by a certified Asbestos Inspector and analysis by an accredited laboratory. Asbestos containing Vermiculite is the one exception — currently, there is no EPA-approved testing method to demonstrate the presence or absence of asbestos mixed in with vermiculite insulation. Consequently, weatherization workers must always presume that asbestos is mixed in with all vermiculite insulation.

See the Wisconsin Weatherization Program Manual, for comprehensive asbestos policies.

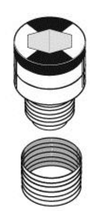
5.7 Electrical Safety

Follow these steps for electrical safety in existing homes:

1. Confirm attics contain no exposed wiring. All splices and connections should be in junction boxes.
2. Install covers on open junction boxes in the attic or elsewhere in the building if an imminent hazard exists for the workers or customer.
3. Mark all junction boxes in the attic that will be concealed by insulation, using flags.
4. Do not insulate wall cavities containing live knob-and-tube wiring. Eliminate live knob-and-tube wiring whenever feasible.
5. If knob-and-tube is not being re-wired as part of the job, isolate live wiring in attics by building a barricade around it. There are several materials that work well as barricades: R-30 un-faced fiberglass batts, concrete-form tube, or other industry accepted materials. Keep the barricade materials at least 3 inches away from the live knob-and-tube wiring.
6. Inspect wiring, fuses, and circuit breakers to confirm wiring is not overloaded. Install S-type fuses where appropriate to prevent circuit overloading. Maximum fuse or breaker amperage for 14-gauge wire is 15 amps and 20 amps for 12-gauge wire.



Knob-and-tube wiring: Prior to insulating around knob-and-tube wiring, barriers must be installed to keep insulation at least 3 inches from the wires.



S-type fuse: An S-type fuse prohibits the customer from oversizing the fuse and overloading an electrical circuit.

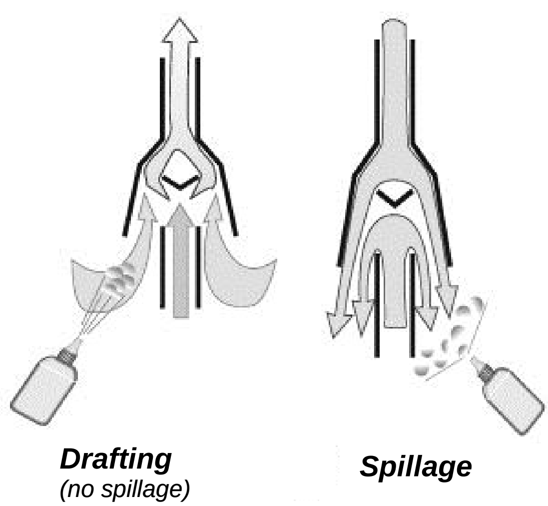
5.8 Worst-Case Draft Protocol

The main purpose of measuring draft is to confirm the combustion gases will vent safely to the outdoors. Draft is also an indicator of the effectiveness of the venting system and the stability of the combustion process. Draft is measured in inches of water column (i.w.c.) or Pascals (Pa).

5.8.1 Measuring Draft

Many combustion appliances exhaust their gases into a chimney or vent. Natural draft is produced by the difference in the weight of a column of flue gasses within a chimney or vent and a corresponding column of air of equal dimension outside the chimney or vent. A negative pressure in the chimney or vent with respect to indoors is created by natural draft. The strength of this draft (weight difference) is determined by the venting height, its cross-sectional area, and the temperature difference between the column of flue gases and the column of air. Measured natural draft in a venting system should always be negative, with respect to indoors. A positive reading indicates the flue gases are spilling into the **combustion appliance zone (CAZ)**. A CAZ is any location in a building where combustion appliances are located, most often the basement in Wisconsin.

Venting systems transport combustion gases using the flame's heat and the gases' buoyancy. Natural draft and fan assisted gas appliances are designed to operate at a natural draft of around negative 0.02 IWC, or - 5 Pascals. Tall venting systems located indoors typically produce stronger drafts, and short or outdoor venting systems produce weaker drafts. Wind and house pressures can have a big impact on natural draft in venting systems. Depressurization can cause spillage of combustion gasses into the CAZ.



Spillage: A smoke tester helps determine if spillage is occurring during appliance operation.

Natural draft appliances connected to chimneys or vents require a draft diverter to dilute the flue gases and limit the chimney temperature, keep the draft from getting too strong, and keep wind gusts from interfering with the appliance's burner. Fan-assisted appliances employ a small fan near the exhaust of their heat exchanger. This fan draws the products of combustion through the heat exchanger, but it has little or no effect on the draft up the chimneys. A poorly-functioning natural draft chimney may allow combustion gases to leak into the CAZ.

Higher efficiency appliances, including sealed combustion heating systems and power-vent water heaters, employ mechanical draft. This mechanical draft is produced by a fan. When the fan is located so as to push the flue gases through the venting system, the draft is forced. When the fan is located so as to pull the flue gases through the venting system, the draft is induced. A positive pressure in the venting system with respect to indoors is created by mechanical draft after the fan. The venting system must be airtight after the fan otherwise; the positive pressure inside the venting system will force combustion gases into the CAZ. The mechanical draft created is strong enough to resist the influence of most indoor and outdoor pressures.

Before testing, inspect the combustion venting system for damage, leaks, disconnections, inadequate slope, and other safety hazards.

Table 5-4: Acceptable Draft Test Readings for Gas Appliances

Acceptable Draft Test Readings for Gas Appliances with Respect to Outdoor Temperature			
°F	<10°	10°-90°	>90°
Pa.	-2.5	(°F_Out / 40) - 2.75	-0.5
IWC.	-.010	(°F_Out / 10,000) - 0.011	-.002

Table 5-5: Acceptable Draft Test Readings for Oil-Fired Appliances

Test Location	Acceptable Draft
Overfire Draft	-0.02 IWC or -5 Pascals
Flue Drafts	-0.04 to -0.06 or -10 to -15 Pascals

5.8.2 Depressurization Testing and Worst-Case Draft Testing

CAZ depressurization is the leading cause of back drafting and flame rollout. Depressurization testing uses the home's exhaust fans, air handler, and appliances to create worst-case depressurization in the CAZ. Using this worst-case testing protocol, the appliance draft and the indoor-to-outdoor pressure differential can be measured to check whether a natural-draft chimney works well enough to be safe.

CAZ Depressurization Test

This test measures the conditions of the building and the CAZ, both before and after weatherization work. The test also helps to determine the precautions needed for the safe operation of combustion appliances in the building. Use the Diagnostic Workbook to document the test results as well as identify possible solutions.

Before the test, run a pressure hose to the outdoors to an area unaffected by the wind and connect it to the gauge's "input" port. Then, put the building in "winter condition" — close all backdraft dampers, windows, and exterior doors (without pinching the pressure hose). Finally, open all interior doors, and close the doors to the CAZ. This procedure assumes the person completing the test can stand in the CAZ with the gauge in hand and measure and read results.

If not true, connect a pressure hose to input the tap of the digital manometer and place the other end of the hose in the CAZ. Close the door so the CAZ hose is not pinched, then continue with the test.

Set the gauge on "PR/PR" mode. The test may be started in one of two ways:

A. **Use the Automatic Baseline Feature of the Digital Pressure Gauge** — press the Baseline button on the digital pressure gauge, and then press the Start button. On windy days, allow the Baseline function to record for at least 60 seconds. After sufficient time has passed, press the Enter button. Begin at Step 2, below.

B. **Manually Record the Baseline Pressure** — begin at Step 1, below.

Follow these steps to perform the CAZ depressurization test:

1. **Baseline depressurization:** Measure and record the baseline pressure differential, or Delta P (ΔP), between the CAZ and the outdoors. If the baseline measurement seems unreasonable, ensure the pressure hose to the outdoors is not constricted.
2. **Turn on exhaust appliances:** Turn on all of the exhaust appliances in the building and record the ΔP between the CAZ and the outdoors. If the building has a power-vented water heater, turn this appliance on at this time. A pressure differential more negative than the reading from Step 1 usually indicates the exhaust fans have depressurized the CAZ. Pressure affects caused by exhaust appliances will be assessed and corrected when the impact could be harmful to the customer or building.
3. **Turn on the air handler:** Turn on the furnace's air handler, and record the ΔP between the CAZ and the outdoors. If the ΔP has become more negative than in Step 2, it usually means leaky return ducts in the CAZ or supply leaks in an attic have depressurized the CAZ. By contrast, a more-positive ΔP usually means leaking supply ducts in the CAZ or return leaks in an attic have pressurized the CAZ. If the CAZ is pressurized by the air handler, turn it off before continuing to Step 4. Use the Diagnostic Workbook to guide duct sealing.
4. **Position interior doors:** Use the digital gauge or a smoke generating testing tool to measure the relative pressure of each room. To use a gauge, connect a hose to the input tap, leave the reference tap open to the house (i.e., not referenced to outdoors), toss the hose into the room, and close the door without pinching the hose.

If the reading is negative (smoke is drawn into the room), open the door. If the reading is positive (smoke is pushed out of the room) or neutral, close the door. Return to the basement, re-connect the pressure tube(s) as before, and record the ΔP between the CAZ and the outdoors.

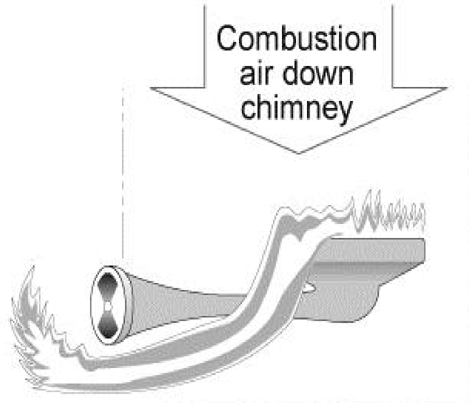
5. **Open the door to the CAZ:** Open the door to the CAZ, and record the ΔP between the CAZ and the outdoors. If the pressure difference is more negative than in Step 4, it may mean the exhaust fans are depressurizing the CAZ.
6. **Worst-case depressurization:** Subtract the Baseline reading from the largest negative reading (or the smallest positive) if baseline was manually measured and recorded, to get the adjusted Worst-Case Depressurization. If the automatic baseline feature was used, record the largest negative reading (or the smallest positive). *******The Diagnostic Workbook will complete this step automatically.*

Table 5-6: Maximum Depressurization for Combustion Appliance Zones

Appliances and Venting Systems	Maximum Depressurization (Pascals)
Orphaned Natural Draft Water Heater (oversized venting system). *Note: chimney lined with clay or other liner but still oversized*	-2
Natural Draft Water Heater and Natural Draft Heating System with common venting	-3
Stand Alone Natural Draft Water Heater (properly sized venting system)	-5
Natural Draft Heating System or Stove (including wood burning systems)	-5
Natural Draft Water Heater and Fan Assisted Heating System (fan inside furnace cabinet) with common venting	-5
Natural Draft Water Heater and Induced Draft Heating System (fan at point of exit at wall) with common venting	-5
Induced Draft Heating System (fan at point of exit at wall)	-15
Power Vented Water Heater and Sealed-Combustion Heating System	-25
The Maximum Depressurization Guideline (MDG) is the most restrictive MDG in the Combustion Appliance Zone (CAZ).	

When results are entered into the Diagnostic Workbook, enter a negative pressure reading as a positive, since the workbook will “flip the signs”. For example, if a pressure of -3.8 is entered, the workbook will display +3.8.

Worst-Case Draft Test



Flame roll-out: Flame roll-out, a serious fire hazard, can occur when the chimney is blocked, the combustion zone is depressurized, or during very windy conditions.

Draft testing under worst-case depressurization conditions is used to evaluate whether the venting system will still remove the combustion gases when the combustion-zone pressure is at the most negative pressure, and most likely to cause a natural-draft chimney or vent to fail. A calibrated digital pressure gauge is essential for accurate and reliable readings of both combustion-zone depressurization and chimney draft.

Since draft and spillage testing identifies whether combustion gases are being exhausted, measure draft and note the effect of potential back-drafting pressure changes created by exhaust fans, furnace-blower operation, or the opening and closing of interior doors.

If the appliance has an existing draft regulator, verify the draft regulator is functioning properly and installed according to the manufacturer's specifications.

Follow these steps to perform a worst-case draft test at the conclusion of each work day during which envelope or duct sealing measures were performed, and again at the final inspection:

1. Set up the house in worst-case depressurization conditions.
2. Drill an appropriately sized hole in the flue(s) of the appliances to be tested. For gas appliances, drill the test hole in the middle of the flue, halfway between the appliance and the chimney. For oil appliances, drill the test hole before the barometric damper.
3. Fire each combustion appliance, starting with the smallest BTU appliance. Check for spillage of combustion products near the flue diverter, hood, or barometric damper. Check for spillage after the appliance has operated for 2 minutes.
4. Measure the draft when the appliance has reached steady state operation.
5. Measure CO level in combustion gases. Test for CO in pre-dilution air. For natural-draft heating systems, measure the CO level in each combustion chamber, and record the highest of the measurements. See *Carbon Monoxide (CO) in Chapter 5 – Section 5.4.1.*

6. Record results on the Diagnostic Workbook. See *Tables 3-2 and Table 3-5 in Chapter 3 – Section 3.8.3 and Section 3.9.2* for minimum acceptable worst-case draft readings for gas- and oil-fired appliances.
7. If the draft is unacceptably weak at worst case, take all reasonable steps to attempt to improve worst-case draft and reduce house depressurization to acceptable levels.

Monitor ambient CO levels during draft testing. An ambient CO level above 35 ppm is a safety hazard – cease testing immediately. The CAZ should be ventilated before the resumption of draft testing and diagnosis of CO problems.

5.9 Make-Up Air Systems

Make-up air may be an option when the combustion appliance zone is excessively pressurized or depressurized and the appliance does not pass worst case draft. Use guidelines listed in *Table 5-6 in Depressurization and Worst-Case Draft Testing in Chapter 5* to determine acceptable pressures.

Add make-up air equal to 40 percent of the total exhaust ventilation. Multiply the total exhaust CFM (both continuous and intermittent) by 40 percent (0.40) to determine the amount of make-up air required (CFMs).

Make-up air systems provide supply air by way of fans and/or ductwork that introduce outdoor air into the home. These systems are sometimes electrically interlocked with exhaust fans elsewhere in the home so both fans run at the same time. This protects against the depressurization caused by large exhaust-only fans such as oversize range hoods. Balancing of the two airflows can be performed by balancing dampers in the fresh air duct. These systems, if properly balanced, can create house pressures closer to neutral than exhaust-only or supply-only systems. Follow the manufacturer's requirements for mixed air temperature and the location of the fresh air inlet.

When make-up air is installed, label the intake fitting "ventilation air intake" and educate the customer to keep yard debris and other contaminants clear of the intake.

5.10 Water-Heater Replacement

Occasionally, water heaters must be replaced for health and safety reasons. For information on replacement installation procedures, refer to *Water Heater Replacement in Chapter 4 – Section 4.1*. These reasons may include, but are not limited to:

1. Water heater is back-drafting/spilling. Refer *to Improving Inadequate Draft in Chapter 3 – Section 3.13.1* for guidance on how to remedy these problems.
2. The shell of the storage tank actively leaks and cannot be repaired.
3. Severe flame roll-out that cannot be repaired.

4. Carbon-monoxide measurement above 100 ppm as-measured or 200 ppm air-free, that cannot be repaired.

5.11 Mechanical Ventilation

Ventilation is an important health-and-safety consideration in homes weatherized in Wisconsin. Many homes have blower-door-measured air tightness and building characteristics that necessitate mechanical ventilation as a means of keeping indoor-air quality at a safe level.

The customer may refuse the installation of ventilation in their home. Any customer refusing the installation of ventilation must sign the *Refusal of Ventilation: Release of Liability, Indemnification and Waiver of Claims*, available via the link at the beginning of Chapter 5. Refusal of ventilation does not constitute refusal of a major measure. An original copy of the waiver must be given to the customer and a copy retained in the customer's file.

5.11.1 Choosing Ventilation Systems

Ventilation systems must be matched to the home. A home may require only simple exhaust fans in bathrooms and/or kitchen. Very tight homes may require a balanced central ventilation system.

When ducted ventilation systems are installed in homes with forced-air heating or cooling systems, the ductwork can be shared in a simplified or ducted-exhaust installation. Though this hybrid approach can save some of the initial cost, these systems are more complicated and prone to pressure imbalances. Install fully ducted systems whenever possible.

In cold climates, heat-recovery ventilators (HRVs) or energy recovery ventilators (ERVs) can offset some of the heat loss from exhausted air. The heat recovery savings will be greatest when winter temperatures are the lowest.

5.11.2 Sizing Ventilation Systems

Whole building ventilation systems are sized according to the size of the home and the number of occupants as described by the ASHRAE 62.2 standard. Use the Diagnostic Workbook, to determine if whole building ventilation is required. Note: Existing ventilation may be modified to provide either continuous or intermittent ventilation at the required amount, based on the integrity of the existing installation.

5.11.3 Local Exhaust Fans

The ASHRAE 62.2 standard for acceptable indoor air quality establishes an on-demand or an optional continuous flow rate for local exhaust in bathrooms and kitchens. An alternate compliance path that increases the flow rate of whole building ventilation to offset the lack of local exhaust is available for existing homes.

Follow these instructions when installing local exhaust fans to remove bulk pollutants and moisture:

1. Locate exhaust fans as close to the source(s) of pollutants/moisture as possible. For example, install bath fans in the shower or as close as practical, and install kitchen fans near the range.
2. Install exhaust fans as close as possible to the heated space, which usually means against the ceiling surface.
3. Consider the positioning of the new fan's exhaust port. Position ceiling fans so the exhaust port runs parallel with the ceiling joists and points toward the existing exhaust termination. If no existing termination is present, best practice is usually to point the fan's exhaust port toward the center of the attic. This makes it easier to attach exhaust ducting.
4. Avoid installing fans in vaulted ceilings, walls, or slopes if possible. These installations displace insulation and make it difficult to avoid cold spots, which foster condensation. In addition, these installations make it difficult to duct the fan to the outdoors.

5.11.4 Whole Building Exhaust Only Ventilation

The ASHRAE 62.2 standard for acceptable indoor air quality establishes a rate for whole building ventilation based on floor area and the number of occupants. When natural ventilation does not fulfill the entire established rate for whole building ventilation, mechanical ventilation is installed. In Wisconsin, the most common approach is exhaust-only ventilation. Local exhaust requirements may also be met by increasing the flow rate of installed whole building ventilation.

Surface-mounted exhaust fan: Exhaust fans aid air quality by drawing fresh air into the building as they remove indoor pollutants.

Follow these instructions for the installation of whole-building exhaust ventilation:

1. Install fans in bathrooms or kitchen when practical to reduce overall flow rate when following alternate compliance for local exhaust requirements.
2. In-line exhaust fans may be installed in a remote location such as the attic or basement. Ducting can be installed to one or two intake locations and then terminated to the outdoors. One option is to use the existing ceiling exhaust as an intake location after removing the fan assembly from the housing. This option avoids cutting new holes in ceilings.
3. Install fans with built-in controls or install a separate control to allow for the adjusting of the flow rate and frequency-of-operation as needed. Label all controls.

4. Install a service or shut-off switch if not an integral part of the fan control. Label all controls.
5. Measure the flow rate of the installed exhaust ventilation and record on Diagnostic Workbook. Record the highest flow rate in the exhaust fan section. Record the continuous or intermittent rate in the ventilation section.
6. Adjust the controls to provide the required flow rate at a continuous rate. Adjust controls for frequency-of-operation when operating intermittently. Intermittent operation should occur at least once in every three-hour time period.
7. Calculate intermittent operation using this formula: required flow / rate measured flow rate x 60. The result is the number of minutes-per-hour the ventilation should operate. The Diagnostic Workbook will assist installers in setting operational controls.

5.11.5 Exhaust Fan Ducting

Discharge exhaust fan ducting to the outdoors and not to an attic, crawl space, or garage, where moisture and pollutants can accumulate. Duct exhaust fans to the outdoors as follows:

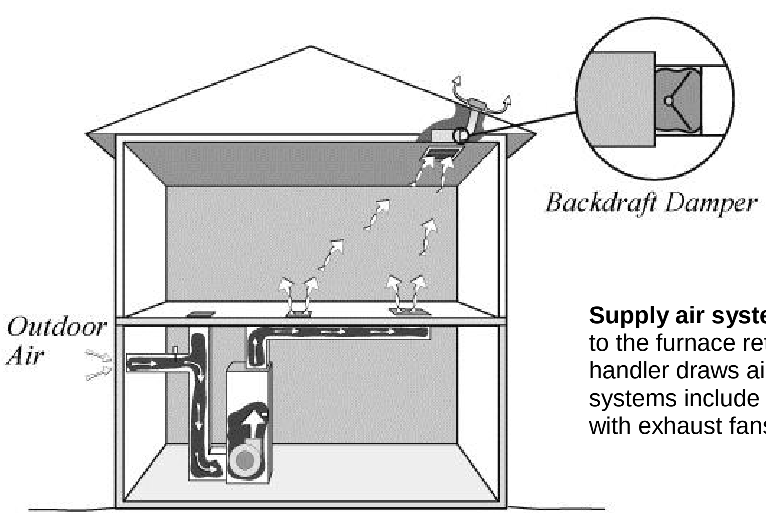
1. Use flexible or rigid ducting material.
2. Ensure a backdraft damper is present. The damper may be part of the termination hood, it may be integrated into the fan unit, or it may be installed separately in the exhaust duct.
3. Where practical, begin the ducting run by connecting a one- to two-foot section of straight rigid duct to the fan's exhaust port, in order to improve airflow.
4. Avoid installing elbows at 90-degree angles — this can reduce airflow. Instead, install elbows at as gradual and smooth of an angle as is reasonable.
5. Make duct runs as short as is practical. Avoid long duct runs, especially where they are above the insulation or running horizontally.
6. Attach the ducting material to the fan's exhaust port and to the termination hood.
7. Seal all joints in the exhaust-ducting run including at the fan and termination.
8. Insulate the ducting to a minimum of R-8 in unheated spaces. Ensure the insulation is secure and provides continuous coverage.
9. In multi-family housing, for continuous ventilation, multiple exhaust fans may be combined into a "collector box" and exhausted with an appropriately sized termination hood. In these cases, assure there is a backdraft damper integrated into every fan unit.
10. Use a termination fitting with an integrated collar. The termination shall have a screen material installed so it does not inhibit damper operation or restrict airflow.

11. Install termination hoods to the outdoors and not to a buffer zone, such as an attic, crawl space, or garage, where moisture and pollutants can collect.
12. A termination shall be installed a minimum of 3 feet away from any property line, a minimum of 3 feet away from operable openings to houses, a minimum of 10 feet away from mechanical intakes, or as required by authority having jurisdiction.
13. Install the top half of roof caps underneath the shingles, in order to prevent rainwater from leaking into the attic. Use galvanized or stainless steel fasteners, and use roofing cement to seal any leakage points.
14. Galvanized steel, stainless steel, or copper shall be used for termination fitting for kitchen exhaust fans.

5.11.6 Supply Ventilation Systems

Supply ventilation systems introduce fresh air into the home, and do not include heat recovery. They are usually installed in conjunction with forced-air heating or cooling systems. They incur an energy penalty as unconditioned air is brought into the home. It is critical with this, and any other installation utilizing the forced-air system, to follow the manufacturer's requirements for mixed air temperature and the location of the fresh air connection. Introducing very cold outdoor air directly into a forced-air furnace creates a risk of cracking the heat exchanger and will void the heating system warranty. The temperature of the air into the return side of the furnace cabinet should never be below 60° F for systems with continuous outdoor air supply or 55° F with an intermittent air system. Also, since this modification could result in cooler supply register air temperatures, the customer must understand and agree to this installation. Simple supply systems are difficult to balance effectively, especially in well-sealed homes. Central balanced ventilation systems are often a better choice considering overall efficiency and the need to balance house pressures.

The most common type of supply-only ventilation includes an outdoor air duct connected to the main return of a central forced-air heating or cooling system. The HVAC system's fan



Supply air system: Fresh air is ducted to the furnace return plenum. The air handler draws air into the home. Some systems include an electrical interlock with exhaust fans.

draws outdoor air into the plenum, delivering ventilation air to the home along with heated or cooled air. No ventilation air is supplied unless heating or cooling is needed.

The fresh air duct should have a balancing damper installed so the airflow can be adjusted during the initial installation. A motorized damper is sometimes installed to close the outdoor air duct when ventilation air is not needed.

Supply ventilation systems pressurize the home, forcing indoor air out through openings in the shell. This may keep outdoor pollutants, such as carbon monoxide from vehicles and lawn chemicals, out of the home, as long as the fresh air intake draws air from a clean location.

The positive house pressure created by supply ventilation systems can force indoor moisture into the walls. This can promote condensation in building cavities during cold weather. Moderate levels of pressurization are not usually a concern, though, if indoor RH is kept at or below 35 percent.

Supply systems introducing air to the HVAC system can be configured to provide fresh air when neither heating nor cooling systems are operating. In this mode, the HVAC fan can be set up to circulate ventilation air only. This method is most efficient when a variable speed HVAC fan allows the slower airflow required for ventilation-only operation. Single-speed HVAC fans move too much air and consume too much electrical power for efficient continuous operation.

5.11.7 Balanced Ventilation Systems

Balanced ventilation systems provide measured fresh air via planned pathways. Of all the ventilation schemes, they can do the best job of controlling pollutants in the home when properly installed. (Note: Wisconsin Uniform Dwelling Code does allow ventilation to be balanced through the use of unplanned pathways when no atmospheric combustion appliances are located in the building. Make-up is required when the combustion appliance zone is excessively pressurized or depressurized. For weatherization purposes, use the Building Depressurization Guidelines to deter excessive depressurization.) See *Table 5-6 in Chapter 5 – Section 5.6.2*.

Balanced systems move equal amounts of air into and out of the home. Most balanced systems incorporate heat recovery ventilators that reclaim some of the heat and/or moisture from the exhaust air stream. Simple mixing boxes are occasionally used to temper incoming air by mixing it with exhaust air, but their cost approaches that of heat recovery ventilators, and they incur an energy penalty as conditioned air is lost to the outdoors.

Balanced systems, when operating properly, reduce many of the safety problems and moisture-induced building damage possible with unbalanced ventilation. Balanced systems are not trouble-free, however. Proper design, installation, and maintenance are required for effective operation.

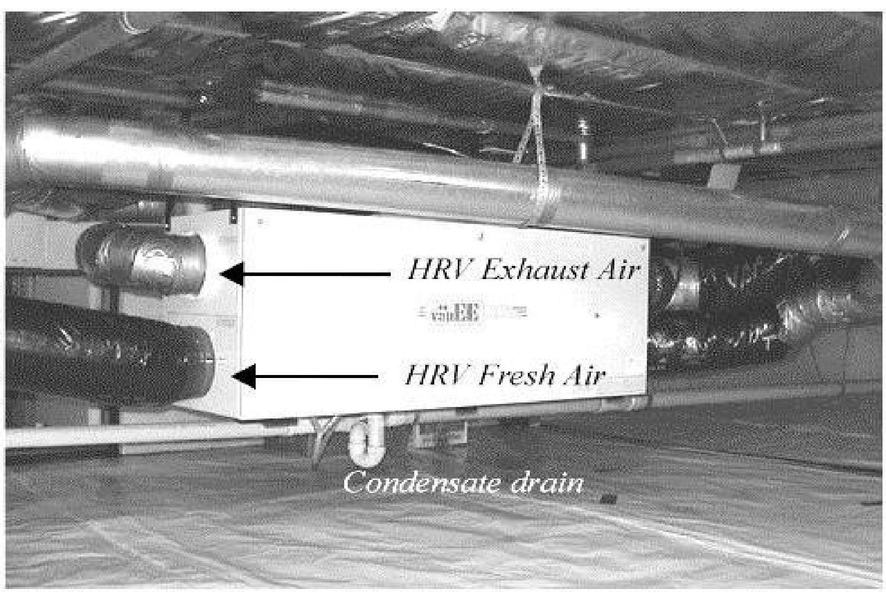
These complicated systems can improve the safety and comfort of home, but they require regular customer maintenance and periodic service (preferably by a knowledgeable professional) to assure they operate properly. Testing and commissioning is vital during both the initial installation and periodic service calls.

Variation 1: Fully-Ducted Balanced Systems

The most effective central ventilation systems include dedicated ductwork for both supply and exhaust air. All the system ducting leads to a central ventilator, which includes an HRV core to reclaim heat.

Fully-ducted systems are installed independently of other forced-air ducting. This gives the designer a high level of control over airflow and house pressure. They are most easily installed in new construction and are more difficult to install during weatherization.

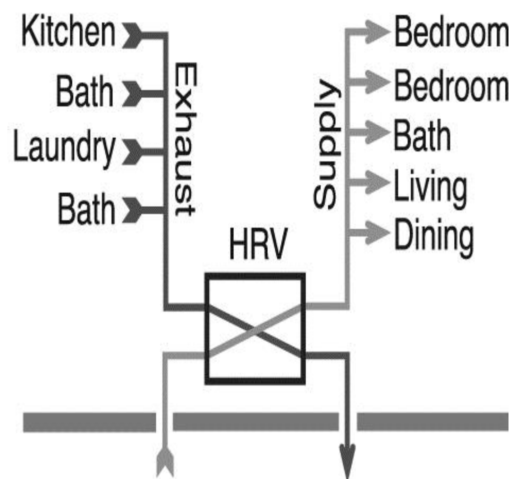
High-quality ductwork is a critical component of successful ventilation systems. Ducts should be sized large enough to minimize static pressure and reduce noise, and hard metal ducting used wherever possible. All seams and joints should be sealed using mastic or metallic tapes or other UL181 approved material. Exhaust grilles should be installed near the sources of contaminants in bathrooms, kitchens, or other areas where other pollutant-producing activities take place.



Fully-ducted heat recovery ventilator: Matched exhaust and supply fans provide balanced airflow. Dedicated exhaust ducting collects pollutants from bathrooms and kitchen. Supply ducting carries fresh air to bedrooms and central living areas. A heat-recovery core reduces energy loss from exhausted air.

Variation 2: Ducted-Exhaust Balanced Systems

Ducted-exhaust systems are connected to central forced-air systems. Dedicated ducting collects pollutants from bathrooms and kitchens. The exhaust air passes through a central HRV core before being exhausted to the outdoors. Fresh air is brought in through the HRV core, collects the heat extracted from the exhausted air, and is introduced to the forced-air system at either the supply or return plenum. Always follow the manufacturer's instructions for mixed air temperature, the location of the fresh air insert, and minimum return air temperature.



Fully-ducted central ventilator: Fully-ducted systems do the best job of collecting pollutants. Installed independently of heating and cooling systems, fully-ducted systems work well in homes with hydronic or electric baseboard heat where no ducting is installed.

The airflow should be balanced in ducted-exhaust systems so house pressures remain close to neutral. In practice, this is harder to achieve than in fully-ducted systems because of the influence of the forced-air blower. With typical airflows of 50-200 CFM, central ventilators are easily overwhelmed by the 500-1500 CFM airflows of forced-air systems. A high level of care is needed during design, installation, and commissioning of ducted-exhaust ventilation systems to achieve proper airflows and to achieve reliably balanced house pressures.

Polyethylene HRV core: This flat-plate counter flow heat exchanger slides out for cleaning.

Variation 3: Simplified Balanced Systems

Simplified, or volume ventilation, systems are connected to central forced-air heating or cooling systems. This is the least-favored ducting option.

Simplified systems draw exhaust air from the forced-air return air plenum. This air passes through the central ventilator that includes an HRV. Most of the exhaust airstream's heat is transferred to supply airstream, and fresh air is re-introduced to the forced-air return ducting. Always follow the manufacturer's recommendation for interlocking the air handler with the fresh air inlet. This system requires regular, effective customer maintenance, as system failure will result if maintenance requirements are not followed.

5.11.8 Heat Recovery Ventilators

Heat recovery ventilators (HRVs) are often installed in conjunction with balanced whole-house ventilation systems. The HRV core is usually a flat-plate aluminum or polyethylene air-to-air heat exchanger in which the supply and exhaust airstreams pass one another and exchange heat through the flat plates.

5.11.9 Heat Recovery Ventilator (HRV) and Energy Recovery Ventilator (ERV) Installation

Follow the specifications below when installing a balanced ventilation system:

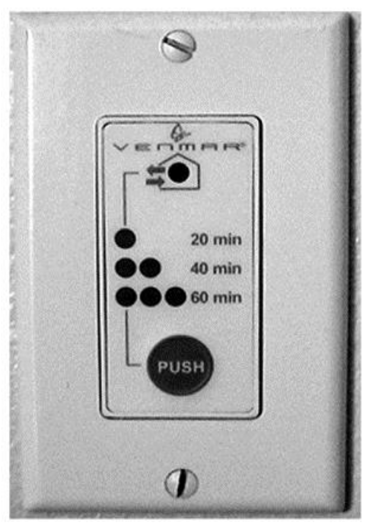
1. Install the system following the manufacturer specifications.
2. Install a backdraft damper between the heat recovery ventilator (HRV) or energy recovery ventilator (ERV) and the exterior.
3. Insulate ducts installed outside of the thermal envelope to a minimum of R-8.
4. Seal the gap between registers or grills and interior surface.
5. When connected to the heating system, exhaust air shall not draw directly from the heating system. Supply ducts should be installed as close to the HVAC system's fan as possible.
6. Educate the customer about how and when to change filter and clean the drain pan, according to manufacturer specifications.

5.11.10 Ventilation Control Strategies

Controls provide an opportunity for fine-tuning ventilation systems. Controls let the installer and customer choose when the system runs and how much air it moves.

Controls also provide an opportunity to adjust the system performance over time. The customer should be advised a periodic review of the control scheme should be performed, perhaps during service visits, to assure the system is providing sufficient fresh air for customer and acceptable moisture control for the building.

Locate the controls in a representative location on a main floor interior wall, and about 48 to 60 inches above the floor. Do not install them on an exterior wall, in a drafty location, or in direct sunlight.



Manual override control: A central heat recovery ventilator, normally operating at low speed, is boosted to high speed by this push-button countdown timer.

Manual Control

Simple on/off manual controls allow the customer to ventilate as needed. These are often used for exhaust fans in bathrooms and kitchens. Their effectiveness relies on a customer's perception of air quality.

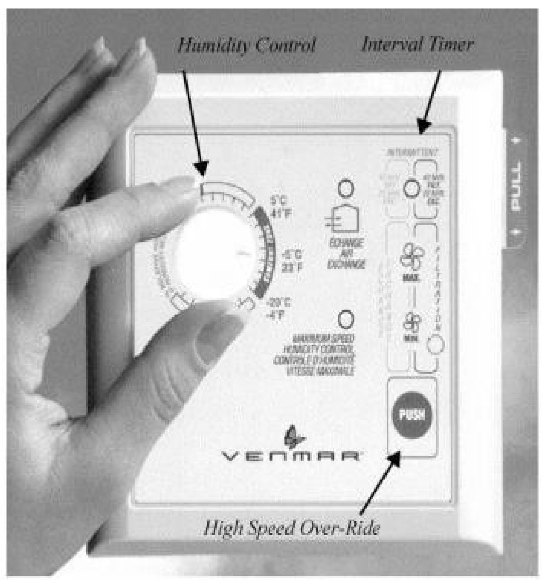
Manual controls sometimes include countdown or time-delay timers activated by customer and run for a specific period of time. In non-owner-occupied homes or other situations where a customer understands and cooperation is unlikely, fan-delay timers can be run in conjunction with bathroom lights to give a set period of ventilation whenever the bathroom lights are used.

Humidity Control

De-humidistats operate equipment based upon indoor humidity levels. They are used with either simple exhaust fans or central ventilation equipment. De-humidistats can be set for a range of humidity levels, and have the advantage of automatic operation that does not require much customer management. They should be set to keep indoor humidity low enough to prevent indoor condensation in the winter. This will vary from 30–50% RH, depending upon the outdoor temperature, effectiveness of windows and insulation, and other factors.

Combination Controls

Central ventilation systems are often operated by a combination of manual and automatic controls. The most common strategy utilizes a multi-speed fan that runs on low or medium speed to provide continuous ventilation. Override switches in the kitchen and bathrooms activate high-speed operation to provide intermittent high-speed operation during polluting activities such as cooking, bathing, or cleaning. The total airflow requirement specified by ventilation standards refers to this high-speed operation.



Central combustion control: The system can be controlled by humidity, time interval, or manually.

Timers allow the low-speed operation to be set for variable intervals such as 20 minutes on/40 minutes off per hour, 30 minutes on/30 minutes off, or whatever total ventilation time is needed. This adjustable interval provides an effective method of matching the ventilation capacity to the customer's needs.

5.12 Dryer Venting

Dryers produce significant moisture (and combustion gases, when gas-fired). These issues become an indoor air quality hazard in homes, if not vented to the exterior.

Educate the customer about proper maintenance for the dryer vent and termination. The customer should clean the exterior vent termination frequently. Twice each year, the customer should clean the rest of the venting system: the venting run, and the connection between the dryer and the ducting.

Consider the following when there is existing dryer venting:

1. If the existing is metal-flex duct and UL listed, the ducting may be left in place if deemed in good condition with no blockage. Shorten or re-route existing metal ducting if needed. Seal all seam and connections with tape or mastic, keeping in mine it may need to be removed for maintenance.
2. If the existing is vinyl duct, re-vent the dryer to the exterior with UL listed metal ducting.
3. If the vent termination is damaged, replace with a new termination.

Follow these instruction when installing new dryer venting

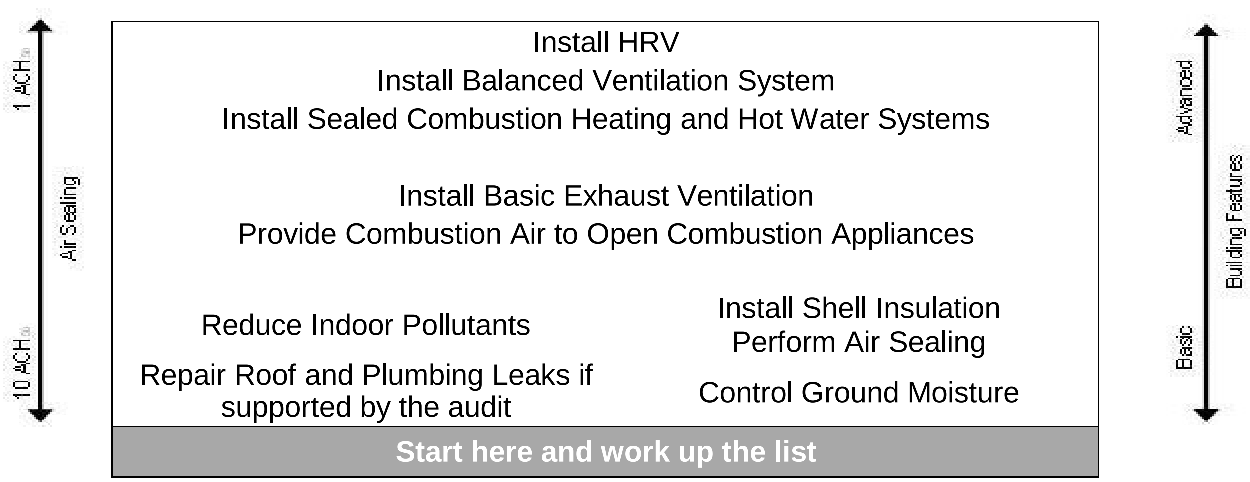
1. Follow the most direct route to the exterior when installing dryer duct, as feasible.
2. Use UL listed materials for ducting. Best practice is rigid metal duct with a smooth interior surface provides less resistance to air flow.
3. Install a dedicated termination with backdraft damper/flapper. Best practice is to install a louvered (three- or four-flapper) hood, as these hoods typically have the strongest airflow and work the best to prevent pest intrusion.
4. Vent all unvented dryers to the exterior. Do not vent dryers into attached garages, under porches, under decks, or where the moisture will damage building components.
5. Seal all seam and connections with tape or mastic, keeping in mind it may need to be removed for maintenance.
6. Use a hose clamp to fasten the duct to the dryer’s exhaust port. Do not use screws to make this connection. The screw tips will catch dryer lint, creating an obstruction and a fire hazard inside the ducting.
7. Insulate, to a minimum of R-8, sections of the dryer duct that run through unconditioned space. Exception: Under mobile homes, ensure a downward pitch so moisture may drain outwards.

5.13 Priorities for Existing Homes

There are some advantages to designing ventilation systems for existing homes. First, the home provides an observable history from which to work. Stained ceilings, peeling paint, and mildewed attic framing all tell the story of how a building operates. The customer may identify problems not immediately apparent, such as periodic back drafting of combustion appliances. In addition, the existing home has already aged, allowing lumber to dry and modern materials to out-gas, reducing the pollutant load on the ventilation system.

First, identify any major sources of moisture and other pollutants, and remove them or seal them away from the house. No ventilation system can effectively handle excess amounts of any pollutants.

Complete shell measures to assure reliable pressure and thermal boundaries. The heating, cooling, and ventilation systems depend on these measures to operate effectively.



Hierarchy of housing needs: Keep the entire structure in mind as you design and install mechanical systems.

The choice of ventilation equipment will depend upon the building's structure, airtightness, customer understanding and commitment to maintenance, and mechanical systems. Many homes may require only exhaust fans. A blower door test, worst-case draft depressurization test, and an assessment of the home's existing ventilation will provide the information to determine the home's ventilation needs. See *Worst-Case Draft Protocol in Chapter 5 – Section 5.6.*

5.13.1 Installation Best Practices

A high level of quality control is needed to assure ventilation systems work as intended. Properly designed and installed systems help create a healthy indoor environment and a long-lived building, while poorly executed systems can be ineffective or dangerous. Complex central heat-recovery ventilation systems require the most attention to design and installation.

Final Inspection and Quality Assurance Standards

Acceptable installation shall meet the following standards:

1. All Health and Safety measures were completed when appropriate to eliminate or reduce existing hazards or to eliminate or reduce hazards created as a result the installation of weatherization materials.
2. CO alarms are installed where required.
3. Smoke alarms are installed where required.

Ventilation for Indoor Air Quality

1. Whole building ventilation and local exhaust were installed as required.
2. Measured flow rate of whole building mechanical ventilation is between 90% and 150% of the ASHRAE 62.2 minimum calculated rate, as determined by the diagnostic workbook.
3. Installed whole-building ventilation operates continually or on an intermittent basis with a customer shut-off switch.
4. The customer signed a “refusal of ventilation” when ventilation was declined.
5. Ventilation Form filled out completely and left with customer.

Dryer Venting

1. Dryer venting is metal, not plastic, and newly installed venting is UL listed.
2. Horizontal venting is secured every four feet.
3. Screws or other penetrations that will catch lint were not used to connect ducting.
4. A termination with a damper was used.
5. The vent system is not connected to any other appliance.
6. The damper has no screen to catch lint.

Chapter 6: Repair

Repairs are defined as items necessary for the effective performance or preservation of installed weatherization materials. Repair measures are required to be reasonable, cost effective, and performed only when needed to install a measure necessary to effectively weatherize a building. Examples include, but are not limited to, repairing minor roof leaks, electrical repairs, and fixing water leaks. Repairs may also include installing protective materials involved with weatherization measures, such as paint used to seal materials installed through weatherization.

Follow all applicable lead and asbestos-safe work practices when performing repairs.

6.1 Windows and Doors

Windows and doors typically make up a small percentage of a building's thermal boundary. It is rare that enough heat loss occurs through them to justify cost-effective repair or replacement.

Experience from blower door testing has shown windows and doors tend not to harbor large air leaks. Though conductive and convective losses through windows and doors are often quite high on a per-square-foot basis, these losses are not affected much by most simple weatherization improvements.

Replacing missing and broken glass, re-glazing glass, installing sash locks, and installing weather-stripping is usually considered air sealing, not repair work (see *Air-Sealing and Indoor Air Quality in Chapter 1 – Section 1.4*).

6.1.1 Window Repair and Replacement

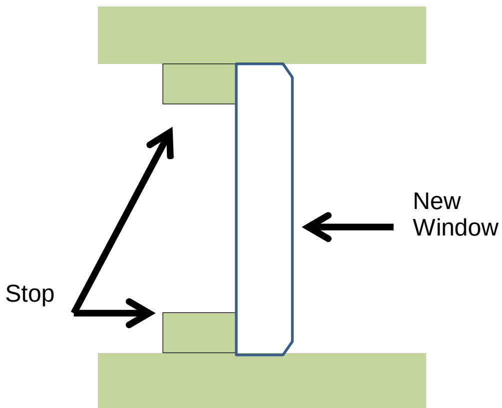
Observe the following standards for window repair and replacement:

1. Seal around a replacement window on the exterior and interior to prevent water intrusion and air infiltration.
2. When replacing or installing new exterior trim or stop, prime all bare wood.
3. When replacing a broken pane of glass, size the replacement pane $^{1}/_{8}$" to $^{3}/_{16}$" smaller than the opening, to allow for movement of the frame.
4. Install tempered safety glass when the location requires it.

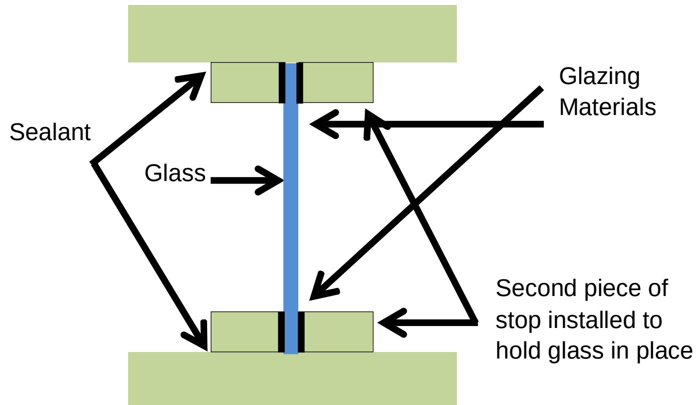
Replacing or Repairing a Basement Window

Determining whether to repair or replace windows located in an unintentionally conditioned basement is based upon customer use. Covering the entire window with plywood or other sheathing should only be considered when it is clear that the customer is agreeable to this option.

Before installing a new basement window, remove rotted framing and replace with pressure-treated lumber. Seal around framing to prevent water intrusion. Standard-size vinyl basement windows are a good choice for replacement when the customer requires an operable window, or cut a custom-sized piece of glass for the opening, allowing natural light to enter. Install a stop inside the framing as needed to place new window or glass against. A second piece of stop is used to hold the glass in place from the inside, creating a fixed-pane window.



Side view of new basement window installation using treated framing stop.



Side view of basement window glass installation using treated framing stop.

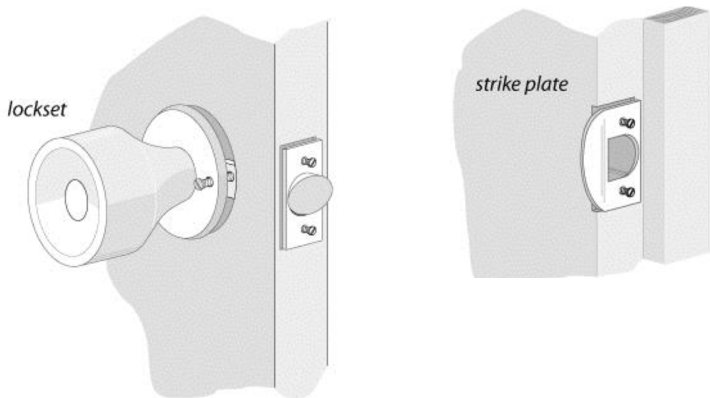
6.1.2 Door Repair and Replacement

Door operation affects building security and durability, so doors are often an important repair priority. Only primary doors may be replaced.

Door Repair

Door repair can also save energy if the existing door fits poorly. To improve the air seal of a door, limit door repair to the following work:

1. Replace missing or inoperable locksets. In some cases, a modernizer kit may be necessary.
2. Replace, install, or reposition the strike plate, as needed.
3. Replace, install, or reposition stops, as needed.
4. Replace deteriorated threshold.
5. Install a door shoe if needed to repair damage.



Minor door repair: Tightening and adjusting locksets, strike plates, and hinges helps doors work better and seal tighter.

Replacing a Primary Door

Follow these instructions when replacing a primary door:

1. Seal around the replacement door on the exterior and interior to prevent water intrusion and air infiltration.
2. If replacing or installing new exterior trim or stop, prime all bare wood.
3. After installation, confirm the door opens and closes smoothly, latches, and locks when shut.

Replacing or Fabricating a Basement Door

In older homes, basement exterior doors are often odd shapes and sizes. Sometimes, no door is present. If a door is present, it is sometimes in disrepair. Often weatherization installers fabricate a replacement door out of lumber — for air-sealing purposes, for security reasons, to preserve weatherization materials, or to maintain the integrity of the existing building materials.

Follow these instructions when fabricating a replacement basement door:

1. Use treated lumber.
2. Take precautions to reinforce the door, to prevent warping and to ensure longevity.
3. Seal around the replacement door framing on the exterior and interior to prevent water intrusion and air infiltration.
4. Insulating the fabricated basement door is optional. If insulated, insulation should be a minimum of R-5.
5. After installation, confirm the door opens and closes smoothly, latches, and locks when shut.

Final Inspection and Quality Assurance Standards

Acceptable installations shall meet the following standards.

General Repairs

1. The repairs are necessary for the effective installation, performance, and/or preservation of weatherization materials installed in the building.
2. The repairs are cost efficient and correct the problem(s) at hand.

Window Replacement

1. Window installation meets program instructions and the window unit is ENERGY STAR® certified.
2. The installed window opens smoothly and operates properly.
3. The installed window is installed square, plumb and true, as structurally allowable.
4. The installed window does not leak.
5. Installation meets all applicable best practices (e.g., flashed effectively, unit is back caulked, etc.)
6. Proper lead-safe work practices are documented in file.
7. The customer file contains photographs of the pre-existing window, and the photographs demonstrate the pre-existing window met the Wisconsin Weatherization Program guidelines for replacement.

Door Repair

1. All necessary door repairs were undertaken.

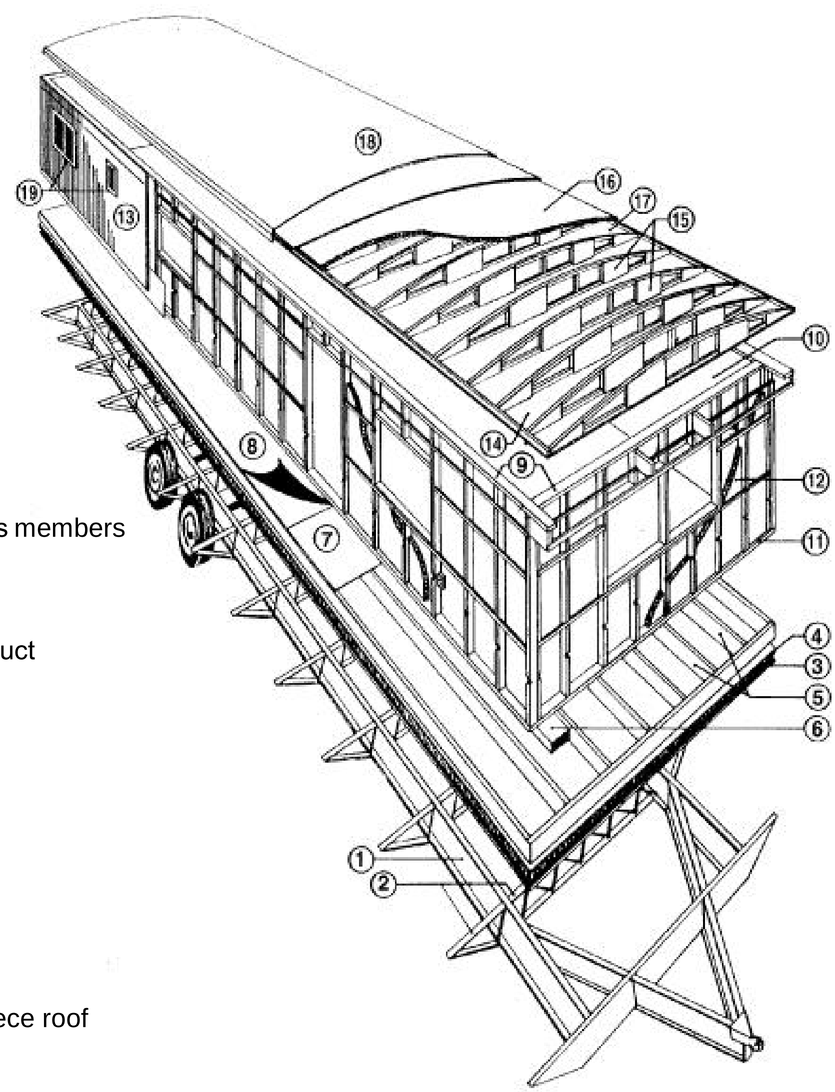
Door Replacement

1. The installed door opens and closes easily, latches tightly, and performs its function.
2. Replacement door meets R-value requirement.
3. Installation meets all applicable best practices (e.g., flashed effectively, back caulked, etc.)
4. Proper lead-safe work practices are documented in file.
5. The installed door does not leak.
6. The installed door is installed square, plumb and true, as structurally allowable.
7. The customer file contains photographs of the pre-existing door, and the photographs demonstrate the pre-existing door met the Wisconsin Weatherization Program guidelines for replacement.

Chapter 7: Manufactured Home Weatherization

7.1 Manufactured Home Weatherization

Manufactured homes, also known as mobile homes, present unique weatherization opportunities and challenges. Often, mobile home weatherization practices differ from the practices for site-built dwellings. Mobile homes typically use more energy per square foot than site-built homes, but their standard construction makes them more straightforward to weatherize. Insulation retrofits, air sealing, duct sealing, and replacement heating systems present some of the best energy-saving opportunities in mobile homes.



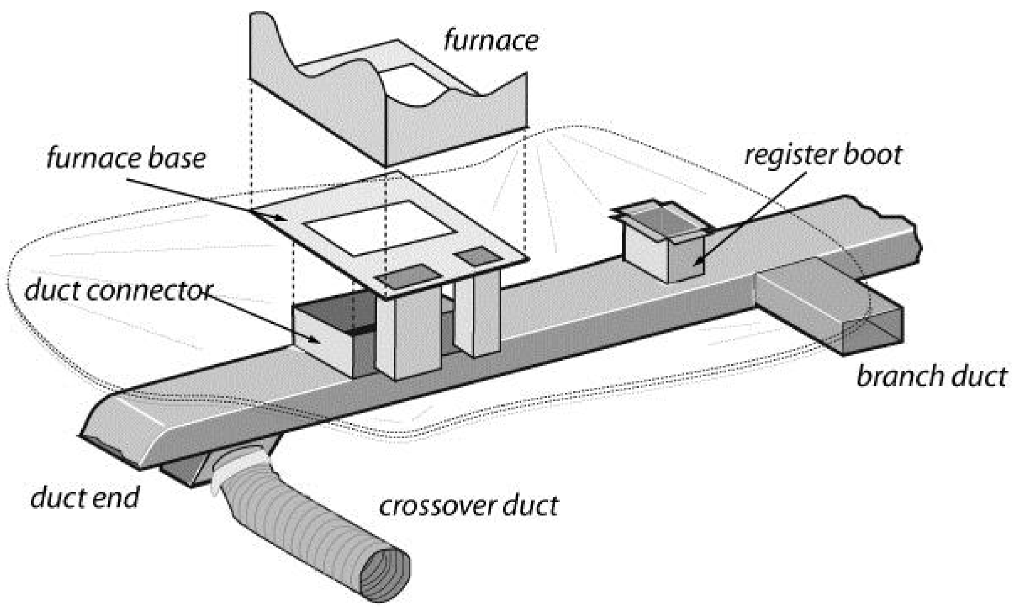
Typical Components of a Mobile Home:

1 — Steel chassis
2 — Steel outriggers and cross members
3 — Underbelly
4 — Fiberglass insulation
5 — Floor joists
6 — Heating/air conditioning duct
7 — Decking
8 — Floor covering
9 — Top plate
10 — Interior paneling
11 — Bottom plate
12 — Fiberglass insulation
13 — Metal siding
14 — Ceiling board
15 — Bowstring trusses
16 — Fiberglass insulation
17 — Vapor barrier
18 — Galvanized steel one-piece roof
19 — Metal windows

7.2 Supply Distribution System

Mobile home supply ducts are usually outside the home's pressure boundary and often leak significantly, presenting an opportunity for savings through effective duct sealing. Sealing the ductwork should be completed prior to any repair work to the belly or insulating the belly cavity. Many leakage points in the system are most easily accessed from underneath the belly.

Visually inspect ducts and registers using a digital camera, borescope, or mirror and flashlight to identify large holes, gaps, or disconnected sections. Take photos by placing the camera (with the strap around the wrist) inside of the ductwork.



Mobile home ducts: Mobile home ducts leak at their ends and joints–especially at the joints beneath the furnace. The furnace base attaches the furnace to the duct connector. Leaks occur where the duct connector meets the main duct and where it meets the furnace. Branch ducts are rare, but easy to find because their supply registers are not in line with the others. Crossover ducts are found only in double-wide and triple-wide homes.

7.2.1 Pressure Pan Duct Testing

To measure the relative leakiness of the forced-air distribution system, complete the following steps:

1. Set up the mobile home in winter condition, with all interior doors open and stationary.
2. Set the digital gauge to "PR/PR" and connect a pressure hose from a reference tap to outside. Measure the baseline House with respect to Outside (HwrtO) pressure. Turn on the blower door fan, and adjust it to create a 50 Pascal pressure difference HwrtO adjusted for baseline.

3. Without changing the blower door speed, disconnect the outdoor pressure hose from the digital pressure gauge. Connect a pressure hose from an input tap to the pressure pan.
4. Go to the supply register located furthest from the furnace on one end of the mobile home. Place the pressure pan over the register and record the pressure difference in the Diagnostic Workbook.
   a. If the positioning of the register does not allow the pressure pan to form an airtight seal, other materials (duct mask and cardboard, etc.) may be used to create an airtight seal over the entire register. After developing an airtight seal, attach a metal pressure probe to the end of the hose. Puncture a small hole in the sealing material, insert the metal probe into the hole, and record the pressure difference.
5. Repeat Step 4 (4a) at all remaining registers in the home.

7.2.2 Interpreting Duct Leakage Results

When duct leakage exists, it allows air to infiltrate the ductwork; and this infiltration causes the pressure difference measured between the supply ducts and the main body of the home. The more duct leakage that exists, the greater the pressure difference between the ducts and the home's interior.

If ducts on one side of the home exhibit higher (less negative) pressures than ducts on the opposite side, substantial duct leakage exists in the general vicinity of those higher-pressure ducts, rather than at each duct individually. If such a discrepancy is observed at the ducts surrounding the furnace, this may indicate a need for duct sealing on the ductwork and connections near the furnace.

7.2.3 Mobile Home Duct Sealing

If possible, seal supply ductwork located in the mobile home belly so the cumulative pressure pan readings of all registers is 3 Pascals or less, when the home is at 50 Pascals with respect to outside. When duct sealing does not reduce the cumulative reading to 3 Pascals or less, discontinue duct sealing and document the results in the Diagnostic Workbook.

The following locations are typically sealed from inside the mobile home:

1. **Furnace to plenum connection when AC is not present:** Access this area by removing the A-coil access panel when no central air conditioning is present. Since the temperature at this location can be very high, it is recommended to use materials other than butyl tape, such as step-flashing cards, whenever possible. Butyl tape sags and loses its adhesive properties quickly at elevated temperatures.

   For small to medium holes apply butyl tape and/or mesh tape and then apply a thick coat of mastic over both. To seal larger holes, attach sheet metal with fasteners taking care to seal the edges using mesh and mastic. Small holes and seams can be sealed with mesh and mastic or mastic alone. Mesh is applied over all butyl tape, overlapping onto the ductwork to assure a lasting seal.

2. **Register risers (collars) to floor and trunk:** Secure riser to trunk and/or floor before sealing connections. Large gaps can be covered with step-flashing cards. Be sure to sandwich mastic between the card and ductwork to obtain a permanent seal. Take care when sealing the riser to the top of the floor covering to allow the register room enough to seat correctly. Do not extend the tape beyond the lip of the register. As with all applications, butyl tape should be covered and overlapped with mesh tape and mastic, completely imbedding all exposed butyl tape, however, this may not always be possible at the top of risers.
3. **In-floor trunk lines:** Short pieces of pre-formed J-channel work well to hold collarless trunks tight to the floor before sealing with mastic. Trim channel as needed to ensure it is covered by the register.
4. **Terminal registers:** Often the ends of trunk runs do not have blocking present. Install a “scoop” or blocking after the last register when it will not cause the air-distribution to become imbalanced. The scoop is constructed of sheet metal and is sealed to the duct walls, as per normal procedures. Ductwork is normally constructed to provide static pressure, which equalizes flow. When scoops are installed, they reduce the ability to create static pressure and the result is increased flow out of the scooped register. If the scoop is installed in ductwork in a room already getting adequate air flow, comfort and pressurization issues may arise.

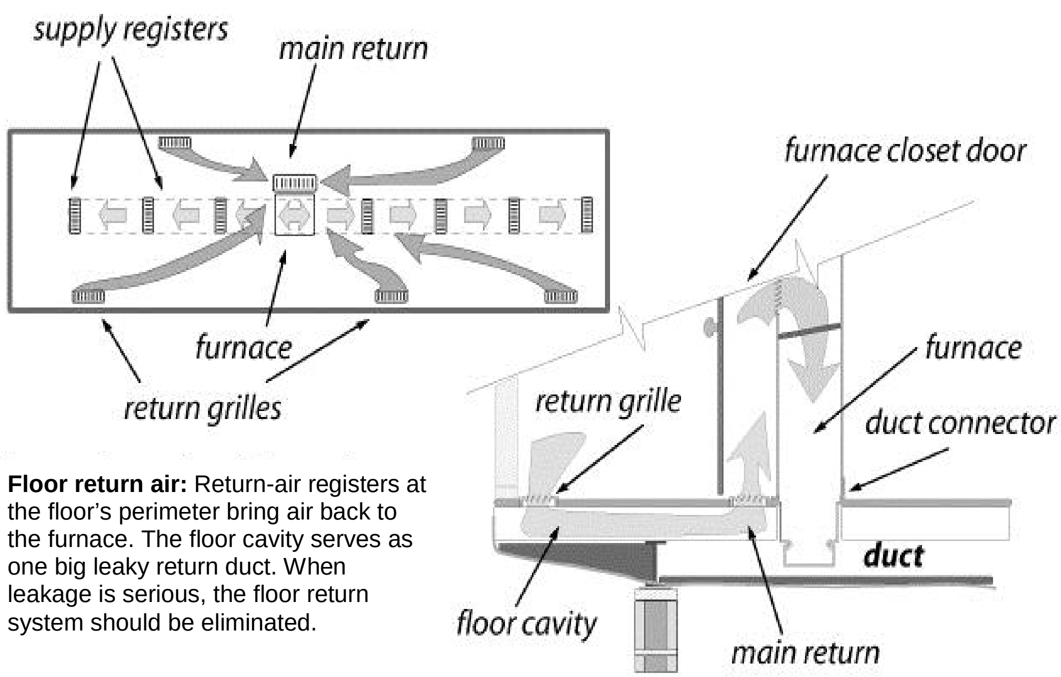
The following locations are typically sealed from under the mobile home. The road barrier (belly) may need to be cut open to gain access to the ductwork.

1. **Trunk to crossover duct on double-wide mobile homes:** Generally constructed of insulated flex-duct, the inner sleeve shall be mechanically secured and sealed to the starter collar of the main trunk. This is usually accomplished with strap ties or large diameter hose clamps. Sealing is generally performed with mastic. The outer sleeve is then secured to the trunk or the road barrier but does not need to be sealed.
2. **Plenum to trunk connections when central AC is present:** The trunk is opened directly below the furnace. It is recommended this piece be removed and replaced with an over-sized piece of sheet metal either mechanically fastened to the inside or outside of the trunk. Placing the piece on the inside of the trunk assures it will never sag or fall out. As with all metal-to-metal connections, sandwich them with mastic. Sealing is performed in the same manner as Number 1 above.
3. **Take-offs from main trunk to side registers:** These connections can only be accessed from below the mobile home. They are particularly leaky in duct-board trunk lines. Seal using the same materials and methods as used for collars and risers.
4. **Ends of trunk runs, abnormal leaks, anomalies, and any seams between sections:** The seams and other unusual leaks can be very difficult to locate. It is recommended the

technician physically inspect all ducting whenever possible, to find these leaks that may not otherwise be addressed. Seal as appropriate for the wide-range of conditions that may be encountered.

7.3 Return Air Distribution System

Many mobile homes do not have ducted return systems; instead, the entire cavity or attic space is used as a return duct. Eliminate floor and ceiling cavities used as return air plenums in favor of having return airflow through the hallway directly into the furnace.



Floor return air: Return-air registers at the floor's perimeter bring air back to the furnace. The floor cavity serves as one big leaky return duct. When leakage is serious, the floor return system should be eliminated.

To eliminate a belly return-air system:

1. Block all floor return registers with a durable and tight air barrier, being careful to find hidden return registers under built-ins, behind furniture, and in kitchen cabinet kick-spaces.
2. In the furnace closet, block all floor duct openings completely. If the existing atmospheric furnace is retained, be careful not to seal its combustion air inlet.
3. Install grilles or a louvered door to provide furnace manufacturer's recommended net free return grille area in the furnace closet door.
4. Measure the temperature rise of the furnace to confirm airflow is within the manufacturer's instructions.

7.3.1 Measuring Temperature Rise

The heating system's temperature rise should be within the range specified on the manufacturer's label. If no manufacturer's information is available, ensure the furnace has sufficient airflow so the temperature rise is between 40° and 80° F.

To test the temperature rise of a mobile-home heating system:

1. Inspect the plenum/furnace joint before measuring the temperature rise. Repair this joint, if needed, after completing testing.
2. Make sure all interior doors are open and stationary, except the furnace closet door.
3. Close the furnace closet door completely.
4. Turn on the furnace and allow the furnace to reach full steady state conditions. Measure the supply temperature at the register closest to the furnace; making sure the airflow to this register is not blocked and no significant duct leakage exists between the furnace and the thermometer.
5. Subtract the house air temperature (the return air) from the supply air temperature. The difference is the temperature rise.

If the temperature rise is too high or too low, investigate for restrictions to airflow or remaining duct leakage. The fan speed may be adjusted to bring the temperature rise within the acceptable range.

7.3.2 Measuring Room Pressure Differences

When interior doors are closed while the heating system operates in a mobile home, the supply air pressurizes the room and creates a pressure imbalance between the room and the main body of the home. This room-to-house pressure difference causes increased air exfiltration through that room's primary pressure boundary. Mitigating or eliminating the room-to-house pressure differences saves energy by reducing air leakage through the room's primary pressure boundary.

To measure individual room pressure differences:

1. Start/operate furnace air handler.
2. Measure the pressure difference across each interior door, one at a time. Place a hose inside the room away from the supply register and connect to the input tap of the manometer. Close the door, making sure the hose is not pinched or restricted. Record the room pressure with respect to house on the Diagnostic Workbook. If the room does not have a supply register, do not measure it.
3. Rooms with a measured pressure of greater than 3 Pascals are excessively pressurized and are not well connected to the house and do not have the necessary path for return air. A connection between the room and house can be achieved by the following:

a. Undercut the door (usually this is the most cost effective option),

b. Install a grille in the door, or

c. Install a jumper duct under the floor.

After determining the size of the opening needed to lower pressurization, consult with the customer as to the best option for their situation. A simple method to determine the size of the opening needed to lower the pressurization in a room is to open the door slowly while measuring the pressure difference across the door until the pressure difference is 3 Pascals or less. Measure the square inches of the opening created. This is the minimum net free area of room-to-house opening required to reduce the pressure difference to 3 Pascals or less.

> ***Example:*** *The door is opened by 2 inches, and the door is 80-inches tall. The net free opening to be added would be 160-square inches. Divide this area by the width of the door to determine how many inches need to be cut off the bottom of the door. An example would be 160/32 or 5 inches. This is probably not going to be an acceptable solution (from a privacy standpoint). A door grille with 160 square inches of net-free area may be a better solution.*

7.4 Floor/Belly Insulation

Mobile home existing floor cavities are usually insulated with wide fiberglass blankets, attached to the bottom of the floor joists (typically 2 x 6 joists). Therefore, the entire cavity is un-insulated. In floors with transverse floor joists (following the width of the home), the duct is attached to the bottom of the floor joists, resulting in a dropped belly. This enlarged floor cavity can require an excessive amount of insulation, unless technicians can pin the belly material up to the floor joists to reduce the belly's volume. Average insulation densities for loose fill insulation installed in mobile home bellies will be 1.25 to 1.75 pounds of blown fiberglass per cubic foot. **Do not dense-pack or over-fill this area.**

7.4.1 Preparations for Belly Insulation

Mobile homes normally have a "road barrier" of fiberboard or tough fabric that protects the floor from rodents and road dirt during transport. Damage to this barrier is common, and results in air leakage.

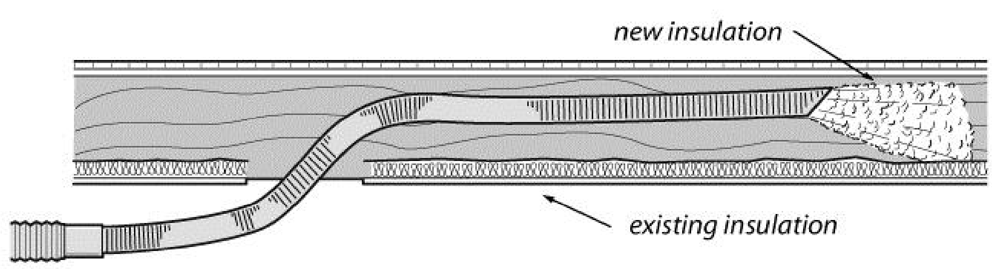
Before installing belly insulation, follow these preparatory steps:

1. Confirm no water or sewer leaks are present. Confirm with customer if previous leaks or frozen pipes have occurred. Document leak locations. If leaks are discovered, contact the energy auditor or project supervisor for guidance on how to proceed.

2. Complete duct sealing (see *Return Air Distribution System in Chapter 7 – Section 7.3*) and non-guideline air sealing around floor penetrations (see *Air Sealing in Chapter 7– Section 7.7*) before installing floor insulation.
3. A vapor barrier may be used to provide a working surface for installers and ground moisture control. Be cautious when site conditions may cause surface water under the mobile home to pool on top of this barrier if leaving in place.
4. Secure water pipes up, as close to the floor joists as possible, so insulation will fill in beneath them. This ensures plumbing pipes are located on the interior (warm) side of the thermal boundary, to prevent frozen pipes. If this is not possible, insulate the pipes separately or insulate the belly underneath the pipes, leaving the space above the pipes un-insulated to allow ambient heat from the home to warm the pipes and prevent freezing.
5. With flexible dropped bellies, try to fasten the belly material to the floor joists in order to eliminate excess volume of the belly.
6. Repair holes in the belly, except those that provide convenient access for blowing insulation. Fasten belly patches with adhesive, clinch staples, or screws and lath strips, to provide durable patches. For large holes in road barriers, preferred patching materials include insulated sheathing board, fiberboard, and nylon reinforced mesh specifically manufactured for mobile homes.

7.4.2 Insulating the Belly from Underneath

Blowing insulation into the belly with a large diameter fill tube from underneath is an effective and preferred installation method. The conditions and space restrictions underneath the mobile home determine whether this option should be considered. A ground moisture barrier makes installing the insulation more comfortable for the installer. Insulation can be blown through existing holes in the road barrier before patching them. Installers should note where insulation has been installed and where it has not been installed. Some of the floor areas usually may only be accessible from underneath if they are to be filled at all.



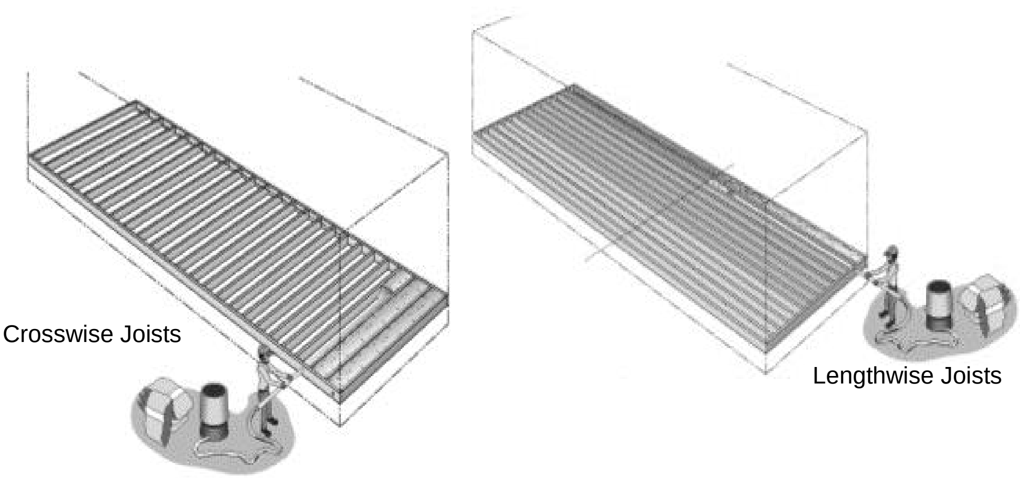
Blowing bellies: A flexible fill-tube, which is significantly stiffer than the blower hose, blows fiberglass insulation through a hole in the belly from underneath the home.

Fill tube inserted into belly hole.

Blowing insulation from under the home: A large diameter fill tube fills cavities rapidly from underneath.

7.4.3 Rim Blow through Rim Joists

Blowing insulation through the rim joist is another installation method. However, rim joists may not be drilled if they are determined to be a structural component of the foundation support system or if floor joists are 24 inches or greater on center. Drilling can be dangerous without a good drill and a sharp bit. To avoid weakening the door threshold, do not drill beneath doors. Do not drill directly through trim covering rim joist. Use wooden plugs to seal holes drilled in the rim joist. When possible, substitute the wing blow (see *Wing Blow in Chapter 7 – Section 7.4.4*) to avoid structural problems.



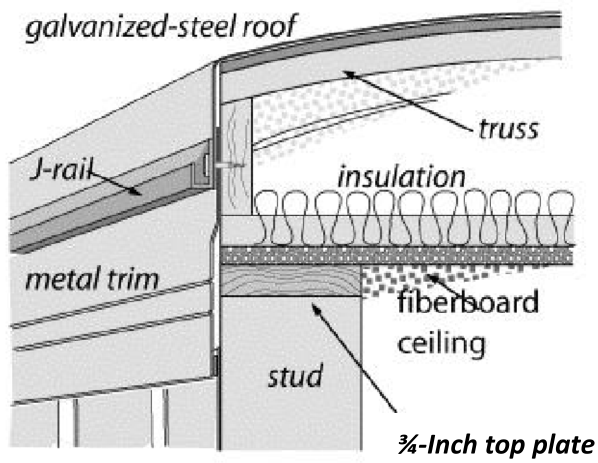
Insulating through the rim joist: Mobile homes have either lengthwise or crosswise joists.

7.4.4 Wing Blow

Blowing insulation through the belly at the wing is a variation of the rim joist blowing technique. This method has some of the advantages of blowing from underneath and blowing through the rim joist. Specific areas, notably the floor cavity between the hole and the installer, need to be insulated using a shorter flexible fill tube. If bellies cannot be insulated through the rim joist and must be insulated from the wing or underneath, the use of a large diameter fill tube is preferred.

7.5 Attic/Ceiling Insulation

Fiberglass batts or blankets are usually present in the narrow roof cavity, but there is typically room for additional insulation. The space available typically varies from 1 or 2 inches along the building's edge, up to 10+ inches in the center for homes with bowstring trusses. Lightweight sloped-roof trusses provide up to 3 inches at the edge and up to 2 feet at the center. Crews may use a variety of methods to insulate mobile home roof cavities, depending on the characteristics of the roof cavity, personal methodology preferences, and conditions on site. Install insulation at uniform coverage and density between 1.25 and 1.75 pounds per cubic foot. Typically, it is more difficult to insulate the edges of the attic, so ensure insulation covers these areas.



Bowstring roof details: Hundreds of thousands of older mobile homes were constructed with these general construction details.

7.5.1 Preparing For Ceiling Insulation

Inspect the ceiling and roof to determine if conditions allow for adding insulation. It is important to perform repairs, as needed, to reinforce the ceiling.

Before installing ceiling insulation, follow these preparatory steps:

1. Hold insulation 3-inches back from recessed light fixtures, fan and heater housings, and chimneys not insulation-contact (IC) rated. IC-rated light and fan fixtures may have insulation surrounding them. Chimneys with zero-clearance thimbles can also contact insulation.
2. Complete air sealing around chimney bypasses above the heating system and water heater if present.
3. Inspect for ceiling openings in closets and cabinets, and confirm insulation will not spill down through the ceiling into these areas.

4. Seal bypasses. If accessibility restrictions prevent air sealing, document the reason(s) in the customer file.
5. Mark the fill tube at 1-foot increments. If the edge is 7 feet from the hole, insert the fill tube to the 7-foot mark; if the fill tube does not go in far enough, try again.

7.5.2 Blowing the Roof Cavity from the Roof Blowing from a Square Hole

With customer approval cutting a 10 inch square hole directly over a truss gives access to two joist cavities and enough room to maneuver a 2 inch diameter fill tube. This large fill tube allows for a fast fill rate. The hole is stuffed with fiberglass batt to make it stand high. Patch the hole with a 14 inch square piece of stiff galvanized steel sheeting, sealed with roof cement and screwed to the roof with sheet-metal screws. Cover the patch with an 18-inch-square piece of peel and seal butyl-aluminum roofing.

7.5.3 Blowing the Roof Cavity through Round Holes

Some technicians prefer drilling smaller holes to cutting the large square holes. This method requires using a smaller diameter fill tube to fill the roof cavity. The holes are filled with plastic plugs and sealed with silicone caulking. The plugs are covered with 6-inch-square patches of peel and seal. With this method, the holes are easier to patch. However, this system requires more holes in the roof.

7.5.4 Blowing a Pitched Roof

Pitched roofs are common in double-wide mobile homes. More volume exists under these roofs than in a metal-roofed single-wide mobile home. The density will be lower (<= 0.6 lb/cf) than when blowing the narrower, more airtight cavities and the cavity does not need to be completely filled to the peak. These roof cavities are often accessible through roof vents or the gable end.

In double-wide mobile homes, adequate clearance may exist to insulate the ceiling cavity as an open blow. Access to the ceiling cavity can be gained through the gable end by removing the siding panels. Planking is usually necessary to distribute the weight of the installer and to make moving among the webbed trusses easier.

Roof-edge blowing: Use a rigid fill tube to blow insulation through the roof edge. This avoids making holes in the roof, though this process requires much care in refastening and re-sealing the roof edge.

7.5.5 Blowing the Roof Cavity from the Edge

Metal roofs on mobile homes are usually fastened only at the edge, where the roof joins the wall. When there is clear access along one long side of the home, this method can result in a fast and effective fill with minimum disturbance to the roof.

This procedure requires scaffolding in order to be performed safely and efficiently.

Carefully re-seal of the roof edge after insulating the cavity. The best way to re-fasten the roof edge is to seal it to the framing with new putty tape and staple it with an air-powered stapler, the way it was originally fastened. Also, seal the J-rail with putty tape, and re-screw it with larger sheet-metal screws.

7.5.6 Interior Drill and Blow

Drilling holes and blowing insulation into the roof cavity through a fill tube from the interior is a good procedure for inclement weather or when the exterior condition of the roof will not support other methods. The larger the hole, the easier it is to maneuver the tube out to the edge of the roof cavity. Use a plastic plug that matches the hole size. Use care not to damage the hole because the edge of the plug will not hide very much damage around the hole. If all of the holes are drilled in a straight-line, trim board may be installed to hide the drill holes.

Installing insulation through the ceiling: The technician pushes the fill-tube into the cavity and out near the edge of the roof. The holes are drilled in a straight line for appearance sake.

7.6 Sidewall Insulation

The sidewalls of many mobile homes are not completely filled with insulation. This reduces the R-value of the existing insulation because of convection currents and air leakage. Before installing sidewall insulation, follow these steps:

1. Ensure the customer is aware of any pre-existing damage to the walls, and also the potential damage that can occur from insulating the walls.
2. With customer approval, remove pictures and wall hangings from the interior walls. Re-hang pictures and wall hangings after insulating the walls.
3. Add nails or screws to interior paneling and trim as necessary to reinforce interior walls.
4. Inspect the electrical system to determine if the wiring and circuit breakers or fuse box is adequate. Check the area around wall switches and outlets to determine if there is evidence of past electrical problems.

Checking walls: Measure the cavity and the existing insulation level. Make sure wall outlets work before and after insulation installation.

Do not insulate the walls if the wiring is in poor condition. If the wiring is poor in a specific area, contact the energy auditor or site supervisor for guidance on how to proceed. Document the conditions in the customer file.

If aluminum wiring is present, take the following precautions:

1. Mark cavities with outlet, switch, or light fixture on the outside siding. These cavities should be carefully tubed rather than stuffed with a batt; or, if excessive movement of the wires will still occur, then the cavity should not be insulated.
2. Test each outlet, switch, or light fixture to confirm that it is operating properly before insulating. Re-test afterward.

Loosening siding for wall insulation: Remove screws at the bottom of the metal siding. Before installing insulation, fasten the siding sheets together at the bottom with a short sheet-metal screw.

7.6.1 Preparing Siding for Wall Insulation

Metal siding on mobile homes is typically installed vertical. Most metal-sided mobile homes have horizontal rows of screws, which attach siding to horizontal 1 x 2 belt rails. Remove the bottom two rows when using the wall stuffing technique. To use the sidewall blowing technique, remove only the bottom row of screws. The metal siding joins piece to piece, with the first piece sliding inside a crimped channel in the second piece. It is better for this joint to remain together. Fastening a short sheet metal screw through the two sheets keeps them together during the insulation process.

Occasionally, mobile-home siding is horizontal instead of vertical. To insulate these cavities, simply remove the bottom row of siding. Reinstall the siding when the insulation work is complete.

7.6.2 Sidewall Blowing Technique

Blowing insulation into mobile-home sidewalls is similar to insulating sidewalls of site-built homes, although the fiberglass insulation is installed at a lower density. Take care not to create bulging walls during installation.

Insulate to the maximum structurally allowable. Insulate walls with complete coverage and uniform density throughout the accessible wall cavity. Insulating above windows is not required.

Blowing walls: Using a fill tube works well for most mobile home wall cavities.

7.6.3 Sidewall Stuffing Technique

The best materials for this method are batts completely encased in breathable polyethylene film. Un-faced batts also work, when installed with a plastic sheet. The smooth plastic sheet allows the batt to slide up the wall against the interior paneling, without snagging or bunching. Some homes do not lend themselves to this technique because of obstructions in the walls.

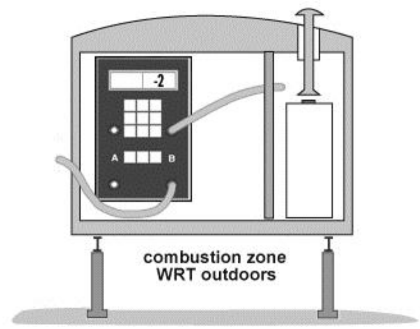
Batt stuffing: When this method works, it is quite efficient. Wall cavities with obstructions or non-standard widths must be blown.

7.7 Air Sealing

See *Air Sealing in Chapter 1 – Section 1.4* for additional information.

7.8 Worst Case Draft Protocol

Conduct building depressurization tests in all units, plus a worst-case draft test on all units with natural-draft combustion appliances. When the water-heater cabinet has an exterior door, best practice is to insert testing probes via interior pathways. Run the hose through the exterior only when an interior pathway is not available.



Water-heater worst-case test: Measure depressurization in the water-heater closet from indoors if possible.

See *Worst-Case Draft Protocol in Chapter 5 – Section 5.6* for additional information.

7.9 Heating Unit Replacement

Replacement furnaces shall be approved for use in mobile homes. Follow current policy for the minimum Annual Fuel Utilization Efficiency (AFUE) rating. Replacement units should fit the footprint of the furnace closet and shall not stick out into the hallway.

Follow these steps when installing a new mobile-home furnace:

1. Install properly sized units according to ACCA Manual J or an equivalent sizing formula. Include a copy of the sizing calculation in the customer file.
2. Properly remove and dispose of existing unit.
3. Install a new furnace base, unless the existing base matches the new furnace.
4. Support the main duct underneath the furnace with additional strapping, if necessary to hold it firmly in place.
5. Attach the furnace base firmly to the duct connector. Seal all seams between the base, the duct connector, and main duct with mastic and fabric tape.

6. Carefully seal the base plate to the floor, in order to prevent air leakage through the belly and floor.
7. Provide a complete air seal and weather seal around the new chimney and combustion air pipe where it penetrates the roof, ceiling, wall, and/or floor.
8. Provide a complete water-tight weather seal at the roof penetration. Reinforce the area underneath the roofing with plywood or other strong material if necessary to create a strong patch and to prevent a low spot in the roof at the penetration. It is best for any roof patch to be slightly elevated from the surrounding roof, to prevent water collection at the patch.
9. Conduct a combustion test, and confirm the test results meet manufacturer's instructions.
10. Install a condensate pump, if necessary, to convey the furnace's condensate to an approved sanitary drain per code. See *Condensate Removal in Chapter 3 – Section 3.8.2*.
11. Use existing distribution system and gas supply line.
12. Provide an owner's manual with heating-system replacements.

Condensate pumps: These small pumps install in the furnace cabinet.

See *Heating System Measures in Chapter 3* for more information.

7.10 Water Heater Replacement

Replacement water heaters shall be approved for use in mobile homes. See *Water Heater Replacement in Chapter 4 – Section 4.1* for additional information.

7.10.1 Gas Water Heater Installations

The following standards are specific to gas water heater replacements:

1. Measure and adjust gas pressure to follow manufacturer's instructions.
2. Follow manufacturer's venting instructions along with the International Fuel Gas Code to establish a proper venting system.
3. Seal the combustion-air sleeve where it meets the water-heater tank, using an approved sealant, to reduce the likelihood of back drafting.
4. Confirm the combustion air sleeve is properly sealed and drawing air from outside of the water heater CAZ.
5. Follow manufacturer's instructions to establish a proper combustion-air system.

6. Verify there are no gas leaks in any of the supply piping.
7. Confirm the presence of a proper sediment trap on the gas line.
8. Test for carbon monoxide.
9. Remove and properly dispose of existing water heater.

7.10.2 Exterior Access Water Heater Closets

Follow these steps when addressing exterior access water heater closet:

1. Insulate water heater closet at the exterior closet door and associated wall area. Cover air vents if they are present and route combustion air (for gas units) from underneath the belly or through skirting.
2. Seal the common wall between the living area and water heater.
3. Assure water heater is properly drafting after completing the work.
4. Insulate all water pipes to prevent freeze-up problems.

7.11 Repair

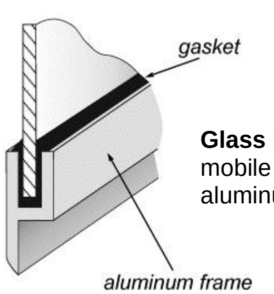
See *Repair in Chapter 6* for more information.

7.12 Window Replacement

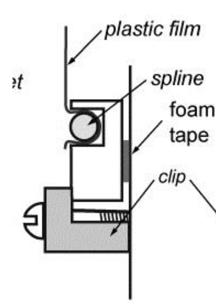
See *Repair in Chapter 6 – Section 6.1.1* for more information.

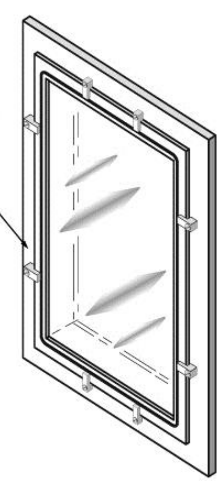
7.13 Interior Storm Windows

Interior storm windows double the R-value of a single-pane window and reduce air leakage, especially in the case of leaky jalousie prime windows. Install interior storm windows on primary single-pane windows that currently have no storm window when selected by the Mobile Home



Glass interior storms: Traditional mobile home storm windows have aluminum frames glazed with glass.





Plastic storms: Some storm-window designs use a lightweight aluminum frame and flexible or rigid plastic glazing.

Energy Audit for replacement as a measure or listed as a repair. The following types of storm windows can be installed:

- Install stationary, removable interior storms with awning- and jalousie-style windows.
- Install sliding interior storm windows to match exterior sliding prime windows. Make sure the movable sash of the storm window is on the same side as the primary window for horizontal sliders.

7.14 Door Replacement

Install minimum R-5 or standard mobile home replacement doors when listed on MHEA as a repair. Mobile home doors come in two basic types: metal mobile home doors and more typical wood-frame residential doors (as in stick-built homes). Mobile home doors swing toward the outdoors, and are usually not standard heights. House-type doors usually swing toward the interior of the home. If the existing door is a conventional door, See *Repair in Chapter 6 – Section 6.1.2*.

To replace a metal mobile home door, follow these steps:

1. Measure the existing door and frame *before removing them* to ensure the replacement door is sized appropriately.
2. Exercise care and caution if removing the existing door trim, to enable trim to be re-attached after the new door is installed.
3. Remove and properly dispose of the old door—do not leave it on-site.
4. Install the new door frame plumb and level, using shims as necessary. Detaching the door from the doorframe first may make it easier to work with the doorframe.
5. Seal the space between the rough framing and the door frame. If spray foam is used for air sealing, use minimal expansion foam, since excessive foam expansion can force the door out of level or plumb.
6. Caulk around the door and frame as necessary to prevent water intrusion.
7. Confirm the new door opens, closes, latches and locks properly.
8. Reattach the door trim.
9. If necessary, install a J-type channel above the door to direct rainwater away from the entry.

Final Inspection and Quality Assurance Standards

Acceptable installations shall meet the following standards.

General Instructions

1. All work follows the regulations of all authorities having jurisdiction.
2. All materials are installed to manufacturer instructions.
3. All debris is removed from the job site and properly disposed, recycled, or delivered to a licensed hazardous waste facility.
4. All applicable building permits were attained.
5. When applicable, all materials must be approved for use in mobile homes.

Heating Systems (See Chapter 3 for general standards)

1. Heating system is approved for mobile homes.
2. Thermostat is located on an interior wall.

Distribution Systems

1. Mobile home return air system is centralized through living space.
2. Sheet metal was used with fasteners to block supply ends that extend beyond the last register and other large holes.
3. Sealing material is not failing.
4. Total measured pressure of supply registers in a mobile home is < 3 Pascals when HwrtO = 50 Pascals, unless sealing activity and documentation shows it is not cost effective to continue.
5. Room pressures are < 3 Pascals when the air handler is operating.

General Repairs

1. The repairs are necessary for the effective installation, performance, and/or preservation of the weatherization materials installed in the building.
2. The repairs are cost-efficient and still correct the problem(s) at hand.

Glass Replacement

1. Glass is the correct type for the installation (e.g., tempered glass is required in doors and sidelights, within 6 feet of tubs, and for all windows less than 18 inches off of ground or floor level. Obscure glass may be required in bathrooms.)

Window Replacement

1. Window installation meets program instructions and is ENERGY STAR certified.
2. The new window opens smoothly and operates properly.
3. The new window is installed squarely, as structurally allowable.
4. The new window does not leak.
5. Installation meets all applicable best practices (e.g., drain planes, back caulked, etc.)
6. Proper lead-safe work practices are documented in file.
7. The customer file contains photographs of the pre-existing window, demonstrating unit met Wisconsin Weatherization Program protocols for replacement.

Door Replacement

1. The new door opens and closes easily, latches tightly, and performs its function.
2. Replacement door meets R-value requirement.
3. Installation meets all applicable best practices (e.g., drain planes, back caulked, etc.)
4. Proper lead-safe work practices are documented in file.
5. The replacement door does not leak.
6. The replacement door is installed squarely, as structurally allowable.
7. The customer file contains photographs of the pre-existing door, demonstrating unit met Wisconsin Weatherization Program protocols for replacement.

APPENDICES

A-1: Glossary A–2

A-2: R-Values for Common Materials A–7

A-3: Insulation Density Calculations A–8

A-4: General Information on Spray Polyurethane Foam (SPF). A–13

A-1: Glossary

ACH: Air Changes per Hour, an estimate of building ventilation or air leakage rates.

ACH50: Air Changes per Hour at 50 Pascals, a measurement of a building's air leakage rate, as determined with a blower door.

ACHn: Air Changes per Hour (natural), an estimate of building ventilation or air leakage rates.

Add-a-Hole Method: A diagnostic test to measure/estimate serial leakage, involving adding a hole of known size to one side of the series leakage path and measuring the pressure differential before and after adding the hole.

AFUE: Annual Fuel Utilization Efficiency — the seasonal efficiency of a space heating system. It is expressed as the percentage of useful energy delivered to a building, as impacted by long-term weather conditions, compared to the amount of energy consumed.

AGA: American Gas Association, an organization that provides standards for gas appliances and fuel systems.

Appliance: Any device (refrigerator, freezer, etc.) powered by electricity designed for household use. May be replaced as an ECM as approved by the Division.

ASHRAE: American Society of Heating, Refrigeration, and Air Conditioning Engineers, an organization that provides standards for a wide variety of space conditioning and ventilation work.

Base Load Measures: Energy conservation measures that reduce any energy use of the dwelling unit that is not driven by weather. Base load ECMs may include water heater replacement, CFL/LED lamp replacement, or refrigerator and freezer replacement.

Basement: The substructure of a building, with the exterior walls forming the building foundation. Most of the basement is usually below ground. Wall heights vary, but are usually higher than 70 inches. In Wisconsin, the basement is often the combustion appliance zone. If the basement is unintentionally heated by ducts or pipes, the work done on the basement is sealing and insulating the box sill and sealing any large opening in the exterior walls. If the basement is intentionally heated, the walls may be insulated on the exterior, based how much is above grade exposure and the results of modeling the building with the NEAT audit. See *Section 2.5 Floor and Foundation Insulation* for more information on treatments.

Blower door: a system used to measure air leakage through a building shell, using a calibrated fan coupled with a pressure gauge.

BTU: British thermal unit, an SI unit of heat energy.

BTUH: BTU per hour, a measurement of an HVAC system's capacity to consume fuel or deliver space conditioning energy.

CAZ: Combustion appliance zone.

CFL: Compact fluorescent lamp.

CO: Carbon Monoxide, a colorless, tasteless, odorless gas that is poisonous, even in very low concentrations. It is commonly the result of incomplete combustion of a fuel.

CO_2: Carbon Dioxide, a colorless, tasteless, odorless gas that interferes with thinking and alertness when present in moderate concentrations and is poisonous in high concentrations.

CFM: Cubic feet per minute, a measurement of air flow (as through a furnace air handler or a blower door).

CFM_{50}: Cubic Feet per minute @ 50 Pascals, a common standardized measurement of air leakage, as determined using a blower door.

Combustion Appliance Zone (CAZ): The area where vented combustion appliances are located. The zone can be located inside or outside the pressure boundary.

Comfort Sealing: Air-sealing work with the primary purpose of controlling drafts, commonly performed with advice from the dwelling unit's occupant. Comfort sealing is performed when blower door testing cannot be performed. When blower door testing cannot be performed, sealing work is limited to: attic bypass and key juncture sealing, glass replacement, and up to one work hour of comfort sealing.

Completed Measure: A measure installed in accordance with all standards and specifications in program policy.

Completed Unit: A dwelling unit that has received all the appropriate weatherization measures required by the measures list or computerized audit, and has passed a final inspection.

Computerized Audit System: The energy audit approved by the Division for use on 1- to 4-unit buildings and mobile homes.

Conditioned: an area or space heated or cooled by a heating or cooling system controlled to maintain habitable temperatures (as by a thermostat).

Crawl Space: An unfinished space under the floor of a building. The exterior walls are usually no higher than 40 to 50 inches. Most crawl spaces have dirt floors. Access hatches sometimes are in the basement through a common wall or in an outside foundation wall. This area often contains plumbing, wiring, and ductwork. Access to this space is usually limited to servicing the plumbing, wiring, or ductwork. The decision on where to insulate in a crawl space depends on if plumbing or ductwork runs through the space. If it does, usually the outside walls and box sill are sealed and insulated using rigid insulation, fiberglass batts, or two-part foam, rated for the application. In unheated crawl spaces, without ducts and pipes, the box sill and floor of the building are sealed and insulated, often with blown cellulose or fiberglass batts. A continuous moisture barrier must be installed if the crawl space has a dirt floor. *See Section 2.5 Floor and Foundation Insulation for more information on treatments.*

CRF: Cannot Reach Fifty – Blower Door procedure when 50 Pascals cannot be reached

Damaged Materials: Materials specifically assigned or designated for a specific dwelling unit/job and are damaged and made unusable either during transit to the job site or at the job site.

DOE: The United States Department of Energy.

Energy Audit: An inspection of the dwelling unit documenting its conditions from a thermal, structural, appliance, lighting, and safety perspective. This may be based on Required Measures List or the Division approved software program that generates a list of recommended weatherization measures for the dwelling unit, according to the software program's specifications.

Energy Conservation Measures (ECMs): The measures installed in a home that return energy cost savings. ECM measures are in contrast with Health and Safety and Repair measures that do not return an energy cost savings benefit

ENERGY STAR®: An EPA/DOE program providing incentives for manufacturers to make energy-efficient products and encouraging consumers to buy these products.

EPA: Environmental Protection Agency

Final Inspection: The inspection performed on a dwelling unit by a non-crew member. The final inspection follows the completion of on-site work. The final inspection must be performed before the owner can sign off.

Friable Asbestos: Any asbestos-containing product that can be crumbled, pulverized, or reduced to powder by hand pressure.

GFCI: Ground fault circuit interrupter.

Guideline Sealing: Air sealing work completed using the Weatherization Cost-Effective Sealing Guidelines, that includes sealing work between the house and the outside. This work often addresses air leakage sealing near the neutral pressure plane.

Heating Costs: Costs of any source of heating in a dwelling unit used for residential heating purposes. All heating costs for commercial, business or any purpose other than the dwelling unit of the applicant are excluded.

Home Energy: All fuel sources used in a dwelling unit. It includes all heating costs and non-heating costs. Non-heating costs are often referred to on utility bills as base load costs (the base costs before heating costs are included).

HVAC: Heating, Ventilation, and Air Conditioning.

IFGC: International Fuel Gas Code.

Infiltration: The uncontrolled air entering the building, usually at the lower portion of the building.

Intentionally conditioned: an area or space intended to be heated or cooled by a heating or cooling system, usually to the level controlled by a thermostat in the space.

IWC: Inches of water column—an SI measurement of pressure.

Key Junctures: Junctions between building components, which require careful sealing and/or insulating, (e.g., wall-floor junctions).

kW: Kilowatt—a measurement of electrical power.

LED lamp: Light-emitting diode light bulb.

kWh: Kilowatt hour—a measurement of electrical use

Lead Safe Working Conditions: Conditions that meet the OSHA and EPA requirements for adequate protection from lead exposure, for both the building occupants and the workers performing the weatherization activities.

Lead Based Paint: Paint that has a lead content of not less than 0.06% by weight or.7 milligrams per square centimeter of painted area.

Make-up Air: Air ducted into a home intentionally to make up for air being exhausted out of the home by exhaust fans or chimneys.

Manual J: The ASHRAE-approved method for calculating building heat loss and estimating the correct capacity for space conditioning systems to be installed.

MHEA: Manufactured Home Energy Audit— Energy audit software by DOE for evaluating and prioritizing weatherization work in manufactured housing.

SDS: Material safety data sheet, describing the hazards of a material and treatment for exposures to the material.

NEAT: National Energy Audit Tool— Energy audit software by DOE for evaluating and prioritizing weatherization work in site-built housing.

Non-Guideline Sealing: Major air-sealing work needed prior to other shell-measure activities, to control gross air leakage and protect the building from deterioration caused by air and moisture migration.

NFPA: National Fire Protection Association, an organization that establishes standards for materials and systems that affect building fire safety.

OSHA: Occupational Safety and Health Administration, the agency that establishes rules and regulations to promote worker safety and health.

Pa: Pascal.

Pascal: the metric unit of pressure.

ppm: Parts per million, a measure of concentration of one material dissolved in another (as in CO contaminating breathing air).

Pressure Boundary: The various materials and components that make up the air barrier of a home.

psi: Pounds per square inch; the SI unit for measurement of pressure.

PVC: Polyvinyl chloride—material used in PVC pipe and plastic sheeting.

SEER: Seasonal Energy Efficiency Ratio — a measurement of air-conditioning efficiency, as impacted by long-term weather conditions.

Short Basement: A cross between a crawl space and a basement. Short basements often have dirt floors and are accessed through doors in the floor or from the exterior of the building. The exterior walls are usually higher that 40 inches but shorter that 78 inches and may vary if the floor is not level. This space often contains the building's heating and water heating equipment. Rarely used on a day-to-day basis, they are often only accessed to service the equipment. If a short basement is unintentionally heated by ducts or pipes, the work done in the space is focused on sealing and insulating the box sill and sealing any large openings in the exterior walls. If a short basement is intentionally heated, the walls may be insulated on the exterior, depending on how much wall is exposed above grade, and based on the results of modeling the building with the NEAT audit. The decision on installing a moisture barrier should be made based on the site conditions. See *Chapter 2.5 Floor and Foundation Insulation* for more information.

Sone: Measurement of noise used in rating exhaust fans.

SSE: Steady State Efficiency, expressed as a percentage; a ratio of the amount of useful energy delivered to a building compared to the amount of fuel consumed.

TESP: Total External Static Pressure; a measurement of resistance to air flow in furnace duct systems.

UDC: Wisconsin Uniform Dwelling Code.

Ventilation: The intentional exchange of indoor air with outdoor air to remove pollutants, especially moisture.

Venting: The system of flues, vent connector, and chimney that exhausts combustion gases out of the home.

WRT: With reference to; used to describe the configuration blower door gauge setup during blower door testing.

Material	R-value
Fiberglass or rock wool batts and blown 1″	2.8–4.0
Blown cellulose 1″	3.0–4.0
Vermiculite loose fill 1″	2.7
Perlite 1″	2.4
White expanded polystyrene foam (beadboard) 1″	3.9–4.3
Polyurethane/polyisocyanurate foam 1″	6.2–7.0
Extruded polystyrene 1″	5.0
Sprayed 2-part polyurethane foam 1″	5.8–6.6
Icynene foam 1″	3.6
Oriented strand board (OSB) or plywood $^1/_2$″	1.6
Concrete or stucco 1″	0.1
Wood 1″	1.0
Carpet/pad $^1/_2$″	2.0
Wood siding $^3/_8$–$^3/_4$″	0.6–1.0
Concrete block 8″	1.1
Asphalt shingles	0.44
Fired clay bricks 1″	0.1–0.4
Gypsum or plasterboard $^1/_2$″	0.4
Single pane glass $^1/_8$″	0.9
Low-e insulated glass (Varies according to Solar Heat Gain Coefficient (SHGC) rating.)	3.3–4.2
Triple glazed glass with 2 low-e coatings	8.3

A-3: Insulation – Density Calculations

homeenergy+

Step 1 – Calculate area of attic: Multiply length time width of the attic to get the area of attic.

30 FT X 50 FT= 1500 SQ FT

Width

Length

Area of Attic

Step 2 – Calculate R-value needed to add: Subtract existing R from desired R to get the R-value need to add.

R-50 – R-26 = R-24

Desired R

Existing R

R Needed to Add

Step 3 – Calculate bag count: Divide area of attic by coverage per bag from the chart on the bag (number double circled in chart on Table 1-1 on Page 1-11) to get the estimated bag count.

1500 SQ FT ÷ 29.1 = 52 BAGS

Net wall Area

Sq. Ft. Coverage per Bag (from chart)

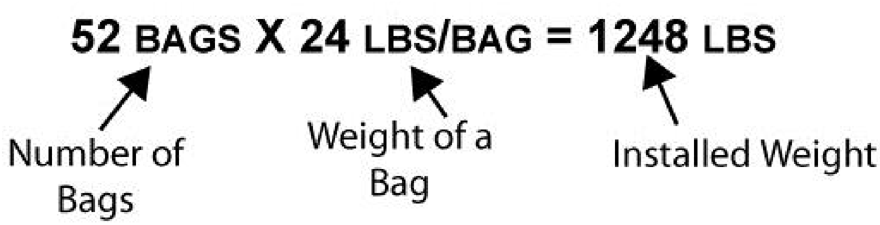
Estimated Bag Count

Divide area of attic by coverage per bag from the chart on the bag to get your Estimated Bag Count.

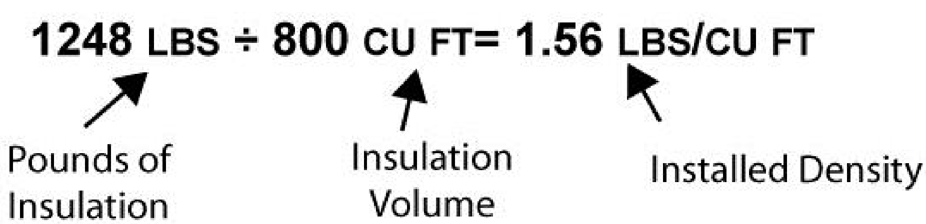
Attic Insulation – Calculating Density

Step 1 – Calculate volume of installed insulation: Multiply area times the depth of the attic insulation to get the volume of insulation.

Step 2 – Calculate the weight of insulation installed: Take the number of bags times the weight per bag to get the total weight.



Step 3 – Calculate the density of installed insulation. Divide pounds of insulation by cubic feet of insulation volume to get the density.



Note: Density should be between 1.3 and 2.0 pounds per cubic foot or conform to the manufacturer's instructions for density, coverage, and bag count for the desired R-value.

Step 1 – Calculate the perimeter of a house: If the house is a simple rectangle or near a simple rectangle, use the formula below. If the house has numerous unequal sides, simply add the lengths together to find the perimeter.

$$(2 \times \underbrace{50}_{\text{Length}} \text{ FT}) + (2 \times \underbrace{30}_{\text{Width}} \text{ FT}) = \underbrace{160}_{\text{Perimeter of House}} \text{ FT}$$

Step 2 – Calculate the total wall area: After calculating the perimeter of the house, multiply it times the wall height. This will give the total wall area.

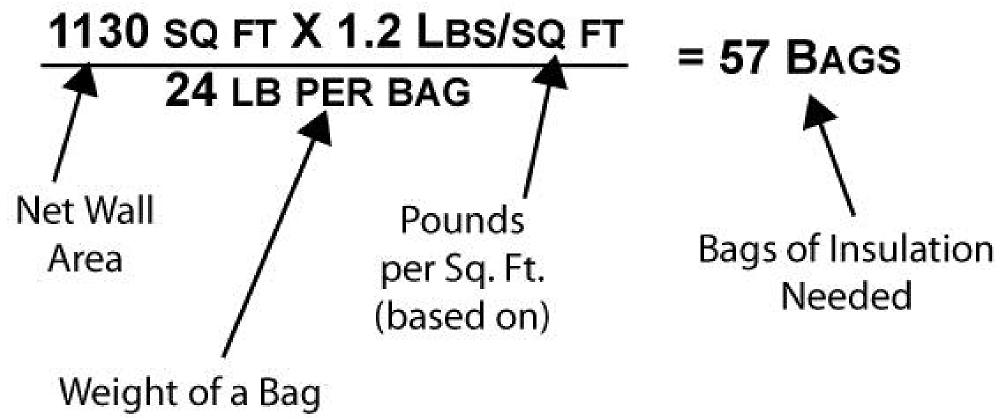
$$\underbrace{160}_{\text{Perimeter of House}} \text{ FT} \times \underbrace{8}_{\text{Height of Wall}} \text{ FT} = \underbrace{1280}_{\text{Total Wall Area}} \text{ SQ FT}$$

Step 3 – Calculate the net wall area: Calculate the sum of the areas of the windows and doors. Subtract them from the total wall area to get the net wall area.

$$\underbrace{1280}_{\text{Total Wall Area}} \text{ SQ FT} - \underbrace{150}_{\text{Area of Windows and Doors}} \text{ SQ FT} = \underbrace{1130}_{\text{Net Wall Area}} \text{ SQ FT}$$

Wall Insulation – Calculating Number of Bags (Continued)

Step 4 – Calculating bag count: Multiply the net wall area by 1.1 to 1.5 pounds per square foot for a 2 x 4 wall. Then divide the number of pounds per bag to get the bag count.



Wall Insulation – Calculating Density

Step 1 – Calculate the wall volume: Multiply the wall's surface area times the depth of the wall cavity converted to feet.

1280 SQ FT **X 3.5/12** FT **= 373** CU FT

Net Wall Area

Inches of Wall Depth

Inches per Foot

Wall Volume

Step 2 – Calculate the weight of the insulation: Multiply the number of bags installed times the weight of a single bag to get the weight of the installed insulation.

57 BAGS **X 24** LBS/BAG **= 1368** LBS

Bags Installed

Weight of a Bag

Pounds of Insulation

Step 3 – Calculate the density of the installed insulation: Divide the pounds of insulation by the cubic feet of insulation volume to calculate the density.

1388 LBS **÷ 373** CU FT**= 3.67** LBS/CU FT

Pounds of Insulation

Insulation Volume

Installed Density

A-4: General Information on Spray Polyurethane Foam (SPF)

Low-Pressure SPF

Low-pressure SPF systems are two-component polyurethane foam products. They are typically delivered to the job site in pressurized canisters (~250 psi), dispensed through unheated hoses through a disposable mixing nozzle system, and applied as a froth-like material to substrate. This type of SPF product is typically used for air sealing and small-scale insulation projects and most commonly come in 200 or 600 board foot disposable kits.

High-Pressure SPF

High-pressure SPF systems are two-component polyurethane foam product~~s~~. They are typically delivered to the job site in unpressurized drums or totes, and dispensed by a proportioner pump where heat and pressure are added. These chemicals travel through heated hoses to a spray gun where the material mixes and is aerosolized during application. This type of SPF product is typically used for larger insulation applications.

Once installed, there is essentially no difference in product performance between low- and high-pressure foams. It should be noted that the main differences between the two types of systems are the application rate, PPE requirements, air borne concentrations of chemicals during application, and capital equipment investment.

Applicators should obtain training from the suppliers of SPF to help assure installation quality and use of all equipment as well as safe handling, use, and disposal of all chemicals used in the process. Spray Polyurethane Foam Alliance (SPFA) also offers additional resources for low and high-pressure SPF products.

Safety and Application

During application of SPF products chemicals are released into the air during the mixing of the chemicals. Chemical fumes can be inhaled and chemical dust can be absorbed through the skin making proper ventilation and appropriate PPE critical in preventing exposure to the applicator. Exposure to SPF chemicals can occur even at low exposure levels. Customers should be informed about the use of SPF products in their home, and installers should be well informed about the procedures used to keep them safe. Employers must assure compliance with OSHA’s hazard communication requirements. Customer’s belongings must be protected from overspray during use, and the substrate that the foam is being applied to must be free of excessive dirt as the foam will expand in all directions. If the area is not properly prepared prior to application the foam may not adhere or can pull away from the surface.

Manufacturer Installation Instructions

SPF applicators should follow all manufacturer installation instructions for the product being used. These instructions include product-specific documents such as application instructions, Safety Data Sheets (SDS), and evaluation reports.