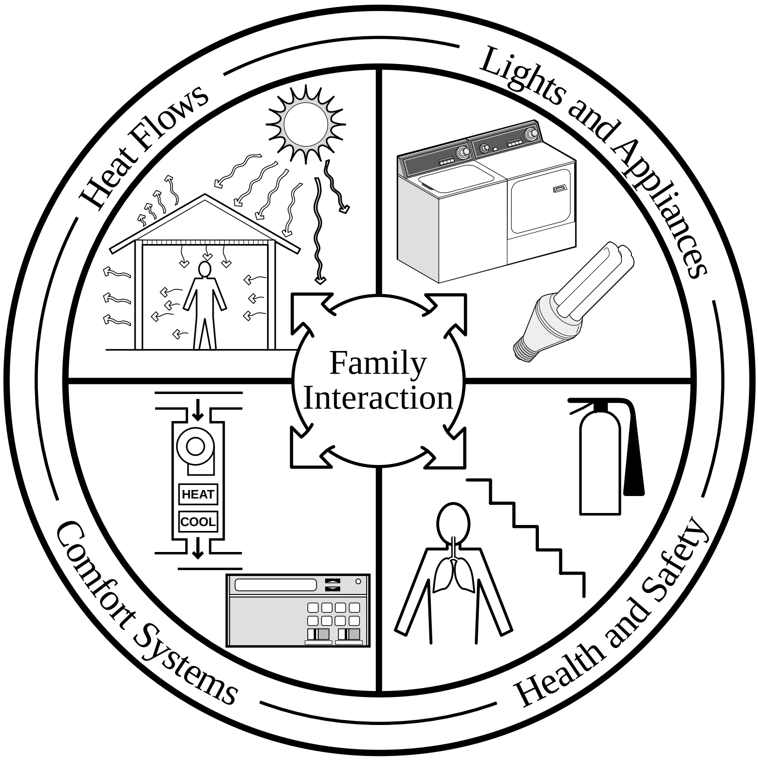
Northeast Weatherization Field Guide



Funded by the Department of Energy's Weatherization Assistance Program through the Boston Support Office

Prepared for the States of Connecticut, Maine, Massachusetts, New Hampshire, New York, Rhode Island, and Vermont

Northeast Weatherization Field Guide

Published for the Department of Energy's Weatherization Assistance Program and the States of Connecticut, Maine, Massachusetts, New Hampshire, New York, Rhode Island, and Vermont

Published by:
Saturn Resource Management
324 Fuller Avenue, N-13
Helena, Montana 59601

Writing and editing: John Krigger
Illustrations: John Krigger and Bob Starkey
DOE Project Coordinators: Dave Mark and Eric Beaton

State technical reviewers:

Glenn Bernard, Connecticut
Tony Gill, Maine
Ken Rauseo, Massachusetts
Andy Gray, New Hampshire
Sam Bell, New York
Pat Costello, New York
Ralph Groves, Rhode Island
Dwight DeCoster, Vermont

Other technical contributors:

R. W. Davis
Rick Karg
Rudy Leatherman
Bruce Manclark
Gary Nelson

FOREWORD

Greetings from the Department of Energy's Boston Regional Office and the State Weatherization Assistance Programs in the Northeast States.

This Field Guide is written to record and communicate the best practices of The Department of Energy's Weatherization Assistance Program (DOE/WAP) in the Northeast States. DOE/WAP was established by Congress to increase the energy efficiency of homes owned or occupied by low-income persons. DEO/WAP goals include reducing energy usage and expenditures, enhancing health and safety, and helping the most vulnerable of the poor.

The topic of heating leads off this Guide as Chapter 1. There is more content here than in any other chapter. The heating content is specific to the Northeast although many subtopics are relevant to other U.S. regions. The next two chapters cover diagnosing and treating the building shell. Chapter 4 covers special considerations for mobile homes. And Chapter 5 covers health and safety for both customer and worker.

This Field Guide contains four different navigational tools to help you find information fast. The first is the table of contents to your right. The second is the index on the last pages of the book. The index is often the most powerful way to start your search because it will often take you to the right page the first try. The third navigational tool is the cross references within the text that help the author minimize repetition. Look to cross references for relationships among topics. The fourth navigational tool is illustration. Your mind will automatically associate topics with the illustrations that accompany. If you remember whether the illustration is on a left-hand page or a right-hand page, you can flip pages until you find the remembered illustration, looking only at one side of the book.

The DOE, the author, and the State reviewers hope that this Guide is useful to you. Criticism and comments are encouraged and should be directed to the author.

CONTENTS

1.0 MECHANICAL SYSTEM SPECIFICATIONS

Combustion heating systems heat most homes. Natural gas and propane systems are most common and they ar basically the same appliances, differing from one another only in the orifice sizes of their burners. The word “gas” used here means either natural gas or propane. Gas furnaces and boilers burn cleanly in comparison to heaters powered by other fuels. The fuel-burning efficiency of gas appliances is difficult to improve, although removing carbon monoxide from combustion gases makes them operate more safely.

Oil-fired appliances often operate significantly below their maximum fuel-burning efficiency. Adjusting fuel-air mixture, draft, as well as, cleaning the burner and heat exchanger can often boost efficiency noticeably.

Chimneys and venting lead off this chapter because they are universal to combustion heating. Gas and oil combustion efficiency and safety are discussed in separate sections. Distribution systems, furnaces and boilers, and installation issues follow the sections on combustion. The chapter closes by addressing water heating, refrigerators, and lighting.

Reference Information on Heating Systems

Reference Title	Chapter / Section
Residential Energy: Cost Savings and Comfort for Existing Buildings, by John Krigger; Third Edition	Chapter 6, Heating
Your Mobile Home: Energy and Repair Guide for Manufactured Housing, by John Krigger; Fourth Edition	Chapter 11, Heating

1.1 Venting combustion gases

Proper venting is essential to operation, efficiency, safety and durability of combustion heaters. The National Fire Protection Association (NFPA) is the authoritative source for information 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 documents.

- NFPA 54: The National Fuel Gas Code
- NFPA 31: Standard for the Installation of Oil-Burning Equipment
- NFPA 211: Standard for Chimneys, Fireplaces, Vents, and Solid-Fuel-Burning Appliances

Table 1-1: *Guide to NFPA Standards*

Topic	NFPA Standard and Section
Vent Sizing	NFPA 54, Part 11
Clearances	NFPA 54, Section 6.3.1, Tables V & VI NFPA 31, Section 4-4.1.1 & Tables 4-4.1.1 & 4-4.1.2 NFPA 211, Sections 6.5, 4.3, 5
Combustion Air	NFPA 54, Section 5.3 NFPA 31, Section 1-9; NFPA 211, Section 8.5 & 9.3

1.1.1 General venting requirements

Combustion gases are vented through vertical chimneys or other types of approved horizontal or vertical vent piping.

Identifying the type of existing venting material, verifying the correct size of vent piping, and making sure the venting conforms to the NFPA codes are important tasks in inspecting and repairing venting systems. Too large a vent often leads to condensation and corrosion. Too small a vent can result in spillage.

The wrong vent materials can corrode or deteriorate from heat. Code violations can create hazards.

1.1.2 Vent connectors

A vent connector connects the venting outlet of the appliance with the chimney. Approved vent connectors for gas- and oil-fired units are made from the following materials.

1. Galvanized-steel pipe (≥ 0.018 inch thick)
2. Aluminum pipe (0.012 inch thick)
3. Type-B vent, consisting of a galvanized-steel outer pipe and aluminum inner pipe (≥ 0.027 inch thick)
4. Type-L vent connector with a stainless-steel inner pipe and either galvanized or black steel outer pipe.
5. Stainless-steel pipe (≥ 0.012 inch thick)
6. Various manufactured vent connectors

Double wall vent connectors are the best choice, especially for appliances with horizontal sections of vent connector. Gas appliances with draft hoods, installed in attics must use a Type-B vent connector. Type-L vent pipe is used for vent connectors for oil and solid fuels.

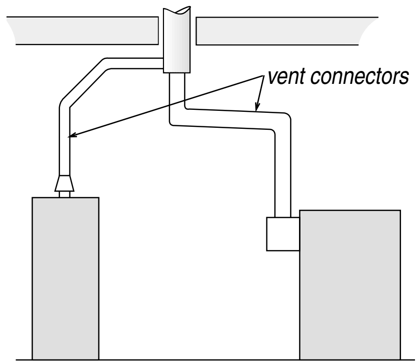
Observe the following general specifications, concerning vent connectors.

- All vent connectors should be free of rust, corrosion and holes.
- Vent-pipe sections should be fastened together with screws.
- The vent connector should be sealed where it enters the chimney.
- A vent connector is almost always the same size as the vent collar on the appliance it vents.
- The chimney combining two vent connectors should have a cross-sectional area equal to the area of the larger vent connector plus half the area of the smaller vent connector. This common vent should be no larger than 7 times the area of the smallest vent. *For specific vent sizes, see NFPA*

codes themselves listed in "Guide to NFPA Standards" on page 1-2.

Table 1-2: *Areas of Round Vents*

Vent diameter	4"	5"	6"	7"	8"
Vent area (square inches)	12.6	19.6	28.3	38.5	50.2



Two vent connectors joining chimney: *The water heater's vent connector enters the chimney above the furnace because the water heater has a smaller input.*

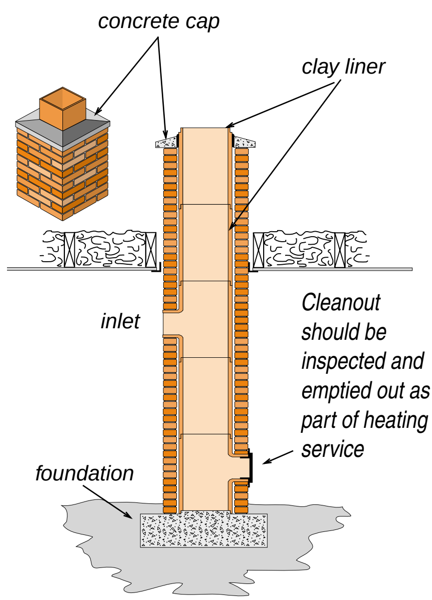
- The horizontal length of vent connectors shouldn't be more than 75% of the chimney's vertical height or have more than 18 inches horizontal run per inch of vent diameter.
- Vent connectors must slope upward toward their outlet or to their connection with the chimney at the slope of 1/4 inch of rise per foot of horizontal run along their entire length to prevent condensation from pooling and rusting the vent.
- When two vent connectors connect to a single chimney, the vent connector servicing the smaller appliance should enter the chimney above the vent for the larger appliance.
- Clearances for common vent connectors are listed here. Other manufactured vent connectors should be labeled with a clearance to combustibles with a reference to a testing and listing agency, like Underwriters Laboratory.

Table 1-3: Clearances to Combustibles for Common Vent Connectors

Vent Connector Type	Clearance
Single-wall galvanized-steel vent pipe	6" (gas) 18" (oil)
Type-B double-wall vent pipe (gas)	1" (gas)
Type L double wall vent pipe (stainless steel inner liner, stove pipe or galvanized outer liner)	9", or 1 vent diameter, or as listed

1.1.3 Chimneys

There are two common types of vertical chimneys for venting combustion fuels that satisfy NFPA codes. First there are masonry chimneys lined with fire-clay tile, and second there are manufactured metal chimneys, including all-fuel metal chimneys and Type-B vent chimneys for gas appliances.



Masonry chimneys: *Remain the most common vent for all fuels.*

Masonry chimneys

Observe the following general specifications for inspecting, repairing, and retrofitting masonry chimneys.

- Masonry chimneys should be supported by their own masonry foundation.
- The chimney's penetrations through floors and ceilings should be sealed with metal as a firestop and air barrier.

- Existing masonry chimneys should be lined with a fireclay flue liner. There should be a $^1/_2$-inch to 1-inch air gap between the clay liner and the masonry of the chimney to insulate the liner. The liner shouldn't be bonded structurally to the outer masonry because it needs to expand and contract independently. The clay liner can be sealed to the chimney cap with a high-temperature flexible sealant.
- Deteriorated or unlined masonry chimneys may be rebuilt as specified above or relined as part of heating-system replacement or venting-safety upgrade. Or, the vertical chimney may be replaced by a sidewall vent with a power venter.

Table 1-4: *Clearances to Combustibles for Common Chimneys*

Chimney Type	Clearance
Interior chimney masonry w/ fireclay liner	2"
Exterior masonry chimney w/ fireclay liner	1"
All-fuel metal vent: insulated double wall or triple-wall pipe	2"
Type B double-wall vent (gas only)	1"

- Masonry chimneys should have a cleanout 12 inches or more below the lowest inlet. Mortar and brick dust should be cleaned out of the bottom of the chimney through the clean-out door, so that this debris won't eventually interfere with venting.

Manufactured chimneys

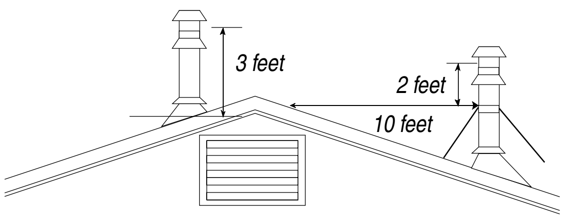
Manufactured metal chimneys have engineered parts that fit together in a prescribed way. Metal chimneys have all manufactured components from the vent connector to the termination fitting on the roof. One manufacturer's chimney may not be compatible with another's connection fittings. Parts include: metal pipe, weight-supporting hardware, insulation shields, roof jacks, and chimney caps.

All-fuel metal chimneys come in two types: insulated double wall metal pipe and triple-wall metal pipe. Install them strictly observing the manufacturer's specifications.

Type-B vent pipe is permitted as a chimney for gas appliances. Some older manufactured gas chimneys were made of metal-reinforced asbestos cement.

Chimney termination

Masonry chimneys should terminate at least three feet above the roof penetration and two feet above any obstacle within ten feet of the chimney outlet. Chimneys should have a cap to prevent rain and strong downdrafts from entering.



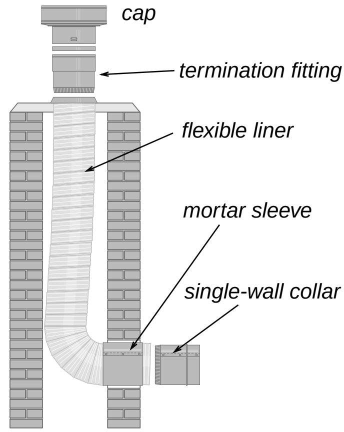
Chimney terminations: *Should have vent caps and be given adequate clearance height from nearby building parts. These requirements are for masonry chimneys and manufactured all-fuel chimneys.*

B-vent chimneys can terminate as close as one foot above the roof on flat roofs and pitched roofs up to a $^{6}/_{12}$ roof pitch. As the pitch rises from $^{6}/_{12}$ to $^{12}/_{12}$ the minimum termination height rises from 1.25 feet to 5 feet. *For more information see Section 7.6 of NFPA 54.*

Metal liners for masonry-chimneys

Unlined masonry chimneys or chimneys with deteriorated liners should be relined as part of heating system replacement. Use either Type-B vent, a flexible or rigid stainless-steel liner, or a flexible aluminum liner. *See also "Power venters for sidewall venting" on page 1-12.*

Flexible liners require careful installation to avoid a low spot at the bottom, where the liner turns a right angle to pass through the wall of the chimney. Follow the manufacturer's instructions, which usually advise stretching the liner and fastening it securely at both ends, to prevent it from sagging and thereby creating a low spot.



Flexible metal chimney liners: *The most important installation issues are sizing the liner correctly and fastening and supporting the ends to prevent sagging.*

If using a flexible metal chimney liner, consider insulating it with vermiculite or a fiberglass-insulation jacket, if the manufacturer's instructions allow. Flexible liners should be insulated especially when installed in exterior chimneys.

Sizing flexible chimney liners correctly is very important. Oversizing is common and can lead to condensation and corrosion. The manufacturers of the liners include vent-sizing tables in their instructions. Sizing flexible chimney liners is also covered by NFPA 54, Part 11, Section 11.2.7. This section prescribes the use of venting tables, designed for Type-B vent, and reducing the capacities listed on the tables by 20%.

1.1.4 Special venting considerations for gas

The American Gas Association (AGA) has devised a classification system for venting systems serving natural gas and propane appliances. This classification system assigns Roman numerals to four categories of venting based on whether there is positive or negative pressure in the vent and whether condensation is likely to occur in the vent.

	Negative-pressure Venting	Positive-pressure Venting
Non-condensing	**I** Combustion Efficiency **83% or less** Use standard venting: masonry or Type B vent	**III** Combustion Efficiency **83% or less** Use only pressurizable vent as specified by manufacturer
Condensing	**II** Combustion Efficiency **over 83%** Use only special condensing-service vent as specified by manufacturer	**IV** Combustion Efficiency **over 83%** Use only pressurizable condensing-service vent as specified by manufacturer
American Gas Association Vent Categories		

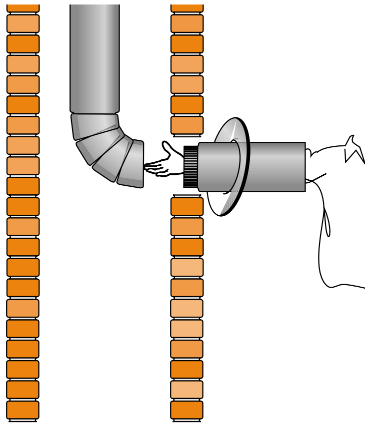
AGA venting categories: *The AGA classifies venting by whether there is positive or negative pressure in the vent and whether condensation is likely.*

A great majority of appliances found in homes and multifamily buildings is Category I, which has negative pressure in a vertical chimney with no condensation expected in the vent connector or chimney. Condensing furnaces are usually Category IV with positive pressure in their vent and condensation occurring in the vent.

Venting fan-assisted furnaces and boilers

Newer gas-fired fan-assisted central heaters control flue-gas flow and excess air better than atmospheric heaters, resulting in their higher efficiency. These are non-condensing furnaces in the 80%-plus Annual Fuel Utilization Efficiency (AFUE) range. Because these units eliminate dilution air and have slightly cooler flue gases, chimneys should be carefully inspected to ensure that they are ready for a possibly more corrosive flue-gas flow. The chimney should be relined when any of the following three conditions are present.

1. When the existing masonry chimney is unlined.
2. When the old clay or metal chimney liner is deteriorated.



B-vent chimney liner: *Double-wall Type-B vent is the most commonly available chimney liner and is recommended over flexible liners. Rigid stainless-steel single-wall liners are also a permanent solution to deteriorated chimneys.*

3. When the new heater has a smaller input than the old one. In this case the new chimney should be sized to the new furnace or boiler and the existing water heater.

For gas-fired 80+ AFUE furnaces, a chimney liner should consist of:

- Type-B vent
- A rigid or flexible stainless steel liner
- A poured masonry liner
- An insulated flexible aluminum liner

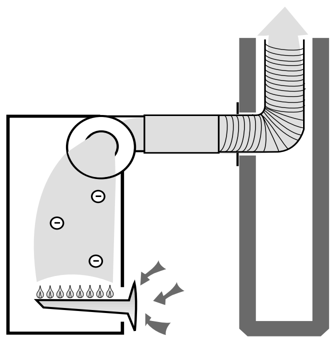
Because of the considerable expense that chimney relining can entail, sidewall venting with a power venter should be considered.

Pressurized sidewall vents

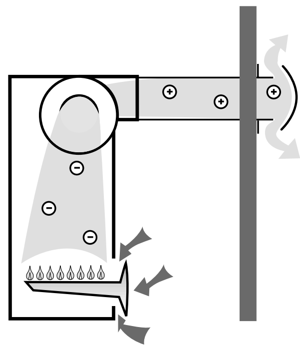
Sometimes, the manufacturer gives the installer a choice of whether to install the furnace or boiler as a fan-assisted unit, venting into a vertical chimney (Category I) or as a positive-draft appliance (Category III), vented through a sidewall vent. Sidewall-vented fan-assisted furnaces and boilers may vent through B-vent, stainless-steel single-wall vent pipe, or high-temperature plastic pipe. Pressurized sidewall vents should be virtually airtight at the operating pressure. B-vent must be sealed with high-temperature silicone caulking or other approved means to air-seal its joints.

Some high-temperature positive-draft plastic vent pipe, used in horizontal installations, was recalled by manufacturers because of deterioration from heat and condensation. Deteriorated high-temperature plastic vent should be replaced by B-vent or airtight stainless-steel vent piping. B-vent must be used in concealed or ventilated areas like crawl spaces or attics.

Existing fan-assisted appliances may have problems with weak draft and condensation when vented horizontally. Horizontally vented, fan-assisted furnaces and boilers may require a retrofit power venter to create adequate draft.



Fan-assisted gas heaters with vertical chimneys: *These 80% AFUE central heaters are almost always vented into atmospheric chimneys, which may need to be relined.*



Fan-assisted heaters with sidewall vents: *Sometimes these appliances are vented through a side wall through airtight plastic or stainless-steel vent pipe.*

Condensing-furnace venting

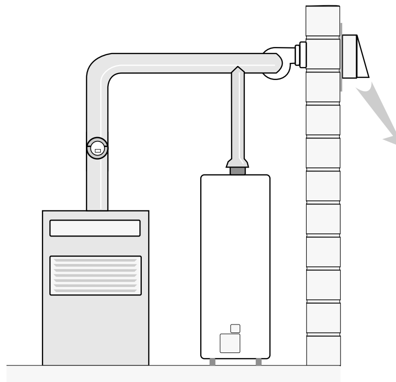
Condensing furnaces with 90+ AFUE are vented horizontally or vertically through PVC Schedule 40 pipe. The vent is pressurized, making it Category IV. Vent piping should be sloped back toward the appliance, so that its system of condensate disposal and treatment can function.

Combustion air is supplied from outdoors through a sealed plastic pipe or from indoors. Outdoor combustion air is highly recommended, and most condensing furnaces are equipped for outdoor combustion air through a dedicated pipe. This combustion-air and venting system is referred to as direct-vent or sealed-combustion.

1.1.5 Power venters for sidewall venting

Power venters install just inside or outside an exterior wall and are used for sidewall venting. Power venters create a stable negative draft.

Modern power venters allow precise control of draft through air controls on the their fans and may give better energy efficiency than existing, unregulated vertical chimneys. Barometric draft controls can also provide good draft control when installed either on the common vent for two-appliances or on the vent connector for each appliance. This more precise draft control, provided by the power venter and barometric damper, minimizes excess combustion and dilution air and can raise combustion efficiency in many cases, compared to the non-adjustable draft of a vertical chimney.



Power venters: *Sidewall venting with a power venter is an excellent option when the chimney is dilapidated or when no chimney exists.*

A single power venter can vent both a furnace or boiler and also a water heater. Flue gas temperatures for power venters can be cooler than temperatures needed to power vertical atmospheric chimneys. Types B or L vent are good choices for horizontal vent piping, depending on whether the fuel is gas or oil.

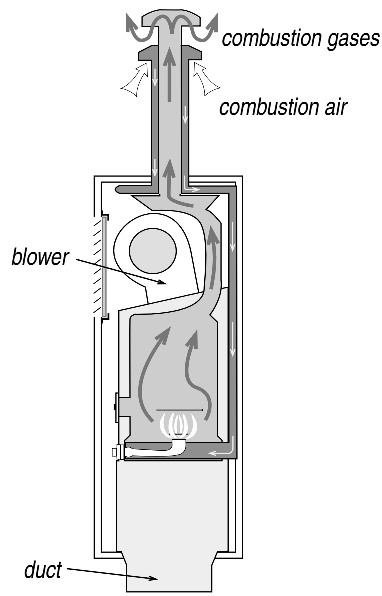
Power venters should be considered as a venting option when:

- Wind, internal house pressures, or nearby buildings have created a stubborn drafting problem that other options can't solve.
- An existing horizontally vented appliance has weak draft and/or condensation problems.
- Clients who currently heat with electricity want to convert to gas space heating and water heating but have no chimney.

- The cost of lining an unlined or deteriorated chimney exceeds the cost of installing a power venter and horizontal vent.
- A floor furnace or other appliance with a long horizontal vent connector has backdrafting problems.
- A water heater is orphaned in a too-large vertical chimney when the heating system is replaced by a horizontally venting system.
- High draft in the existing vertical chimney is creating unstable combustion or low steady-state efficiency in the gas appliances connected to it.

1.1.6 Mobile-home furnace venting

Mobile homes require furnaces designed and approved for use in mobile homes. Mobile-home furnaces are direct-vented, sealed-combustion units that require an outdoor source of combustion air. Mobile-home furnaces may be atmospheric (no draft fan) or fan-assisted. The fan may draw combustion air from a concentric space created by the double-wall chimney or from a duct connected to the ventilated crawl space. Mobile-home furnaces often have a manufactured chimney that includes a passageway for admitting outdoor combustion air supply.

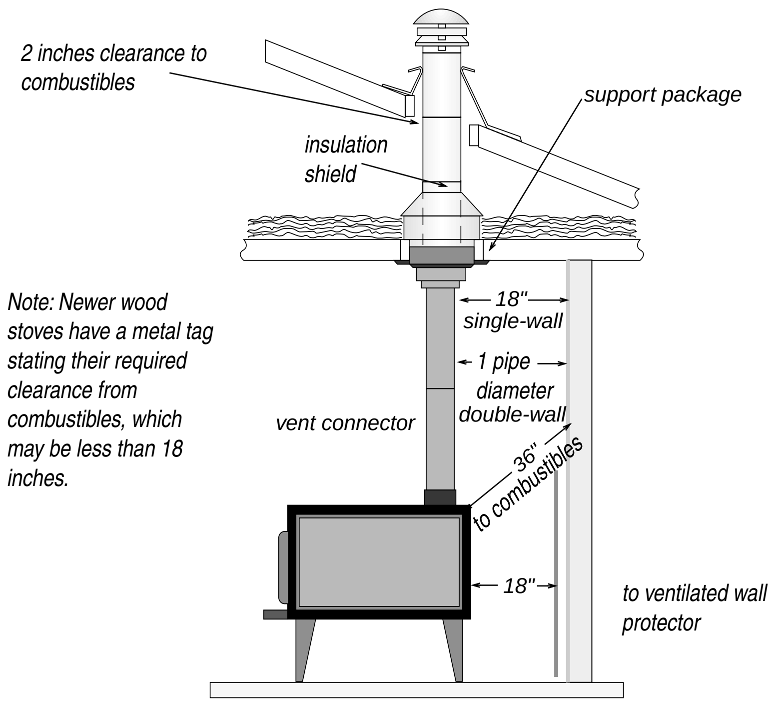


Mobile home furnace venting: *Mobile home furnaces have a sealed-combustion venting and sealed combustion-air systems.*

When replacing mobile-home furnaces, note the differences between old furnace and new in the way each supplies itself with combustion air, and follow manufacturer’s installation instructions exactly. The chimney assembly must often be replaced when the furnace is replaced. *See "Mobile home heating" on page 4-3.*

1.1.7 Wood-heating venting and safety

Wood heating is a popular and effective auxiliary heating source for homes. However, wood stoves and fireplaces can cause indoor-air-pollution hazards and fire hazards. It's important to inspect wood stoves to assess potential hazards.



Wood-stove installation: *Wood-stove venting and clearances are vitally important to wood-burning safety. Read and follow all manufacturer's instructions for the stove and its venting components.*

Stoves that are listed by a testing agency like Underwriters Laboratory have a tag stating their clearance from combustibles. Unlisted stoves should conform to the minimum clearances shown here. Ventilated wall protectors, described in NFPA codes and standards, generally cut the listed clearance in half. *See "Venting combustion gases" on page 1-2.*

All components of wood-stove venting systems should be approved for use with wood stoves. Chimney sections penetrating floor, ceiling, or roof should have approved thimbles, support packages, and ventilated shields to protect combustible materials from high temperatures.

- ✓ Inspect stove, vent connector, and chimney for correct clearances from combustible materials as listed in NFPA 211. Ensure that stove is sitting on a noncombustible floor.
- ✓ Inspect vent connector and chimney for leaks and seal leaks with a high-temperature sealant designed for use with metal or masonry.
- ✓ Inspect chimney and vent connector for creosote build-up and clean chimney if significant creosote build-up exists.
- ✓ Inspect the house for soot on seldom-cleaned horizontal surfaces. If soot is present, inspect and replace the gasket on the wood-stove door. If necessary, seal other air leaks, and take steps to improve draft as necessary, to reduce indoor smoke emissions.
- ✓ Inspect and clean stack damper and/or combustion air intake if necessary.
- ✓ Check catalytic combustor for repair or replacement if the wood stove has one.
- ✓ Assure that heat exchange surfaces and flue passages within the wood stove are free of accumulations of soot or debris.
- ✓ Ask the customer to light the stove, and test the ambient air around the stove for carbon monoxide.

1.2 COMBUSTION AIR

Combustion appliances need a source of combustion air while they are operating. This source must deliver between 15 cfm and 500 cfm of air to the appliance. The lower end of this scale represents small furnaces and space heaters and the upper end represents wood-burning fireplaces or large boilers in multifamily buildings.

Table 1-5: *CFM Air Requirements for Combustion Appliances*

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

The goal of assessing combustion air is to verify that there is an adequate supply and that a combustion-air problem isn't creating CO or interfering with combustion.

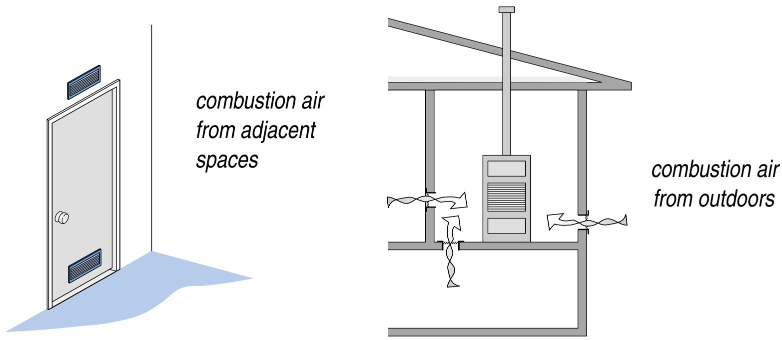
A combustion zone is an area containing one or more combustion appliances. Combustion zones are classified as either un-confined spaces or confined spaces for the purpose of determining whether combustion air can come from the combustion zone or whether combustion air must come from an area—indoors or outdoors—outside the combustion zone. Un-confined spaces are open or connected to enough building air leaks to provide combustion air. Confined spaces are combustion zones with a closed door and confining walls that present an additional air barrier between the appliance and outdoors. A relatively airtight home is itself a confined space and must bring combustion air in from outdoors.

Combustion air is supplied to the combustion appliance in a five ways.

1. To an un-confined space through adjacent spaces and ultimately from the outdoors through leaks in the building.
2. To a confined space through an intentional opening or openings between the combustion zone and other indoor areas where air leaks replenish combustion air.
3. To a confined space through an intentional opening or openings between the combustion zone and outdoors or ventilated intermediate zones like attics and crawl spaces.
4. Directly from the outdoors to the combustion appliance through a duct. Appliances with direct combustion-air ducts are called sealed-combustion appliances.
5. From the outdoors to the combustion zone, or else directly to the appliance through a dedicated combustion-air pipe or duct.

1.2.1 Un-confined-space combustion air

Combustion heaters located in most attics and crawl spaces get adequate combustion air from leaks in the building shell. Even when a combustion heater is located within the home's living space, it usually gets adequate combustion air from air leaks in the building shell unless the house is too airtight or the combustion zone is depressurized. *See "Worst-case depressurization test" on page 1-24.*



Passive combustion-air options: *Combustion air can be supplied from adjacent indoor spaces or from outdoors according to NFPA 54, The National Fuel Gas Code.*

1.2.2 Confined-space combustion air

A confined space is defined as a room containing one or more combustion appliances that has less than 50 cubic feet of volume for every 1000 Btu per hour of appliance input. A combustion appliance located in a confined space, surrounded by materials that are relatively effective air barriers, may need a vent to an adjacent indoor area, the crawl space, or outdoors.

For every 1,000 Btu/hour input, combustion-air vents should have 2 square inches (in^2) of net free vent area. For example, the furnace and water heater are located in a furnace closet. The furnace has an input rating of 100,000 Btu/hour. The water heater has an input rating of 40,000 Btu/hour. There should be 28 in^2 of free ventilation area to the furnace room ([100,000 + 40,000]/1,000 = 14 x 2 in^2 = 28 in^2).

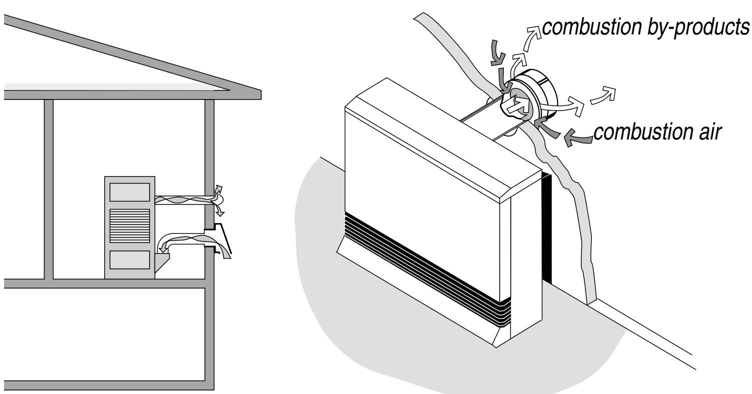
In confined spaces or airtight homes where outdoor combustion air is needed, prefer low inlets to high ones. The preferred installation is to connect the combustion zone to a ventilated crawl space or to some other unheated and non-airtight intermediate zone within the building. For exterior-wall openings connecting the combustion zone with outdoors, choose an outdoor location that is sheltered, where the wall isn't parallel to prevailing winds. Wind blowing parallel to a wall and at a right angle to the vent opening tends to de-pressurize that opening and the combustion zone connected to it. In some cases, outdoor combustion-air openings have caused water pipes to freeze.

1.2.3 Proprietary combustion-air systems

Any passive combustion-air inlet can potentially depressurize the combustion zone because pressure from wind or stack effect can exhaust air from the combustion zone instead of supplying air. Several proprietary systems are available that offer better assurance of adequate combustion air. These systems are particularly appropriate in confined areas suffering from: stubborn problems with draft, combustion-zone depressurization, inadequate combustion-air, or a combination of these problems.

Direct combustion-air supply

Many new combustion appliances are designed for direct outdoor-air supply to the burner. These include most condensing furnaces, mobile home furnaces, mobile home water heaters, many space heaters, and some non-condensing furnaces and boilers. Some appliances give installers a choice between

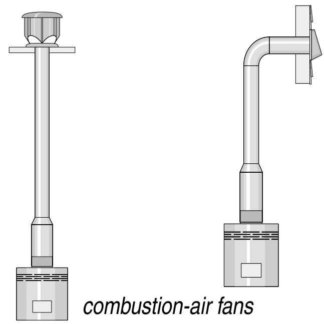


Sealed combustion: *Sealed combustion appliances draw combustion air in and exhaust combustion by-products either using a draft fan or by pressure differences created by the fire.*

indoor and outdoor combustion air. Outdoor combustion air is usually preferable in order to prevent the depressurization problems, combustion-air deficiencies, and draft problems common in atmospheric, open-combustion systems.

Fan-powered combustion air

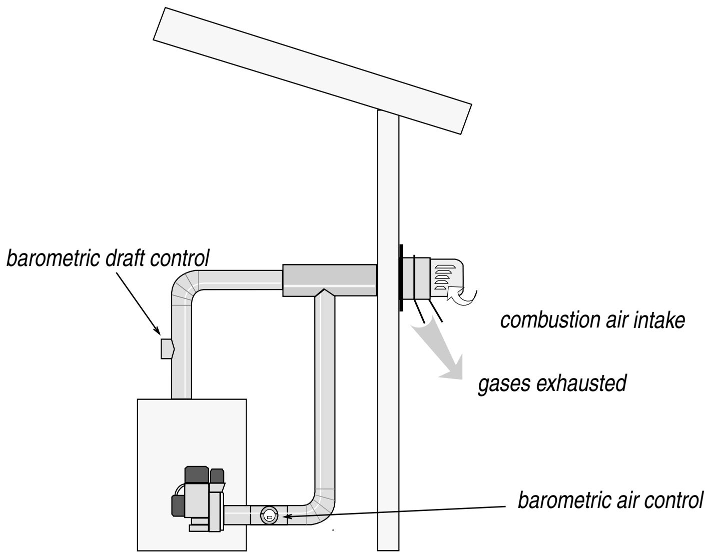
Field Controls Inc. manufactures a proprietary combustion-air system that introduces outdoor air through a fan that sits on the floor and attaches to a combustion-air duct to outdoors.



Fan-powered combustion air: *Fans for supplying combustion air can help solve stubborn combustion air and drafting problems.*

Direct combustion air supply to oil-fired heaters

Oil furnaces and boilers can be either purchased new or else retrofitted with a sealed combustion-air and venting system. The burner fan is fitted with an air boot that feeds the burner with outdoor air. The amount of outdoor air fed to the burner is usually regulated by a barometric draft control.



Sealed-combustion, oil-heating retrofit: *Direct supply of combustion air to gun-type oil burners is a good option for shielding the oil burner from house pressures.*

Combustion air combined with power venting

Both gas- and oil-fired heating systems can be supplied combustion air by proprietary systems that combine power venting with powered combustion-air supply. The combustion air simply flows into the combustion zone from outdoors, powered by the power venter. If the appliance has a power burner, like a gun-type oil burner, a boot may be available to supply combustion air directly to the burner as shown here.

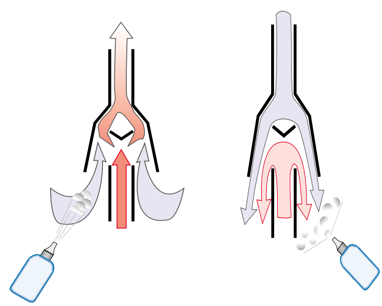
1.3 MEASURING DRAFT AND HOUSE PRESSURES

The main purpose of measuring draft is to insure that the combustion gases are being vented from a dwelling. Draft measurements can also give clues about the combustion efficiency of the furnace or boiler.

Technicians create worst-case conditions for naturally drafting appliances in order to insure that appliances will draft even in the worst-case conditions of house depressurization. Depressurization is the leading cause of backdrafting and flame roll-out.

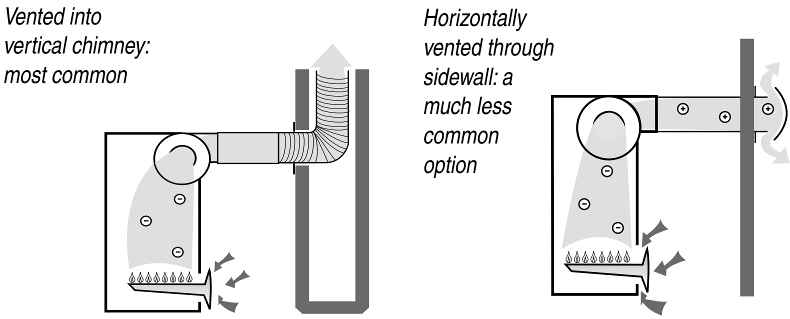
1.3.1 Types of draft in combustion appliances

There are several different classifications of combustion appliances based on the type of draft they employ to exhaust their flue gases. Most existing appliances exhaust their gases into an atmospheric chimney. An atmospheric chimney produces negative draft—a slight vacuum. The strength of this draft is determined by the chimney's height, its cross-sectional area, and the temperature difference between the flue gases and outdoor air. Atmospheric draft should always be negative.



Negative versus positive draft: *With positive draft air flows down the chimney and out the draft diverter. A smoke bottle helps distinguish between positive and negative draft.*

Most existing gas and oil appliances are designed to operate with a negative 0.02 inches of water column (IWC) or –5 pascals chimney draft. Tall chimneys located indoors can produce strong drafts and short chimneys or cold chimneys typically produce weak drafts. Wind and house pressures affect draft.

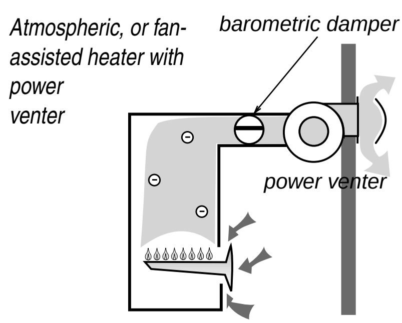


Fan-assisted draft: *Mid-efficiency gas furnaces, boilers, and water heaters are usually vented into vertical chimneys but are occasionally vented through the sidewall.*

Atmospheric combustion appliances exhaust combustion gases solely by their buoyancy. Fan-assisted appliances have the help of a small fan near the exhaust of their heat exchanger that regulates airflow through the heat exchanger.

Power burners have fans at the intake of the combustion chamber to mix combustion air with fuel and inject the mixture into the combustion chamber. The standard power oil burner is the most common type of power burner. Most appliances with draft-assisting fans and power burners vent into atmospheric chimneys.

Positive-draft appliances, which are either condensing or non-condensing, vent horizontally and require airtight chimneys. Most positive-draft appliances are condensing furnaces and boilers. Most non-condensing positive-draft appliances are boilers, although some furnaces and newer water heaters are also designed to vent through positive-draft, sidewall vents.



Power-vent draft: *A power venter is an external draft-inducing fan that helps atmospheric, and fan-assisted furnaces, boilers, and water heaters vent through sidewall vents.*

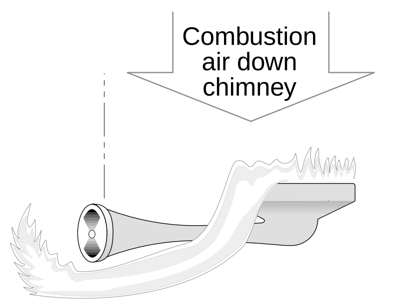
Power venters with sidewall vents are a good alternative, when a vertical chimney is inadequate or non-existant. Yet another venting option is a draft inducer, a fan installed inside a vertical chimney, used to increase draft.

1.3.2 Worst-case depressurization test

This test uses the home's air handler, exhaust fans, and chimneys to create worst-case depressurization in the combustion zone. During this worst-case situation, you measure the indoor-outdoor pressure difference and chimney draft. The reason for these tests is that worst-case conditions do occur and sometimes expose occupants to severe safety hazards.

The worst-case pressure difference is measured: *combustion zone with reference to (WRT) outdoors*. This measurement is compared with values listed in the table entitled, "House Depressurization Limits" on page 1-26.

Draft is measured *chimney WRT combustion zone*. Atmospheric-draft gas appliances are draft-tested during the worst-case conditions. This worst-case draft test will discover whether the venting system will exhaust the combustion gases when the indoor pressure conditions are as unfavorable as you can make them.



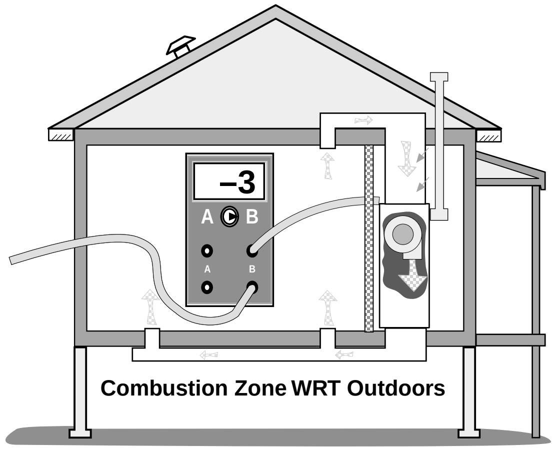
Flame roll-out: *Flame roll-out can occur during times when the combustion zone is depressurized beyond 8 pascals or during very cold weather.*

A sensitive digital manometer is usually used for accurate and reliable readings of both combustion-zone depressurization and chimney draft.

1. With exterior doors and windows closed, connect a digital manometer to read: *combustion zone WRT outdoors* and record the natural pressure difference at that time.

2. Turn on the exhaust fans, clothes dryer, and air handler; then measure the *combustion zone-WRT-outdoors* pressure difference again.

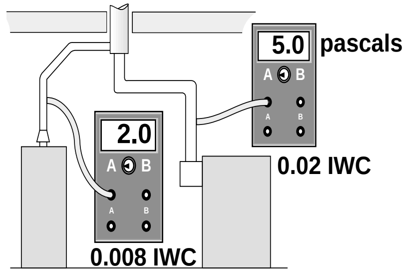
A reading of –3 pascals indicates that there is a significant and possibly dangerous depressurization of the combustion zone.



Worst-case depressurization: *Worst-case depressurization testing is used to identify pressure sources that affect draft and combustion air, so that those sources can be reduced or eliminated if the depressurization is excessive.*

3. While air handler and exhaust fans are running, open and close interior doors until the negative pressure difference between the combustion zone and outdoors is at its maximum. Record this maximum or worst-case depressurization value. A *combustion zone-WRT-outdoors* pressure difference of more than–3 pascals during this test indicates a danger of backdrafting naturally drafted gas and oil appliances. A *combustion zone-WRT-outdoors* pressure difference of –8 pascals or more indicates a danger of flame roll-out. *See "House Depressurization Limits" on page 1-26.*

4. Operate each gas atmospheric-draft boiler, furnace, or water heater under these same worst-case conditions. Measure draft with a manometer. Test for backdrafting with smoke. Acceptable draft should be reached within 2 minutes of start-up.



Worst-case draft testing: *Measure draft for atmospheric gas appliances at worst-case conditions to ensure proper venting.*

5. For all other types of combustion appliances, compare the worst-case depressurization measured in Step 3 above with values in Table 1.6, "House Depressurization Limits" on page 1-26.

Table 1-6: *House Depressurization Limits*

Appliance	Chimney Height	Unlined Exterior Chimneys	Lined Interior Chimneys
Gas-fired furnace, boiler, or water heater	13 or less 14–20 >21	5 Pa. 5 Pa. 5 Pa.	5 Pa. 6 Pa. 7 Pa.
Oil-fired furnace, boiler, or water heater	13 or less 14–20 >21	4 Pa. 4 Pa. 4 Pa.	4 Pa. 5 Pa. 6 Pa.
Fireplace (wood or gas)	all heights	3 Pa.	4 Pa.
Airtight fireplace, wood stove	all heights	10 Pa.	10 Pa.
Fan-assisted gas appliances	all heights / horizontal	15 Pa.	15 Pa.

6. Take all necessary steps to identify and remove excessive negative house pressures. *See "Duct-induced room pressures" on page 2-25.* Also, take appropriate measures to increase draft through chimney improvements, combustion air, or other measures to ensure venting of combustion

gases. *For more information, see"Venting combustion gases" on page 1-2 and "Combustion air" on page 1-16.*

Ambient CO levels should be monitored in the combustion zone during draft testing, especially if depressurization of the combustion zone exceeds –5.0 pascals during house-depressurization testing. If ambient CO levels in the combustion zone exceed 20 parts per million (ppm), draft tests should cease for the technician's safety. The combustion zone should be ventilated before testing and repair of CO problems resumes.

Naturally drafting chimneys should have –1 to –6 pascals of draft, depending on outdoor temperature—measured chimney with reference to the combustion zone—while at worst-case conditions. The lower the outdoor temperature, the higher this negative draft should be. Combustion gases shouldn't spill for longer than 30 seconds from the combustion device while operating at worst-case conditions. *For information on measuring house pressures, see "Measuring duct-induced room pressures" on page 2-25.*

Table 1-7: *Minimum Negative Natural Draft for Various Outdoor*

Outdoor temp.	Draft	Draft
under 20°F	0.02 in. W.G.	–5 pascals
20°F to 40°F	.016 in. W.G	–4 pascals
40°F to 60°F	.012 in. W.G	–3 pascals
60°F to 80°F	.008 in. W.G	–2 pascals
above 80°F	.004 in. W.G	–1 pascal

1.3.3 Improving inadequate draft

If measured draft is below minimum draft pressures, investigate the reason for the weak draft. Inspect the chimney. Open a window or door to observe whether the addition of combustion air will improve draft. If this added air strengthens draft, the problem usually is depressurization. If opening a window has no effect, the chimney is blocked or has significant leakage. *See "Combustion air" on page 1-16.*

Chimney improvements to solve draft problems

- ✓ Repair chimney obstructions, disconnections, or leaks, which can weaken draft.
- ✓ Measure the size of the vent connector and chimney and compare to vent-sizing information listed in NFPA 54, Part 11. A vent connector or chimney liner that is either too large or too small can also result in poor draft.
- ✓ If wind is causing erratic draft, consider a wind-dampening chimney cap.
- ✓ If the masonry chimney is deteriorated, consider installing a new chimney liner. *See "Metal liners for masonry-chimneys" on page 1-7.*

Duct improvements to solve draft problems

- ✓ Repair return-duct leaks near furnace.
- ✓ Isolate furnace from return registers by air sealing.
- ✓ Improve balance between supply and return air by installing new return ducts, transfer grills, and jumper ducts. *See"Improving duct-system airflow" on page 1-57.*

Reducing depressurization from exhaust devices

- ✓ Isolate furnace from exhaust fans and clothes dryers by air sealing between the combustion zone and zones containing depressurizing forces.
- ✓ Reduce capacity of large exhaust fans.

Combustion and make-up air

- ✓ Provide make-up air for dryers and exhaust fans.
- ✓ Provide combustion-air inlet to combustion zone. *See "Combustion air" on page 1-16.*

1.4 COMBUSTION SAFETY AND EFFICIENCY TESTING

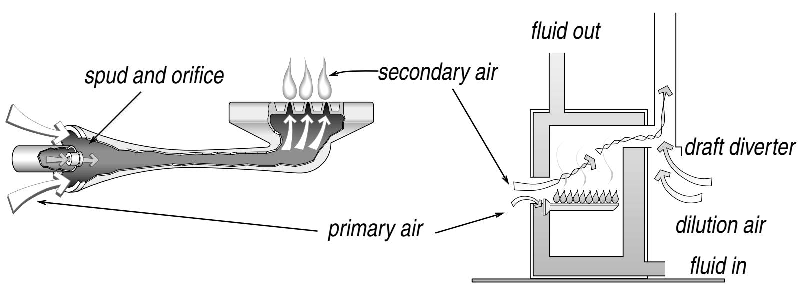
This section specifies maintenance, repair, and efficiency improvements to the combustion systems of existing heating appliances. Procedures outlined here require training, skill, experience, and knowledge of the health and safety hazards associated with combustion heating systems.

For oil-fired systems there is opportunity for significant energy savings by adjustments to the combustion system. For gas, there is less opportunity.

For both oil and gas, safety testing is extremely important. Heating systems with their burners, heat exchangers, and chimneys are often neglected for decades.

1.4.1 Gas burner safety and efficiency testing

Gas burners should be maintained every 2 to 4 years. These following specifications apply to gas furnaces, boilers, water heaters, and space heaters.

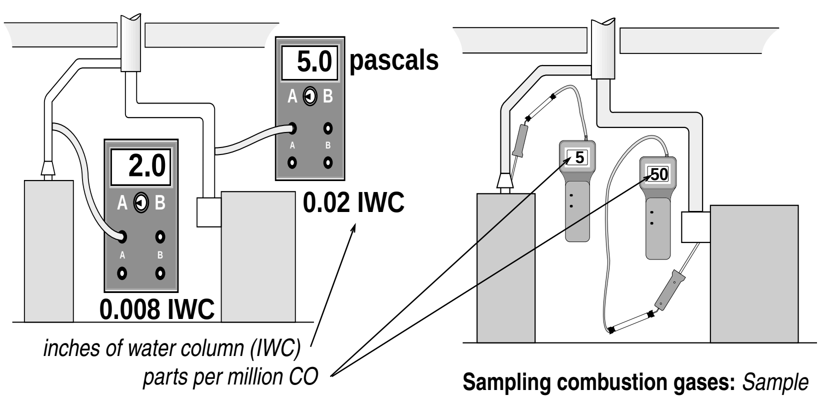


Atmospheric gas burners: *These burners use the heat of the flame to pull combustion air into the burner. Dilution air, entering at the draft diverter, limits the excess air and reduces the likelihood of condensation in the chimney.*

Gas-burner inspection and testing

Perform the following inspection procedures and maintenance practices on all gas-fired furnaces, boilers, water heaters and space heaters. The goal of these measures is to reduce CO, stabilize flame, and test safety controls. *For information on the effects of CO, see “Carbon monoxide” on page 5-3.*

- ✓ Inspect the burners for dust, debris, misalignment, and other flame-interference problems. Clean, vacuum and adjust as needed.
- ✓ Look for soot, burned wires, and other evidence of flame roll-out.
- ✓ Inspect the heat exchanger for leaks. *See “Inspecting furnace heat exchangers” on page 1-50.*
- ✓ Assure that all 120-volt wiring connections are enclosed in covered electrical boxes.
- ✓ Clean and adjust thermostat and check thermostat heat-anticipator setting. The thermostat’s heat anticipator setting should match the measured current in the control circuit.
- ✓ Determine that pilot is burning (if equipped) and that main burner ignition is satisfactory.
- ✓ Sample the undiluted combustion gases with a calibrated flue-gas analyzer.



Measuring draft: *Measure chimney draft downstream of the draft diverter.*

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

- ✓ Test pilot-safety control for complete gas valve shutoff when pilot is extinguished.

- ✓ Check venting system for proper size and pitch.
- ✓ Check venting system for obstructions or blockages.
- ✓ Measure chimney draft downstream of the draft diverter.
- ✓ Test to ensure that the high limit control extinguishes the burner before furnace temperature reaches 200° F.
- ✓ Measure gas input, and observe flame characteristics if soot, CO, or other combustion problems are present.

Proceed with burner maintenance and adjustment when:

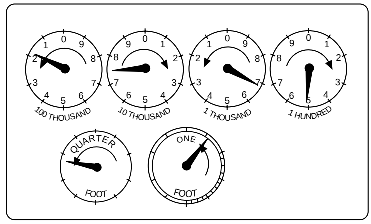
- The appliance has not been serviced for two years or more.
- CO is greater than 50 ppm.
- Visual indicators of soot or flame roll-out exist.
- Burners are visibly dirty.
- Measured draft is low or nonexistent.

Gas-burner maintenance includes the following measures.

- ✓ Remove dirt, rust, and other debris that may be interfering with the burners.
- ✓ Remove causes of CO and soot, such as closed primary air intake, over-firing, and flame impingement.
- ✓ Take action to improve draft, if inadequate because of improper venting, obstructed chimney, etc.
- ✓ Seal leaks in vent connectors and chimneys.
- ✓ Adjust gas input.

Measuring BTU input on natural gas appliances

Use the following procedure when it's necessary to measure the input of a natural gas appliance.



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.*

1. Turn off all gas combustion appliances such as water heaters, dryers, cook stoves, and space heaters that are connected to the meter you are timing, except for the appliance you are testing.
2. Fire the unit being tested and watch the dials of the gas meter, which is usually outdoors.
3. Carefully count how long it takes for one revolution of $^1/_2$, 1, or 2 cubic-foot dial. Find that number of seconds on Table 1-8 on page 33 in the column marked "Seconds per Revolution." Read over to the correct column for the $^1/_2$, 1, or 2 cubic-foot dial and record the input in thousands of Btus per hour.

Note: Table 1-8 on page 33 assumes that gas is 1000 Btu per cubic foot. Where Btu values differ from this figure—especially at high elevations—obtain the correct Btu value from the gas supplier and apply the formula shown below.

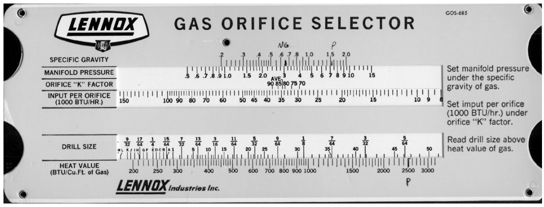
(Btu value from supplier ÷ 1000) X Btu/hr input from table = Actual Btu/hr input of appliance

4. If the measured input is higher or lower than input on the name plate by more than 10%, adjust gas pressure up to 0.25 IWC. If the measured value is still out of range,

Table 1-8: *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		
	1/2 cu. ft.	1 cu. ft.	2 cu. ft.		1/2 cu. ft.	1 cu. ft.	2 cu. ft.		1/2 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

replace the existing orifices with orifices sized to give the correct input.



Gas orifice selector: *Gas furnaces may need orifice replacement if the furnace or boiler input is out of range. Use manufacturer's tables or a gas orifice selector like this one.*

1.4.2 Leak-testing gas piping

Natural gas and propane piping systems may have leaks at their joints and valves. Find gas leaks with an electronic combustible-gas detector, often called a gas sniffer. A gas sniffer will find all significant gas leaks if used carefully. Remember that natural gas rises from a leak and propane falls, so position the sensor accordingly.

- ✓ Sniff all valves and joints with the gas sniffer.
- ✓ Accurately locate leaks using a non-corrosive bubbling liquid, designed for finding gas leaks.
- ✓ All gas leaks should be repaired.

1.4.3 Oil-burner safety and efficiency

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

Oil-burner inspection and testing

Use visual inspection and combustion testing to evaluate oil burner operation. An oil burner passing visual inspection and giving good test results may need no 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 achieve a minimum standard for oil-burner safety and efficiency:

- ✓ Inspect burner and appliance for signs of soot, overheating, fire hazards, or wiring problems.
- ✓ Verify that all oil-fired heaters are equipped with a barometric draft control, unless they have high-static burners or are mobile home furnaces.
- ✓ Assure that all 120-volt wiring connections are enclosed in covered electrical boxes.
- ✓ Inspect fuel lines and storage tanks for leaks.
- ✓ Inspect heat exchanger and combustion chamber for cracks, corrosion, or dirt buildup.
- ✓ Check to see if flame ignition is instantaneous or delayed. Flame ignition should be instantaneous, except for pre-purge units where the blower runs for a while before ignition.
- ✓ 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.
- ✓ Analyze the flue gas for O_2 or CO_2, temperature, CO, and steady-state efficiency (SSE). Sample undiluted flue gases before the barometric draft control.
- ✓ Measure chimney draft downstream from the barometric draft control and over-fire draft.
- ✓ 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.

Table 1-9: *Minimum Combustion Standards for Oil-Burning Appliances Without Flame-Retention Burners*

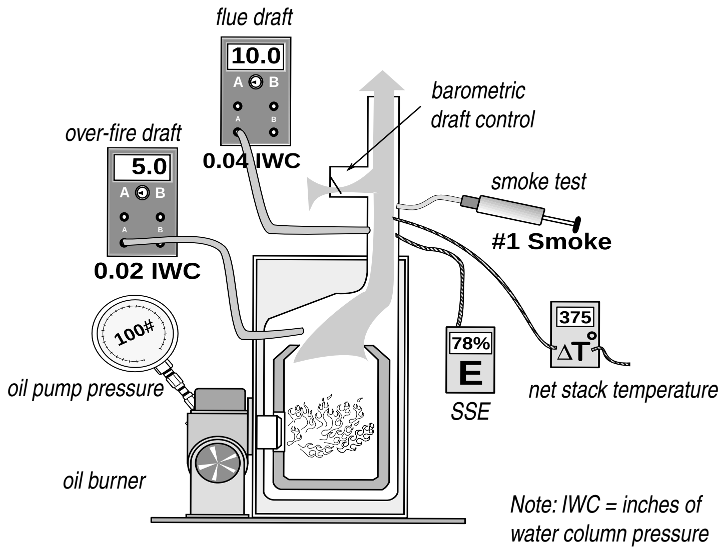
Oil Combustion Performance Indicator	Standard
Oxygen (% O_2)	4–9%
Stack temperature (°F)	325°–600°
Carbon monoxide (CO) parts per million (ppm)	≤ 100 ppm
Steady-state efficiency (SSE) (%)	≥ 75%
Smoke number (1–9)	≤ 2
Excess air (%)	≤ 100%
Oil pressure pounds per square inch (psi)	≥ 100 psi
Over-fire draft (inches water column or IWC)	.02 IWC
Flue draft (inches water column or IWC)	.04 IWC

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

✓ Measure transformer voltage, and adjust to manufacturer's specifications if necessary.

✓ Assure that barometric draft controls are mounted plumb and level and that the damper swings freely.

✓ Time the CAD cell control or stack control to verify that



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

the burner will shut off, within 45 seconds, when the cad cell is blocked from seeing the flame.

Oil burner maintenance and adjustment

After evaluating the oil burner's initial operation, perform some or all of the following maintenance tasks as needed to optimize safety and efficiency as part of weatherization service.

✓ Verify correct flame-sensor operation.

✓ Replace burner nozzle and match the nozzle to the heat load requirements of the home.

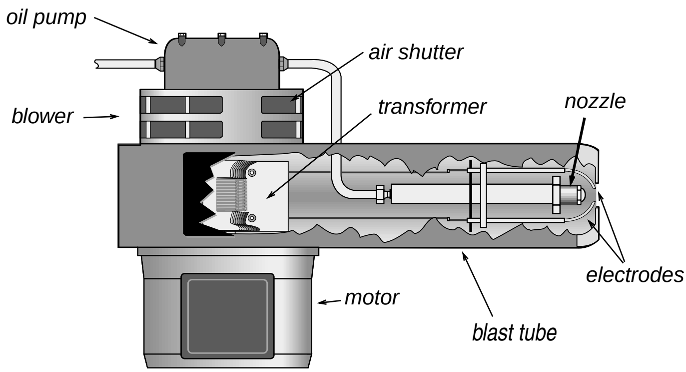
✓ Clean the burner's blower wheel.

✓ Replace oil filter(s).

✓ Clean or replace air filter.

✓ Remove soot and sludge from combustion chamber.

✓ Remove soot from heat exchange surfaces.



Oil burner: *Should have annual maintenance because its performance and efficiency will deteriorate over time if neglected.*

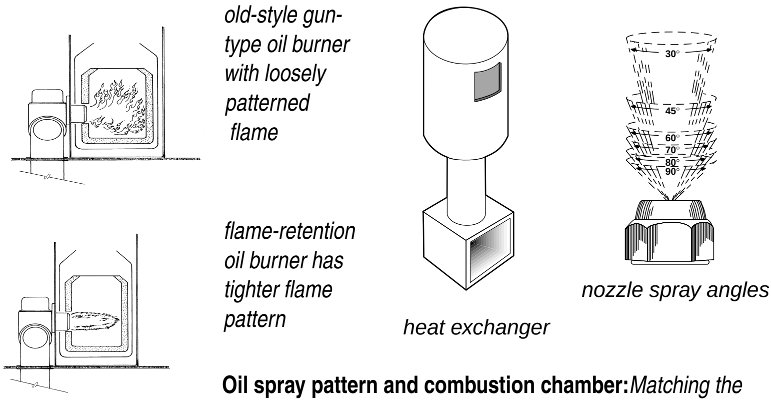
- ✓ Clean dust, dirt, and grease from the entire burner assembly.
- ✓ Set oil pump to correct pressure.
- ✓ Adjust air shutter for specified oxygen and smoke.
- ✓ Adjust barometric damper for flue draft of 0.02-to-0.04 IWC (before barometric damper).
- ✓ Adjust gap between electrodes to manufacturer's specifications.
- ✓ Repair the ceramic combustion chamber, or replace it if necessary.

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

Burner replacement with flame-retention burner

A flame-retention burner is a newer type of oil burner that gives a higher combustion efficiency by swirling the mist or oil and air to produce better mixing. Flame-retention burners waste less heat and have steady-state efficiency (SSE) of 80% or slightly more. Replacing an existing burner with a flame-retention model may be cost-effective if the existing SSE is less than

75%. Flame-retention-burner motors run at 3450 rpm and older oil burners run at 1725 rpm motor speed. Looking for the nameplate motor speed can help you discriminate between the newer and older burners.



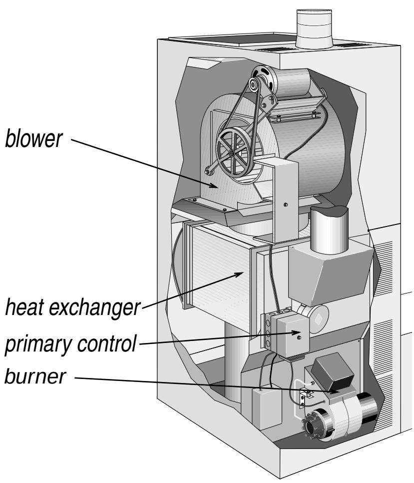
Oil spray pattern and combustion chamber: *Matching the burner's spray pattern to the combustion chamber is important to retrofit applications.*

If a furnace or boiler has a sound heat exchanger but the oil burner is inefficient or unserviceable, the burner may be replaced by a newer flame-retention burner. The new burner must be tested for efficient and safe operation as described previously.

- Size the burner and nozzle to match the building's heat load, making adjustments for new insulation and air sealing done during weatherization. (With steam heating size the burner to existing radiation surface area.)
- Install new combustion chamber, choosing one that fits the size and shape of the burner flame. Or, change nozzles on the new burner to produce a flame that fits an existing combustion chamber that is still in good condition. Either way, the flame must fill the combustion chamber without impinging.
- Match nozzle's spray angle to the dimensions of the combustion chamber.

1.5 Heating-system replacement specifications

Don’t assume that older furnaces and boilers are inefficient until testing them. Before deciding to replace a heating system, every effort to repair and retrofit it should be made. Replacement parts like gas valves and controls for older heating units are commonly available. Repair is defined as any work needed to bring heating appliance up to manufacturer’s specifications for safe and efficient operation. Repair items include replacing blower motors and pumps, fixing vent connectors and chimneys, or other activities required to bring heating appliance up to safe and operable condition.



Oil-fired downflow furnaces: *Their design hasn’t changed much in recent years except for the flame-retention burner.*

Heating appliances are often replaced when the cost of repairs and retrofits exceeds one half of estimated replacement costs. Estimate the repair and retrofit costs and compare them to replacement cost before proceeding.

New heating appliances must be installed to manufacturer’s specifications, following all applicable building and fire codes. Replacement furnaces and boilers should have a minimum AFUE of 80%. Gas furnaces and boilers with AFUEs of 90% should be considered also. These high-efficiency furnaces should be direct-vent, sealed-combustion units.

Heating appliances that are not operational and/or not repairable may be replaced. Heating appliance may also be replaced if the current system is a gravity furnace or boiler, converted from coal.

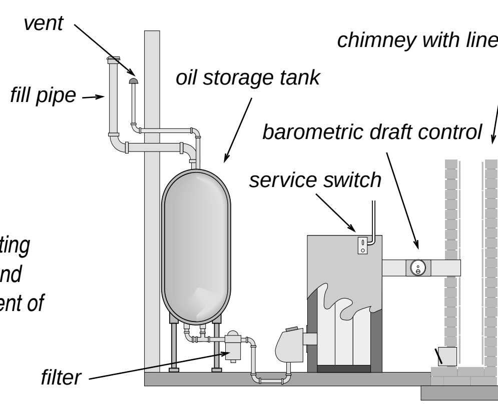
Heat load calculations, used to size the new heater, should consider the lower heating loads, resulting from insulation and air-sealing work. Heat load calculations should follow Manual J procedures.

Specifications are presented here first according to fuel-type—oil or gas—then by distribution type: forced air, hot water, or steam.

1.5.1 Oil-fired heating installation

The overall goal of the system replacement is to provide an oil-fired heating system in virtually new condition, even though components like the oil tank, chimney, piping, or ducts may remain. Any maintenance or repair on these remaining components should be considered part of the job. Any design flaws related to the remaining components should be uncovered and corrected during the heating-system replacement.

✓ Examine existing chimney and vent connector for suitability as venting for new appliance. The vent connector may need to be re-sized and the chimney may need to be relined.



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

✓ Check clearances of heating unit and its vent connector to nearby combustibles, by referring to NFPA 31. *See "Clearances to Combustibles for Common Vent Connectors" on page 1-5.*

✓ Test oil pressure to verify compliance with manufacturer's specifications.

✓ Test transformer voltage to verify compliance with manufacturer's specifications.

✓ Adjust oxygen, flue-gas temperature, and smoke number to within manufacturer's specifications.

✓ Inspect oil tank and remove deposits at bottom of tank as part of new installation.

✓ Install new fuel filter and purge fuel lines as part of new installation.

✓ Bring tank and oil lines into compliance with NFPA 31, Chapters 2 and 3.

Table 1-10: *Minimum Combustion Standards for Oil-Burning Appliances With Flame-Retention Burners*

Oil Combustion Performance Indicator	Standard
Oxygen (%O2)	4–7%
Stack temperature (°F)	300°–500°
Carbon monoxide (CO) parts per million (ppm)	≤ 100 ppm
Steady-state efficiency (SSE) (%)	≥ 80%
Smoke number (1–9)	≤ 1
Excess air (%)	≤ 25%
Oil pressure pounds per square inch (psi)	≥ 100-150 psi (pmi)*
(Over-fire draft (inches water column or IWC)	.02 IWC
Flue draft (inches water column or IWC)	.04 IWC

* pmi = per manufacturer's instructions

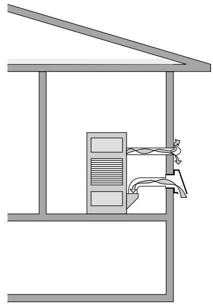
1.5.2 Gas-fired heating installation

The overall goal of the system replacement is to provide an gas-fired heating system in virtually new condition, even though components like the gas lines, chimney, water piping, or ducts may remain. Any necessary maintenance or repair on these remaining components should be considered part of the installation. Any design flaws in the distribution system, chimney, or other remaining component should be uncovered and corrected during the heating-system replacement.

The new furnace should have an Annual Fuel Utilization Efficiency of at least 80% and have a draft-assisting fan, electronic ignition, and no draft diverter. However, a sealed-combustion, condensing furnace with an AFUE of at least 90% is preferred.

- ✓ Check clearances of heating unit and its vent connector to nearby combustibles, according to NFPA 54.
- ✓ Clock gas meter to insure correct gas input. *See "Measuring BTU input on natural gas appliances" on page 1-32.*
- ✓ Measure gas pressure to ensure that it is within manufacturer's specifications. Adjust gas pressure if necessary to obtain proper gas input.
- ✓ Test gas water heater to insure that it vents properly after installation of a sealed-combustion, 90+ AFUE furnace.
- ✓ Set thermostat's heat anticipator to the amperage measured in the control circuit, or follow thermostat manufacturers instructions for adjusting cycle length.
- ✓ Follow manufacturer's venting instructions along with NFPA 54 to establish a proper venting system. *See"Guide to NFPA Standards" on page 1-2 for more information about National Fire Protection Association (NFPA) Standards.*
- ✓ Ensure proper sediment trap on gas line.

1.5.3 Furnace replacement

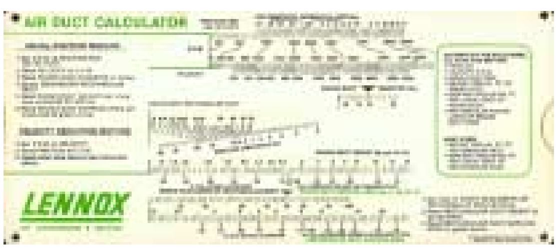


Sealed combustion heaters: *Sealed combustion furnaces and boilers prevent the air pollution and house depressurization caused by their open-combustion heating units.*

The overall goal of furnace replacement is to provide a forced-air heating system in virtually new condition, even though existing supply and return ducts may remain. Any design flaws in the supply and return ducts and registers should be uncovered and corrected during the furnace replacement.

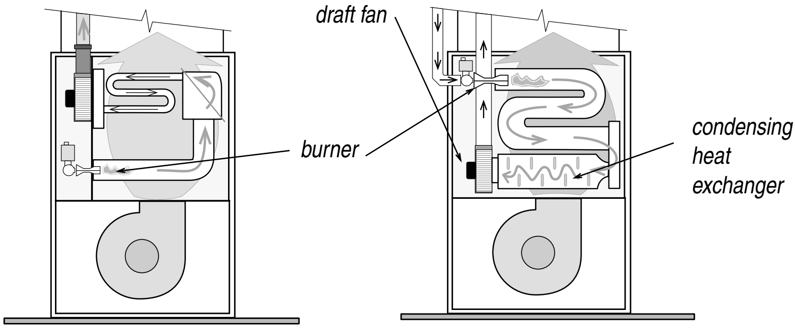
Observe the following standards in furnace installation.

- ✓ Furnace should be sized to the approximate heating load of the home, accounting for post-weatherization heat-loss reductions.
- ✓ Installer should add return ducts or supply ducts as part of furnace replacement to improve air distribution, to eliminate duct-induced house pressures, and to establish acceptable values for static pressure and heat rise.



Sizing ducts: *Use Manual D, by the Air Conditioning Contractors of America, or a duct-size calculator like the one shown above to ensure correct matching between new furnace and existing ducts. These calculators are available from furnace manufacturers.*

- ✓ Supply and return plenums should be mechanically fastened with screws and sealed to air handler with mastic and fabric mesh tape to form an essentially airtight connection on all sides of the joint.



80+ gas furnace: *An 80+ furnace has a restrictive heat exchanger, a draft fan, and no draft diverter or standing pilot.*

90+ gas furnace: *A 90+ furnace has a condensing heat exchanger and a stronger draft fan for pulling combustion gases through its more restrictive heat exchanger.*

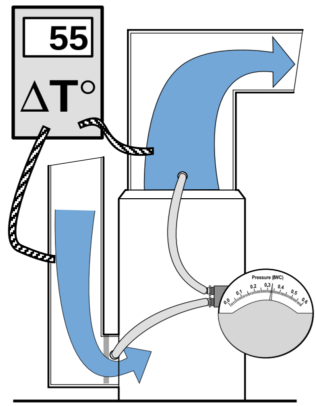
✓ All ducts should be sealed as described in *“Duct air-tightness standards” on page 1-53*.

✓ Heat rise (supply temperature minus return temperature) must be within manufacturer’s specifications.

✓ High limit should stop fuel flow at less than 200°F. Furnace must not cycle on high limit.

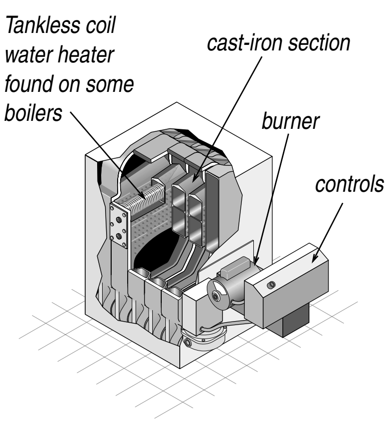
✓ Fan control should be set to activate fan at 130° to 140° F and deactivate it at 95° to 100° F. Slightly higher settings are acceptable if these recommended settings cause a comfort complaint.

- ✓ Static pressure, measured in both supply and return plenums should be within manufacturer's specifications.
- ✓ Blower must not be set to operate continuously.
- ✓ Holes through the jacket of the air handler must be sealed by installer with mastic or foil tape.
- ✓ Filters should be held firmly in place and provide complete coverage of blower intake or return register. Filters must be easy to replace.



Static pressure and temperature rise: *Testing static pressure and temperature rise across the new furnace should verify that the duct system isn't restricted. The correct airflow, indicated by these tests, is necessary for high efficiency.*

1.5.4 Boiler replacement

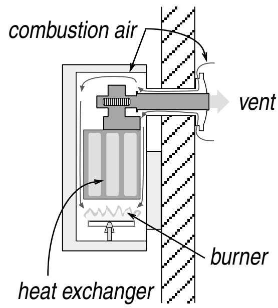


Cast-iron sectional boilers: *Are the most common boilers for residential applications.*

The overall goal of boiler replacement is to provide a hydronic heating system in virtually new condition, even though existing supply and return piping may remain. Any design flaws in the piping and controls should be uncovered and corrected during the boiler replacement. Boiler piping and controls are complex and there are many options for zoning, boiler staging, and energy-saving controls. Dividing homes or multifamily buildings into several zones—each with its own thermostat—can significantly improve energy efficiency over operating a single zone, especially with multifamily buildings where different parts of the building can have widely varying heating loads.

The new boiler should have an AFUE of at least 80%. The new boiler should be equipped with electronic ignition and a draft-assisting fan. It should not have a draft diverter.

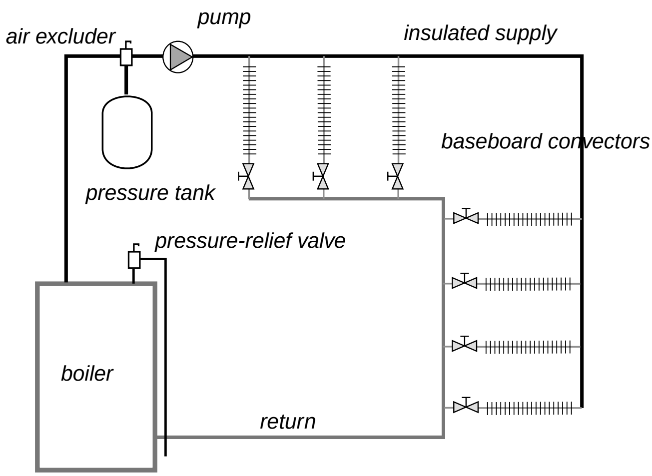
Boiler seasonal efficiency is more sensitive to proper sizing than is furnace efficiency. A boiler should not be oversized by more than 15%. Consider the following specifications when replacing boilers.



Wall-hung boiler: *Energy-efficient wall-hung boilers require less space of standard boilers.*

- ✓ An effective air-excluding device or devices must be part of the new hydronic system.
- ✓ Install the pump near the downstream side of the pressure tank to prevent the suction side of the pump from depressurizing the piping, which can pull air into the piping.
- ✓ The pressure tank must be replaced or tested for correct pressure during boiler installation.
- ✓ Verify that return water temperature is above 130° F for gas and above 150° F for oil, to prevent acidic condensation within the boiler. Install piping bypasses, primary-secondary piping, or other strategies, as necessary, to prevent condensation within the boiler.
- ✓ Recognize the boiler installation's potential for causing condensation in the vent connector and chimney. Condensation in boiler venting is often unavoidable and must be designed into the venting system.

✓ A pressure-relief valve must be installed with the new boiler.



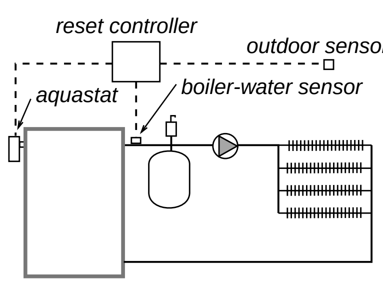
Simple reverse-return hot-water system: *The reverse-return method of piping is the simplest way of balancing flow among heat emitters.*

✓ Maintaining a low-limit boiler-water temperature is wasteful. Boilers should be controlled for a cold start, unless the boiler is used for domestic water heating.

✓ Insulate all supply piping, outside conditioned spaces, with foam or fiberglass pipe insulation.

✓ Extend new piping and radiators to conditioned areas like additions and finished basements, currently heated by space heaters.

✓ For large boilers, consider installing reset controller to adjust water temperature according to outdoor temperature.



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

- ✓ For large boilers, consider installing a cutout controller that prevents the boiler from firing when the outdoor temperature is above a certain setpoint where heat is not needed.

1.5.5 Electric-furnaces and electric baseboard heat

The purpose of servicing electric furnaces and heat pumps is to clean the heat exchangers and blower. Sealing ducts is also very important because electric heat is so expensive.

- ✓ Check and clean thermostat.
- ✓ Check and oil blower motor if applicable.
- ✓ Clean all filters. Replace if necessary.
- ✓ Vacuum and clean housing around electric elements, if dirty.
- ✓ Clean fins on electric-baseboard systems, if applicable.
- ✓ Take extra care in duct sealing and duct airflow improvements for electric furnaces because of the high cost of electricity. *See "Duct air-tightness standards" on page 1-53 and "Improving duct-system airflow" on page 1-57.*
- ✓ Verify that safety limits, heat rise, and static pressure conform to manufacturer's specifications.

1.6 Forced-air system standards

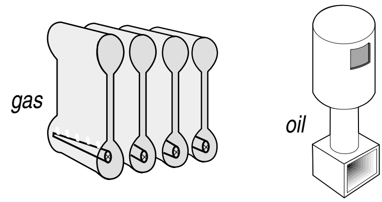
The overall system efficiency of an oil or gas forced-air heating system is affected by blower operation, duct leakage, balance between supply and return air, and duct insulation levels. Retrofits to the forced-air system generally are more cost-effective than retrofits to the combustion side of the heat exchanger.

1.6.1 Inspecting furnace heat exchangers

Leaks in heat exchangers is a common problem, causing the flue gases to mix with house air. Ask clients about respiratory problems, flue-like symptoms, and smells in the house when the heat is on. Also, check around supply registers for signs of soot, especially with oil heating. All furnace heat exchangers should be inspected as part of weatherization. *For information on combustion testing, see "Combustion safety and efficiency testing" on page 1-29.* Consider using the following 7 general options for evaluating heat exchangers.

1. Look for flame-damaged areas near the burner flame.
2. Look for rust at exhaust ports and vent connector.
3. Measure the oxygen or carbon dioxide concentration in the flue gas before the blower starts and just after it has started. There should be no more than a 1% change in the oxygen concentration or no more than a 0.5% change in carbon dioxide.
4. Look for flame impingement on the heat exchanger during firing.
5. Observe flame movement, change in chimney draft, or change in CO reading as blower is turned on and off.

6. Examine the heat exchanger, shining a bright light on one side and looking for light traces on the other using a mirror to peer into tight locations.
7. Employ chemical detection techniques, following manufacturer's instructions.



Furnace heat exchangers: *Although no heat exchanger is completely airtight, it should not leak enough to display the warning signs described here.*

Heat exchangers with large leaks should always be replaced.

1.6.2 Furnace operating standards

Apply the following furnace-operation standards to maximize the heating system's seasonal efficiency and safety.

Check temperature rise after 5 minutes of operation. Refer to manufacturer's nameplate for acceptable heat rise (supply temperature minus return temperature). The heat rise should be between 40°F and 70°F with the lower end of this scale being preferable for maximum efficiency.

- All forced air heating systems must deliver both supply and return air to the intentionally heated portion of the house. It is not allowable to take return air from an unintentionally heated area of the house such as a basement.
- The fan-off temperature should be between 95° and 100° F, with the lower end of the scale being preferable for maximum efficiency.
- The fan-on temperature should be less than 130° to 140° F.
- The high-limit controller should shut the burner off before the furnace temperature reaches 200°F.
- On time activated fan controls verify that the fan is switched on within two minutes of burner ignition and is switched off within 2.5 minutes of the end of the combustion cycle.

Table 1-11: *Furnace Operating Parameters*

Inadequate heat rise: condensation and corrosion possible.	Heat rise OK for both efficicincy and avoidance of condensation.	Heat rise excessive: Check fan speed, heat exchanger and ducts.

20° 45° 70° 95°

Heat Rise = Supply Temperature – Return Temperature

Excellent fan-off temperature if comfort is acceptable.	Borderline acceptable: Consider replacing fan control.	Unacceptable range: Significant savings possible by replacing fan control.

85° 100° 115° 130°

Fan-off Temperature

Excellent fan-on temperature range: No change needed.	Fair: Consider fan-control replacement if fan-off temperature is also borderline.	Poor: Replace fan control.

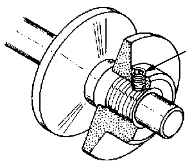
90° 110° 130° 150°

Fan-on Temperature

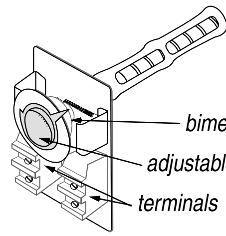
If the heating system does not conform to these standards consider the following improvements.

✓ Reduce heat rise by cleaning or changing dirty filters, cleaning the blower, increasing fan speed, and improving ducted air circulation. *See "Improving duct-system airflow" on page 1-57.*

✓ Adjust fan control to conform to the above standards or replace the fan control if adjustment fails. Many fan controls on modern furnaces aren't adjustable.



Adjustable drive pulley: *Moves back and forth allowing the belt to ride higher or lower, adjusting the blower's speed.*



A fan/limit control: *Turns the furnace blower on and off, according to temperature and also turns the burner off if the heat exchanger gets too hot.*

✓ Adjust the high-limit control to conform to the above standards or replace the high-limit control.

1.6.3 Duct air-tightness standards

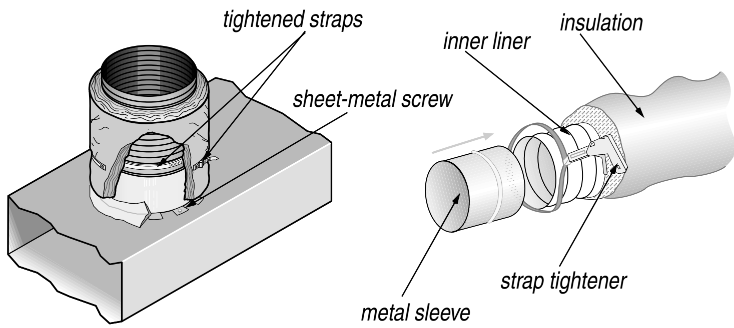
Duct air leakage is a major energy-waster in homes where the ducts are located outside the home's thermal boundary in a crawl space, attic, or leaky basement. When the weatherization job will leave these intermediate zones outside the thermal boundary, duct air-sealing is cost-effective.

Ducts should be tested to determine how much they leak before any duct air sealing is performed. *For information on duct testing, see "Duct airtightness testing" on page 2-20.*

Duct leakage sites

The following joints should be inspected and sealed if testing points to significant duct leakage. Ducts located outside the thermal boundary or in an intermediate zone like a ventilated attic or crawl space should be sealed. The following is a list of duct-leak locations in order of their relative importance. Leaks nearer to the air handler see higher pressure and are more important than leaks further away.

- ✓ Plenum joint at air handler: These joints may have been difficult to fasten and seal because of tight access. Go the extra mile to seal them airtight with mastic and fabric mesh tape.
- ✓ Joints at branch takeoffs: These important joints should be sealed with a thick layer of mastic. Fabric mesh tape is a plus for new installations or when access is easy.
- ✓ Joints in sectioned elbows: Known as gores, these are always leaky.
- ✓ Tabbed sleeves: Attach the sleeve to the main duct with 4-to-6 screws and apply mastic plentifully.
- ✓ Flexduct-to-metal joints: Clamp the flexduct's inner liner with the strap tensioner. Run a screw or two next to the strap when the flexduct is pulling slightly on the metal collar to keep it from separating. Clamp the insulation and outer liner with another strap.

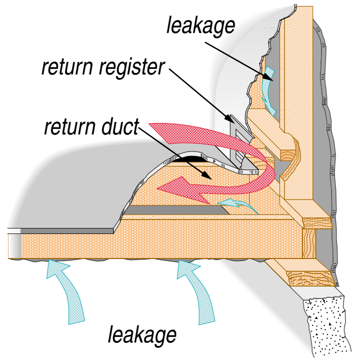


Flexduct joints: *Flexduct itself is usually fairly airtight, but joints, sealed improperly with tape, can be very leaky. Use methods shown here to make flexduct joints airtight.*

- ✓ Support ducts and duct joints with duct hangers where needed.

✓ Seal leaky joints between building materials composing cavity return ducts, like panned floor cavities and furnace return platforms. Even better: replace cavity-return ducts with new metal return ducts.

✓ Seal leaky joints between supply and return registers and the floor, wall, and ceiling to which they are attached.



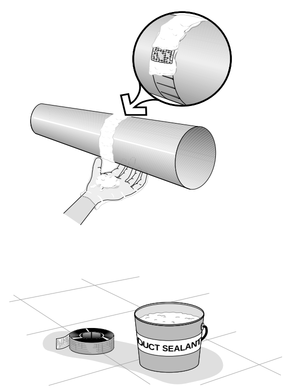
Panned floor joists: *These return ducts are often very leaky and may require removal of the panning to seal the cavity.*

✓ Plug open supply and return registers in unconditioned areas.

✓ Seal penetrations made by wires or pipes traveling through ducts. Even better: move the pipes and wires and patch the holes.

Materials for duct air-sealing

Duct mastic is the preferred duct-sealing material because of its superior durability and adhesion. Apply at least $^{1}/_{16}$-inch thick and use reinforcing mesh for all joints wider than $^{1}/_{8}$ inch or joints that may experience some movement.



Duct mastic: *Mastic, reinforced with fabric webbing, is the best choice for sealing ducts.*

Tape should never be expected to hold a joint together nor expected to resist the force of compacted insulation or joint movement. Joints should rely on mechanical fasteners to prevent joint movement or separation.

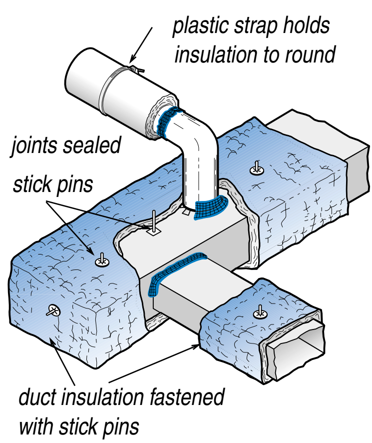
Butyl-aluminum tape is the only acceptable tape product allowed for duct sealing. However, tape is always much more likely to fail than mastic. Do not use this type of tape on or near the supply plenum as it may exceed the temperature rating of the tape.

Aluminum foil or cloth duct tape are not good materials for duct sealing because their thin adhesive often fails after a short time.

1.6.4 Duct insulation

Insulate supply ducts that run through unconditioned areas outside the thermal boundary such as crawl spaces and attics with a minimum of R-6 vinyl- or foil-faced duct insulation. Don't insulate ducts that run through conditioned areas unless they cause overheating in winter or condensation in summer. Follow the best practices listed below for installing insulation.

- Always perform necessary duct sealing before insulating ducts.
- Insulation should cover all exposed supply ducts, without significant areas of bare duct left uninsulated.
- Insulation should be fastened by mechanical means such as stuck ups, twine, or plastic straps. Tape can be effective for covering joints in the insulation to prevent air convection, but tape will usually fail if expected to resist the force of the insulation's compression or weight.



Duct insulation: *Supply ducts, located in unheated areas, should be insulated to a minimum of R-6.*

1.6.5 Improving duct-system airflow

If occupants complain of lack of heat, there may be inadequate airflow. The airflow capacity of the air handler may be checked in relationship to the size of the furnace or air conditioner. For combustion furnaces there should be 110-to-150 cfm of airflow for each 10,000 Btuh of output. Central air conditioners and heat pumps should deliver 400 cfm of airflow per ton of cooling or heating capacity. *See "Furnace replacement" on page 1-44 for more information about airflow indicators.*

When the air handler is on there should be a strong flow of air out of each supply register, providing its balancing damper is open. Low airflow may mean that a branch is blocked or separated, or that return air is not sufficient. When low airflow is a problem, consider the following improvements.

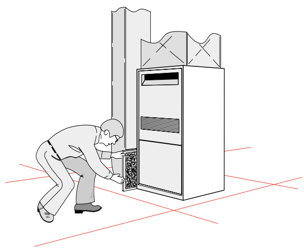
- ✓ Clean or change filter.
- ✓ Clean furnace blower.
- ✓ Clean air-conditioning or heat pump coil.
- ✓ Increase furnace fan speed.
- ✓ Lubricate blower motor and check tension on drive belt.
- ✓ Add another return-air duct.
- ✓ Repair or replace bent, damaged, or restricted registers.

Filter and blower maintenance

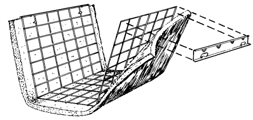
A dirty filter can reduce airflow significantly. Special air-cleaning filters offer more resistance than standard filters, especially when saturated with dust. Take action to prevent filter-caused airflow restriction by the following steps:

- Install a filter whistle that indicates when the filter is dirty.

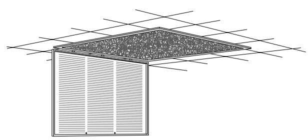
- Insure that filters are easy to change or clean.



Panel filter installed in filter slot in return plenum



Washable filter installed on a rack inside the blower compartment.



Panel filter installed in return register

Furnace filter location: *Filters are installed on the return-air side of forced air systems. Look for them in one or more of the following places.*

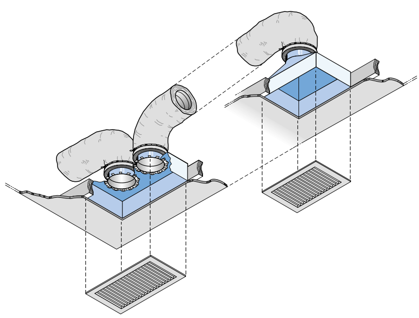
- Stress to the client the importance of changing or cleaning filters, and suggest to the client a regular filter-maintenance schedule.
- Clean the blower. This task involves removing the blower and removing dirt completely with a brush or water spray.
- Measure the current draw of the blower motor in amps. If the amp measurement exceeds the motor amp rating by more than 10%, replace the motor.

Duct improvements to increase airflow and improve comfort

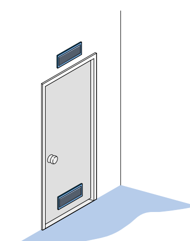
Consider the following improvements in response to customer complaints and conditions you observe during a thorough duct inspection. Unbalanced airflow through ducts can pressurize or depressurize rooms, leading to increased air leakage through the building shell. *For information on how to test these room pressures, see "Measuring duct-induced room pressures" on page 2-25.*

- Remove obstructions to registers and ducts such as rugs, furniture, and objects placed in ducts, like children's toys and water pans for humidification.

- Remove kinks from flex duct, and replace collapsed flex duct and fiber duct board.
- Install additional supply ducts as needed to provide heated air throughout the building, especially into additions to the building.
- Install additional return ducts as needed to provide heated air throughout the building, especially into additions to the building. *See "Sizing ducts" on page 1-44.*
- Install a transfer grille between the bedroom and main body of house may also be done to help improve airflow. Undercutting bedroom doors, especially in homes with central return systems.
- Retrofit jumper ducts, composed of one register in the bedroom, one register in the central return-air zone, and a duct in between (usually running through an attic or crawl space).
- Install registers and grilles where missing.



Jumper ducts can bring air from a restricted area of the home back to a main return register.



Installing grills in doors or through walls allows return air to escape from bedrooms

Restricted return air: *Return air is often restricted, requiring a variety of strategies to relieve the resulting house pressures and low airflow. Installing an additional return duct directly into the air handler may sometimes be necessary.*

New ducts

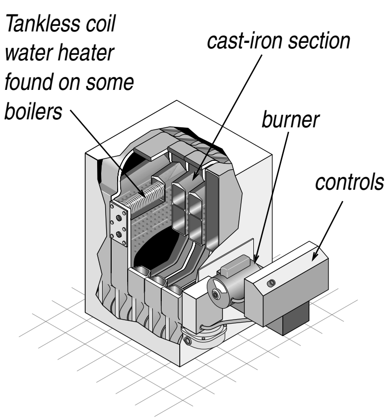
New ducts should not be installed in unconditioned spaces unless absolutely necessary. If ducts are located in unconditioned spaces, joints shall be sealed and the ducts insulated as described previously. *See "Duct air-tightness standards" on page 1-53 and "Duct insulation" on page 1-56.*

New ducts must be physically connected to the existing distribution system or to the furnace. Operable registers should terminate each new supply or return branch duct.

1.7 Hot-water and steam standards

The following standards refer to hydronic systems commonly found in single-family homes. Hydronic systems found in multifamily buildings are generally more complex and should be tested and evaluated by professionals experienced in their operation. Observe the following standards for servicing hot-water and steam heating systems in single family structures.

1.7.1 Hot-water space-heating



Cast-iron sectional boilers: *Are the most common boilers for residential applications.*

Hot-water heating is generally a little more efficient than forced-air heating and considerably more efficient than steam heating. The most significant energy wasters in hot-water systems are off-cycle flue losses stealing heat from stored water and boilers operating at too high a water temperature.

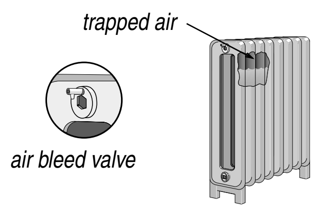
Consider the following safety checks and improvements.

- ✓ Check for leaks on the boiler, its fittings or on any of the distribution piping connected to the boiler.
- ✓ Confirm the existence of a 30-psi-rated pressure-relief valve and replace or add one if necessary. Note signs of leakage or discharges and find out why the relief valve is discharging.
- ✓ Make sure that the pressure tank isn't waterlogged. This could cause pressure-relief valve discharge. Test pressure tank for its rated air pressure—often 15 psi.

- ✓ If rust is observed in venting, verify that return water temperature is above 130° F for gas and above 150° F for oil, to prevent acidic condensation.
- ✓ High-limit control should deactivate burner at 180° F or less.
- ✓ Lubricate circulator pump(s) if necessary.

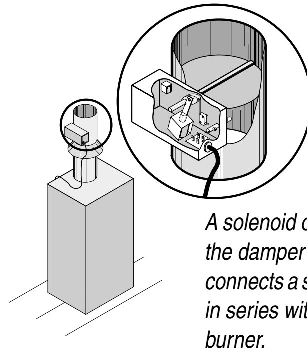
Consider the following efficiency improvements.

- ✓ Repair water leaks in the system.
- ✓ Boiler should not have low-limit control for maintaining a minimum boiler-water temperature, unless the boiler is heating domestic water in addition to space heating.
- ✓ Bleed air from radiators and piping through air vents in elbows or radiators. Most systems have an automatic fill valve. If there is a manual fill valve for refilling system with water, it should be open to push water in and air out, during air purging.
- ✓ Consider installing electric vent dampers on atmospheric 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.*

- ✓ Consider installing reset controllers on larger boilers to regulate water temperature, depending on outdoor temperature.
- ✓ Clean fire side of heat exchanger of noticeable dirt.
- ✓ Vacuum and clean fins of fin-tube convectors if you notice dust and dirt there.
- ✓ Insulate all supply piping, passing through unheated areas, with foam pipe insulation, at least one-inch thick, rated for temperatures up to 200° F.



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.*

1.7.2 Steam heating

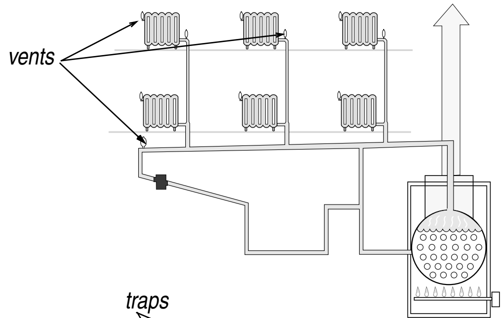
Steam heating is less efficient than hot-water heating because a steam boiler heats water to its boiling point before making any steam or doing any space heating. Higher temperature heating systems are less efficient than lower temperature ones. Steam boilers are also more hazardous because of the steam pressure. For these reasons heating-system replacement with a hot-water or forced-air system should be considered.

If the steam-heating system must remain, operate it at the lowest steam pressure that will heat the building. This may be considerably less than 1 psi on the boiler pressure gauge. Large buildings may need higher steam pressures but smaller ones can operate at small steam pressure. Traps and air vents are crucial to operating at a low steam pressure. Electric vent dampers will reduce off-cycle losses for both gas- and oil-fired systems.

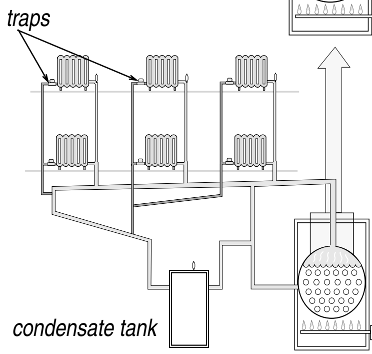
Perform the following for safety checks steam systems.

- ✓ Verify that steam boilers are equipped with high pressure limits and low-water cut-off controls.

One-pipe and two-pipe steam systems: *Still common in multifamily buildings, one-pipe steam works best when very low pressure steam can drive air out of the piping and radiators quickly through plentiful vents. Vents are located on each radiator and also on main steam lines.*



Two-pipe steam systems: *Radiator traps keep steam inside radiators until it condenses. No steam should be present at the condensate tank.*

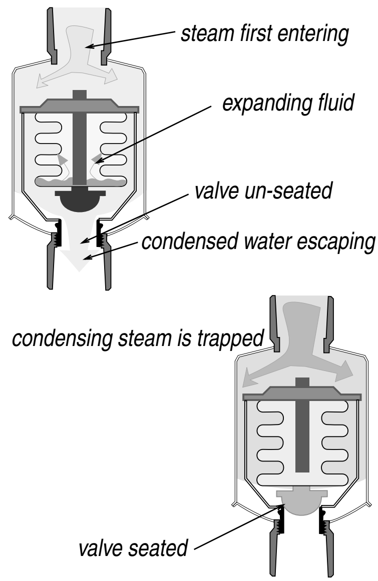


- ✓ Verify that high-pressure limit control is set at or below 1 (one) psi.
- ✓ Verify that flush valves on low water cutoffs are operable and do not leak.
- ✓ On steam boilers with externally mounted low water cut-offs, verify the function of the control by flushing the low water cutoff with the burner operating. Combustion must cease when the water level in the boiler drops below the level of the float.

Consider the following efficiency checks and improvements for steam systems.

- ✓ Verify steam vents are operable and that all steam radiators receive steam during every cycle. Unplug vents as necessary. Add vents to steam lines and radiators as needed to achieve this goal.

- ✓ Check steam traps with a digital thermometer or listening device to detect any steam escaping from radiators through the condensate return. Replace leaking steam traps or their thermostatic elements. Repair leaks on the steam supply piping or on condensate return piping.
- ✓ Consider a flame-retention burner and electric vent damper as retrofits for steam boilers.
- ✓ Clean fire side of heat exchanger of noticeable dirt.
- ✓ Drain water out of blowdown valve until water runs clear.

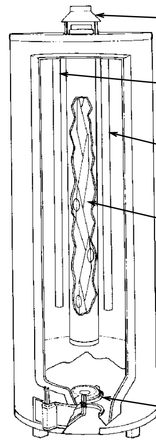


Steam traps: *Steam enters the steam trap heating its element and expanding the fluid inside. The expanded element plugs the steam's escape with a valve.*

- ✓ Check with owner about chemicals added to boiler water to prevent corrosion. Add chemicals if necessary.
- ✓ All steam piping, passing through unconditioned areas, should be insulated to at least R-3 with fiberglass pipe insulation rated for steam piping.

1.8 WATER-HEATERS

Gas-, propane-, and oil-fired water heaters must be tested, maintained, and repaired as described in the sections on burners and venting. *See "Measuring draft and house pressures" on page 1-22 and "Combustion safety and efficiency testing" on page 1-29.*



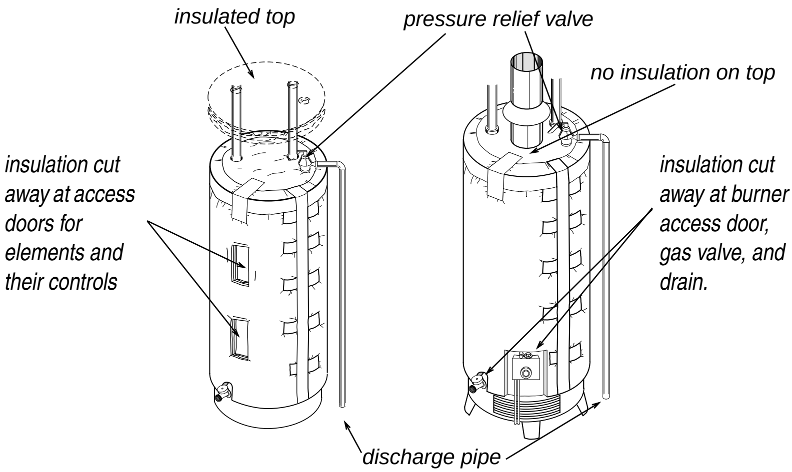
Standard gas water heater: *Is an open combustion appliance often troubled by spillage and backdrafting.*

- ✓ All water heaters must have a pressure-and-temperature relief valve and a safety discharge pipe. Install a relief valve and discharge pipe if none exists. The discharge pipe should terminate 6 inches above the floor or outside the dwelling as specified by local codes. The discharge pipe should be made of rigid metal pipe or approved high temperature plastic pipe.
- ✓ Water heaters should be re-insulated to at least R-10 unless water-heater label gives specific instructions not to insulate or water heater is already insulated.
- ✓ Water heater insulation must not obstruct draft diverter, pressure relief valve, thermostats, hi-limit switch, plumbing pipes, or access plates.
- ✓ Adjust water temperature to a maximum of 120°F with clients' approval, unless the client has a older automatic dishwasher without its own water-heating booster. In this case the maximum setting is 140°F.

1.8.1 Gas- and oil-fired water-heater insulation

- Keep insulation at least 3 inches away from the burner.

- Insulation should not extend below the top of the water heater’s gas valve or oil burner.
- Do not insulate the tops of gas- or oil-fired water heaters.



Water heater insulation: *Insulation should be installed carefully so it doesn’t interfere with the burner, elements, draft diverter, or pressure relief valve.*

Electric water-heater insulation

- Set both upper and lower thermostat to keep water at 120°F before insulating water heater.
- Insulation may cover the water heater’s top if the insulation will not obstruct the pressure relief valve.
- Access holes should be cut in the insulation for the heating-element thermostats.

1.8.2 Gas- and oil-fired water heater service

Gas- and oil-fired water heaters should be inspected and tested, using specifications listed in the following sections:

- “Venting combustion gases” on page 1-2.
- “Combustion air” on page 1-16
- “Combustion safety and efficiency testing” on page 1-29.

1.8.3 Gas- and oil-fired water heater installation

Gas- and oil-fired water heaters are just small boilers and should comply with the specifications listed in the following sections: “Venting combustion gases” on page 1-2, “Combustion air” on page 1-16, and “Heating-system replacement specifications” on page 1-40.

An oil-fired water heater’s oil burner should be tested as specified in the following sections.

- “Oil-fired heating installation” on page 1-41.
- “Minimum Combustion Standards for Oil-Burning Appliances With Flame-Retention Burners” on page 1-42.

A gas-fired water heater should be tested as specified in the following sections.

- “Gas-fired heating installation” on page 1-43.
- “Gas burner safety and efficiency testing” on page 1-29.

1.8.4 Pipe insulation

- Insulate the first 6 feet of both hot- and cold-water pipes.
- Cover elbows, unions and other fittings to same thickness as pipe.
- Keep pipe insulation at least 6 inches away from flue pipe.
- Interior diameter of pipe sleeve must match exterior diameter of pipe.

1.8.5 Electric water–heater efficiency

A replacement electric water heater should have an energy factor of at least 0.88 and be equipped with at least three inches of foam insulation.

1.8.6 Gas water-heater replacement

Existing gas water heaters typically use 275 or more therms per year. New gas water heaters us as little as 175 therms per year.

A savings of 50-to-100 therms can repay the initial investment in 3-to-7 years at today's gas costs.

Any replacement gas water heater must have an energy factor of at least 0.61 and have a minimum of 2 inches of foam insulation. An replacement oil-fired watershed have an energy factor of at least 0.55 and have at least 1 inch of foam insulation. Replacement water heaters should be wrapped with external insulating blankets, unless the manufacturer recommends against installing an external blanket.

In tight homes or homes where the mechanical room is located in living areas, replacement gas or oil water heaters must be either power-draft or sealed-combustion. Sealed-combustion water heaters are preferred in tight homes with a water heater installed in the living space.

1.9 Appliances and Lighting

The importance of lights and appliances to residential energy-conservation programs is increasing with the increasing cost of electricity.

1.9.1 Refrigerator and freezer setpoints

The most important issue for operating existing refrigerators is the temperature setpoint of the refrigerator and freezer compartments. The refrigerator temperature should be around 38° and the freezer should be around 0° for optimal energy efficiency. Try these settings and if they are acceptable fine; if they aren't, instruct the customer move the temperature setting down very gradually until it is acceptable.

1.9.2 Refrigerator assessment and replacement

Refrigerators that are more than 10 years old usually consume between 1100 and 1500 kilowatt-hours per year. New Energy Star® rated refrigerators use less than 550 kilowatt-hours per year. Replacement should be considered on a case-by-case basis depending on energy consumption as determined below.

1.9.3 Measuring refrigerator energy consumption

Measuring refrigerator energy consumption is performed during an energy audit and education visit. The meter should record consumption for at least two hours.

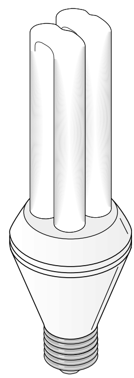
1. Connect the refrigerator to a recording kilowatt-hour meter set to record the number of kilowatt-hours used in a two-hour or longer period.
2. If the refrigerator is an automatic defrost model, check several times during the two hour test to ensure that automatic defrost has not activated. If it has, there will be a new wattage draw besides the resting condition and com-

pressor-on condition. If the defrost comes on during the test, start the test again.

3. Divide the number of kilowatt-hours by the hour duration of the test. This gives you the number of kilowatts (or kilo-watt-hours per hour). Multiply this number times the total number of hours in a year: 8766 hours per year. The product of this calculation is annual kilowatt-hours.

1.9.4 Lighting assessment and replacement

Most homes have 6-to-12 lamps that burn for more than two hours per day. Incandescent lamps that burn for more than two hours per day should be considered for retrofit by more-efficient compact fluorescent lamps (CFLs). This easy retrofit has as good an economic return as any retrofit mentioned in this field guide.



Compact fluorescent lamp: *These advanced lamps use about one-third of the electricity of the incandescent lamps they replace.*

2.0 ASSESSING AIR LEAKAGE THROUGH THE BUILDING SHELL AND THROUGH DUCTS

Weatherization technicians test and evaluate the house pressures, air leakage, duct leakage and heating-system performance before deciding exactly what kinds of energy-efficiency measures are most appropriate for a home. Evaluating the test data helps technicians anticipate backdrafting and other unintended problems relating to cost-effective shell air sealing and duct sealing.

Air leaks can bring pollutants in or let pollutants, generated indoors, out. Air leakage through the building shell and the operation of the home's air handler and ducts are interrelated. The air handler's blower, ducts, exhaust fans, chimneys create house pressures that drive air through leaks in the building shell.

Air-sealing or duct sealing may affect combustion-appliance venting by increasing house pressures or reducing the available supply of combustion air.

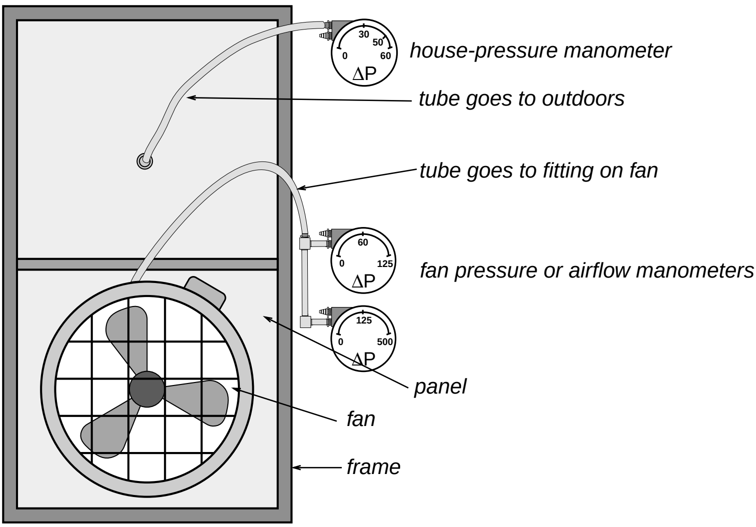
The test methods, presented here, would almost never all be performed on a single home. Deciding which tests to conduct is a matter of experience. The goal of air-leakage and pressure testing is to measure leakage rates and decide how much time and effort is required to achieve acceptable air-leakage and duct-leakage rates, while safeguarding indoor air quality. *For more on indoor air quality, see "Client health and safety" on page 5-2.*

Reference Information on Assessing Shell and Duct Air Leakage

Reference Title	Chapter / Section
Residential Energy: Cost Savings and Comfort for Existing Buildings, by John Krigger; Third Edition	Chapter 3, Air Leakage
Your Mobile Home: Energy and Repair Guide for Manufactured Housing, by John Krigger; Fourth Edition	Chapter 5, Air Leakage

2.1 HOUSE AIRTIGHTNESS TESTING

House airtightness testing was made possible by the development of the blower door, shown here. The blower door measures a home's leakage rate at the standard pressure of 50 pascals. This leakage measurement can be used to compare homes with one another and set air-leakage standards.



Blower door components: *Include the frame, panel, fan, and manometers.*

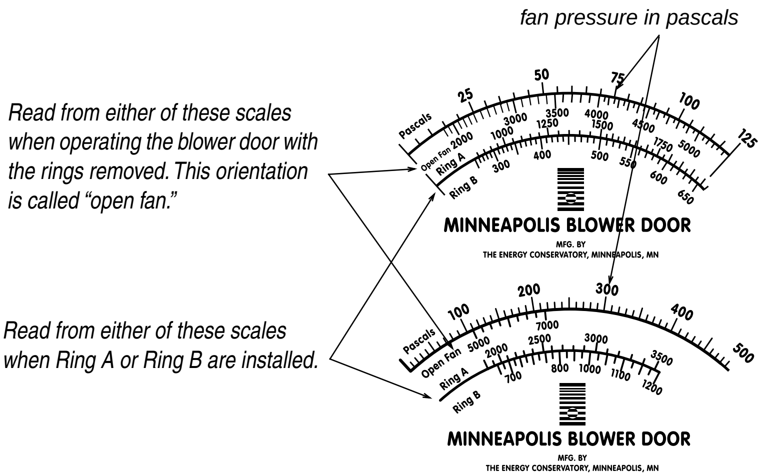
The blower door also allows the technician to test parts of the home's air barrier to locate air leaks. Testing air barriers with a blower door isn't always necessary. Sometimes air leaks are obvious. Other times the leaks are hidden, and the technician wants to obtain clues about their location without crawling needlessly into dark and dirty places. This section outlines the basics of blower door testing along with some techniques for gathering clues about the location of air leaks.

2.1.1 When not to air seal

Perform no air sealing when there is obvious threat to the occupants health, the installers health, the building's durability, or to the effectiveness of the air-sealing materials. *See "Health and Safety Information" on page 5-1 for more information.* The following circumstances must be corrected before or during air-sealing work, or else air-sealing shouldn't be performed.

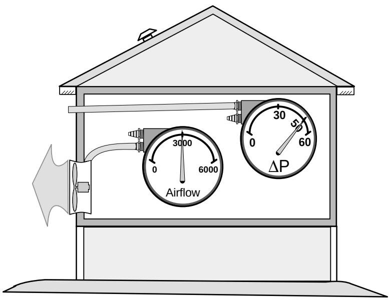
1. The building is scheduled for demolition or major rehabilitation and the materials would likely be removed.
2. Moisture has caused structural damage, rot, mold or mildew growth.
3. Fire hazards place building's life and occupant safety in jeopardy.
4. Carbon monoxide levels exceed suggested action levels.
5. Combustion zones pressure exceed -5 pascals when the air handler is running.
6. Chimney drafts of combustion appliances do not meet minimum standards.
7. Unvented space heater will be used after air-sealing work.
8. Infestations, vermin, or sanitary issues are present.

9. The building is already at or below the Building Tightness Limit and no mechanical ventilation exists or is planned.



Blower door analog gauges: *Blower door airflow gauges provide ranges for accurate measurement of homes with a wide variety of airtightness.*

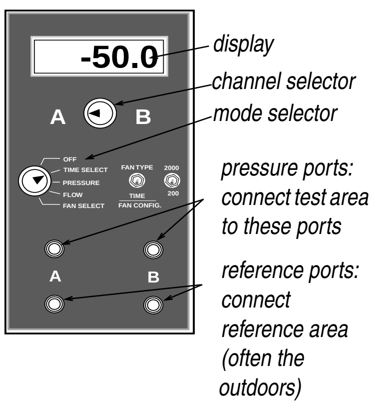
2.2 BLOWER-DOOR TESTING



Standard blower door test: *The house is depressurized to –50 pascals and the airflow through the fan is measured.*

The blower door measures airflow at 50 pascals house pressure (CFM_{50}), producing a number that is used to compare the leakiness of homes. The blower door also creates pressure differences between rooms in the house and intermediate zones like attics and crawl spaces that can give clues about the location and size home's air leaks. *For more information on air-leak location, see "Sealing bypasses" on page 3-3.*

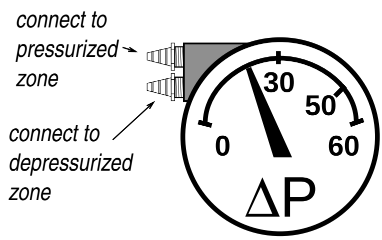
Measuring house pressure differences



Digital manometers: *Are popular for diagnosing zone pressures and duct pressures because of their convenience and accuracy.*

Connecting the manometer's hoses correctly is essential for pressure testing. A widely accepted method for recording correct hose connection helps avoid confusion. This method uses the phrase "with reference to", abbreviated "WRT" to discriminate between the input zone and reference zone for a particular measurement. The outdoors is the most commonly used reference zone for pressure diagnostics and is considered to be 0 pascals. For example, *house WRT outdoors* = –50 pascals means that the house (input) is 50 pascals negative compared to the outdoors (reference or zero-point). The pressure reading in the last example is called the *house-to-outdoors* pressure difference.

There are two common ways to measure intermediate-zone pressures during blower-door testing. The first is measuring *house WRT zone*, also called the *house-to-zone* pressure. The second is measuring *zone WRT outdoors*, also called the *zone-to-outdoors pressure*. These two pressures should add up to –50 pascals, which is the *house-to-outdoors pressure* during a standard –50-pascal blower-door depressurization test. Therefore, the *house-to-zone pressure* plus the *zone-to-outdoors* pressure equals the *house-to-outdoors* pressure.



Analog manometers: *These less expensive manometers measure only pressure magnitude. You must know which zone is pressurized and which is depressurized.*

Because these intermediate-zone pressures add up to –50 pascals, subtracting either one of these zone pressures from –50 pascals gives you the other one. For this reason, many technicians measure only one pressure, feeling confident that they know the other. Some technicians consider *zone-to-outdoors* more reliable because the outdoors is the reference zone for the blower-door test. Other technicians prefer *house WRT zone* because you only need one hose connected to the manometer. It's often wise to measure both pressures—especially in complicated homes with multiple air-leakage problems.

2.2.1 Preparing for a blower door test:

Preparing the house for a blower door test involves putting the house in its heating or cooling operating condition with all conditioned zones open to the blower door. Anticipate safety problems that the blower door could cause, particularly with combustion appliances. Understand how you will use the measurements you take during the blower door test.

- ✓ Identify location of the thermal boundary and which house zones are conditioned.
- ✓ Identify and repair large air leaks that could prevent the blower door from achieving adequate house pressure.
- ✓ Survey pollutants that may pollute the air during a blower door test—wood-stove or fireplace ashes for example.
- ✓ Measure house volume if you plan to use ACH_{50} (air changes per hour at 50 pascals) or ACH_n (air changes per hour—natural).
- ✓ Put the house in its heating and/or cooling mode with windows, doors, and vents closed and air registers open.
- ✓ Turn off combustion appliances temporarily.
- ✓ Open interior doors so that all indoor areas inside the thermal boundary are connected to the blower door.
- ✓ Ensure children and pets are at a safe distance from fan blades.

2.2.2 Blower door test procedures

Blower door tests are used by technicians charting their progress in air sealing homes. They are also used by inspectors and auditors to assess a building's leakiness.

1. Install blower door frame, panel, and fan in an exterior doorway.
2. Follow manufacturer's instructions for fan orientation and manometer setup for either pressurization or depressurization.
3. Connect the house-pressure manometer to measure *house WRT outdoors*.
4. Connect the airflow manometer to measure *fan WRT zone near fan inlet*. The zone near the fan inlet is indoors for depressurization and outdoors for pressurization.
5. Make pretest adjustments to manometers following manufacturer's instructions.

6. Turn on the fan and adjust its speed to produce 50 pascals of pressure difference between indoors and outdoors.
7. Read the CFM_{50} from the airflow manometer or from the second channel of a two-channel digital manometer.
8. If the house cannot be depressurized to –50 Pa, depressurize to highest multiple of 5 and multiply your measured airflow by the "can't reach 50" (CRF) factors in the conversion table shown here.

Table 2-1: *"Can't Reach Fifty" Factors*

House Pressure	15	20	25	30	35	40	45
Can't Reach 50 Factor	2.2	1.8	1.6	1.4	1.3	1.2	1.1

Thanks to The Energy Conservatory

Post-blower-door-test essentials

Be sure to return all temporary measures, taken to facilitate the blower door test, to their original condition.

✓ Inspect all pilot lights of combustion appliances to assure that blower door testing did not extinguish them.

✓ Reset thermostats of heaters and water heaters that were turned down for testing.

Approximate leakage area

There are several ways to convert blower door CFM_{50} measurements into square inches of total leakage area. The simplest way to convert CFM_{50} into an approximate leakage area (ALA) is to divide CFM_{50} by 10. The ALA can help you visualize the size of openings you're looking for in a home or section of a home.

$$\mathbf{ALA = CFM_{50} \div 10}$$

2.2.3 Building tightness limits (BTL)

Air leakage must provide fresh outdoor air when no mechanical ventilation system exists because the air leaks are the home's only source of fresh air to remove pollutants. Follow these steps to determine the building tightness limit (BTL).

1. Obtain the number of occupants by each of the following ways, and then use the largest number: a) actual number of occupants, b) number of bedrooms plus one, or c) minimum of 5 occupants per living unit
2. Use Zone 2 in the table below to find your n-value. (New York and New England are all in Zone 2, except for a region of Northern Maine along the Canadian border near Presque Isle.)

Table 2-2: *n-Values for Use in Calculating Building Tightness Limits*

Zone ↓	# of stories →	1	1.5	2	3
1*	Well-shielded	18.6	16.7	14.9	13.0
	Normal	15.5	14.0	12.4	10.9
	Exposed	14.0	12.6	11.2	9.8
2	Well-shielded	22.2	20.0	17.8	15.5
	Normal	18.5	16.7	14.8	13.0
	Exposed	16.7	15.0	13.3	11.7

* Relevant to Northern Maine only.

Courtesy of Home Energy Magazine, Lawrence Berkeley Lab, and George Tsongas

BTL example: *For a 3-story New York residence (Zone 2) with normal shielding: n=13.0.*
BTL = 15 cfm x 7 occupants x 13.0 = 1370 CFM_{50}.

3. Decide whether the building is well-shielded from wind, directly exposed to wind, or "normal," which means somewhere in-between exposed and well-shielded.
4. Find the factor "n" where the column representing the building's number of stories meets the row representing your location and the building's shielding. (This factor converts 50-pascal airflow to natural airflow and vice versa.)

5. Use one of the following simple formulas to determine the building tightness limit.

$$\text{BTL CFM}_{50} = 15 \text{ cfm} \times \# \text{ occupants} \times n$$

Or, if there are more than 322 square feet of floor space per occupant:

$$\text{BTL CFM}_{50} = \frac{0.35 \text{ ACH50} \times \text{volume} \times n}{60}$$

If the existing CFM_{50} is near or below the BTL, air sealing is not an energy-conservation priority. Air sealing may still be important to prevent humid indoor air from migrating into attics and building cavities.

Pollution control and ventilation may also be priorities for homes testing below the BTL. The importance of pollution control and ventilation depend on answers to the following questions.

- Are sources of moisture like ground water, humidifiers, water leaks, or unvented space heaters causing indoor dampness, high relative humidity, or moisture damage? *See "Solutions to moisture problems" on page 5-8*
- Do occupants complain or show symptoms of building-related illnesses?
- Are there combustion appliances located in the living space?
- Are the occupants smokers?

Pollutant sources combined with tight houses produce poor indoor air quality. Inform residents about removing pollution sources and ventilating their homes. Take appropriate steps during weatherization to reduce pollutants and to install mechanical ventilation if needed. *See "Mechanical ventilation" on page 5-10.*

2.3 PRESSURE-TESTING AIR BARRIERS

Leaks in air barriers cause energy and moisture problems in many homes. You can test air barriers for leakiness during blower-door testing. Air-barrier leak-testing avoids unnecessary visual inspection and air-sealing in hard-to-reach areas. Air-barrier pressure testing uses a manometer to measure pressure differences between zones in order to estimate air leakage between zones. Specifically air-barrier leak-testing can:

- Evaluate the airtightness of portions of a building's air barrier—especially floors and ceilings.
- Decide which of two possible air barriers to air seal—for example, the floor versus foundation walls.
- Estimate the approximate leakage area (ALA) of air leaks through a particular air barrier, for the purpose of estimating the materials and labor necessary to seal the leaks.
- Determine whether building cavities like floor cavities, porch roofs, and overhangs are conduits for air leakage.
- Determine whether building cavities, intermediate zones, and ducts are connected by air leaks.

Air-barrier leak-testing provides a range of information from simple clues about which parts of a building are leakiest to specific estimates of the airflow and hole size through a particular air barrier like a ceiling.

Primary versus secondary air barriers

Intermediate zones are unconditioned spaces, sheltered within the exterior shell of the house. Intermediate zones include: unheated basements, crawl spaces, attics, enclosed porches, and attached garages. Intermediate zones can be included inside the home's primary air barrier or outside it. Intermediate zones have two potential air barriers: one between the zone and house and one between the zone and outdoors. For example, an attic or roof space has two air barriers: the ceiling and roof.

The primary air barrier should be adjacent to the insulation to ensure the insulation's effectiveness, so testing is important to

Table 2-3: *Air Permeance of Building Materials at 50 Pascals Pressure*

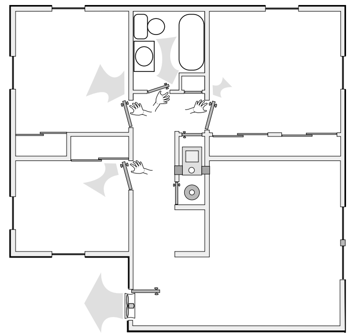
Material	CFM_{50} per 100 ft.^{2}
5/8" Oriented strand board	0.091
1/2" Drywall	0.26
4-mil air barrier paper	0.26
15# perforated felt	2.5
Concrete block	7.6
5/8" tongue-and-groove wood sheeting	300
6" fiberglass batt	490
1.5" wet-spray cellulose	1100

Based on: "Air Permeance of Building Materials" by Canada Mortgage Housing Corporation. Units converted from all-metric by the author. Values less than 2 would be considered an air barrier by Canadian authorities.

verify that insulation and primary air barrier are together. Together the air barrier and insulation for the thermal boundary. The most airtight of these two air barriers is the primary air barrier and the least airtight is the secondary air barrier. Sometimes we're surprised during testing to find that our assumed primary air barrier is actually secondary, and the secondary air barrier is actually primary. The air barrier should be a material that is continuous, sealed at seams, and is itself relatively impermeable to airflow.

2.3.1 Very simple pressure tests

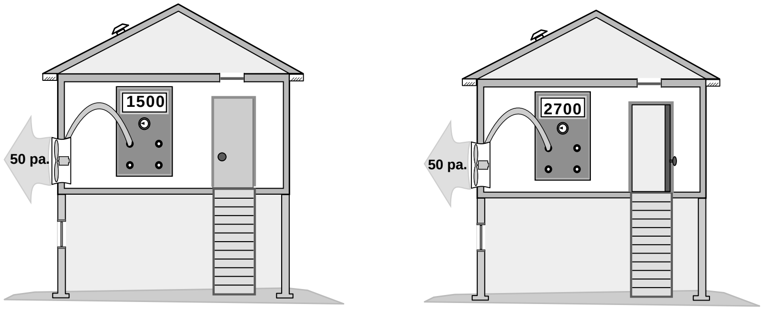
You can find valuable information about the relative leakiness of rooms or sections of the home with closable interior doors during a blower-door test. Listed below are 5 simple methods



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 that room.*

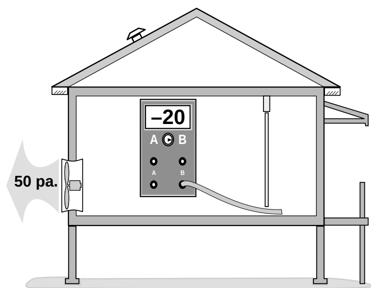
1. *Feeling zone air leakage:* Close an interior door partially so that there is a one-inch gap between the door and door jamb. Feel the airflow along the length of that crack, and compare that airflow intensity with airflow from other rooms, using the same technique. Discovering that there is a lot of leakage coming from one zone and only a little coming from another is this test's limit.
2. *Difference in CFM50:* Check the difference in CFM_{50} when an interior door is closed versus when it is open. You will probably have to adjust the blower door after closing or opening the interior door to restore 50 pascals house pressure. This technique works well for basements, attached garages, hallways in multifamily buildings, crawl spaces with interior access hatches, and other zones that

may contain significant air leaks.



Basement air-leakage test: *Basement door is closed and then opened during a blower door test. The difference in CFM50 between the first and second example means the floor is a fair air barrier. Leakage through the foundation walls, rim joist, and dirt floor are responsible for the 1200 CFM_{50} difference between the two readings.*

3. *Zone pressure difference:* Check the pressure difference between a closed room or zone and the main body of a home. Larger pressures indicate larger potential air leakage within the closed room or zone or else a tight air barrier between the zone and main body.



Bedroom test: *This bedroom pressure difference may be caused by its leaky exterior walls or tight interior walls, separating it from the main body of the home.*

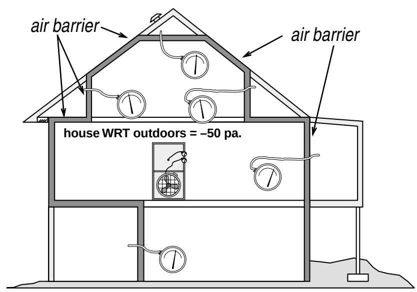
4. *Observing the ceiling/attic floor:* Pressurize the home to 50 pascals and observe the top-floor ceiling from the attic with a good flashlight. Air leaks will show in movement of loose fill insulation, blowing dust, moving cobwebs, etc.
5. *Observing smoke movement:* Pressurize the home to 50 pascals and observe the movement of smoke through the house and out of its air leaks.

All of these tests are approximations and observations. Feeling airflow with your hand is crude and inaccurate, but this simple technique has pointed out many air leaks that may have remained hidden without it. Air leakage, restricted by closing a door, may have almost equal alternative paths rendering tests 2 and 3 inaccurate. However, closing doors to leakier rooms will usually produce a greater reduction in CFM_{50} than closing doors to tighter ones. Leakier rooms will usually have greater pressure differences with the main zone than tighter rooms. Only practice and experience can guide your decisions about the applicability and usefulness of these tests.

2.3.2 Using manometers to test air barriers

The digital manometer or analog manometer, used for blower door testing, can also measure pressures between intermediate zones, conditioned zones, and outdoors during blower-door tests.

When the blower door depressurizes the house to –50 pascals, the home's intermediate zones will also be depressurized to between 0 and –50 pascals. The amount of depressurization depends on relative leakiness of the zone's two air barriers.



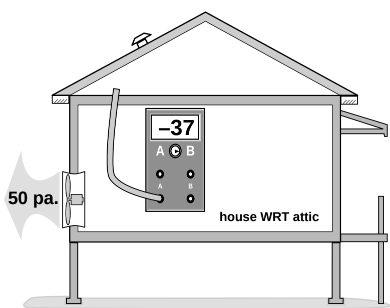
Pressure-testing building parts: *Measuring the pressure difference across the assumed thermal boundary tells you whether the air barrier and insulation are aligned. If the manometer reads close to –50 pascals, they are aligned. Lesser negative readings indicate misalignment.*

For example, in an attic with a very well-ventilated roof and a fairly airtight ceiling, the attic won't be depressurized much by a blower-door test. The leakier the ceiling and the tighter the roof, the more an attic will be depressurized. This holds true for other intermediate zones like crawl spaces, attached garages, and basements.

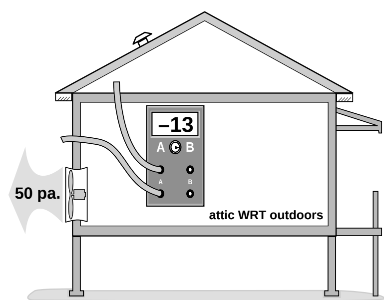
2.3.3 Simple attic leak testing

Air-sealing crews commonly use simple diagnostic techniques like the attic-pressure procedure described below. This procedure assumes that the roof is well-vented. There are many variations of this test used to evaluate other air barriers in other intermediate zones.

1. Depressurize house to –50 pascals with a blower door.
2. Find an existing hole or drill a hole through the ceiling between the conditioned space indoors and the attic.
3. Connect the input port (digital manometer) or the high-pressure port (analog manometer) to a hose connected into the attic.
4. Leave the reference port (digital manometer) or the low-pressure port (analog manometer) open to the indoors.
5. Read the negative pressure given by the manometer. This is the *house-to-attic* pressure, which will be –50 pascals if the ceiling is airtight and the roof well-vented.
6. If the reading is significantly different from –50 pascals, find the air barrier's largest leaks and seal them.
7. Repeat steps 1 through 5, performing more air-sealing as necessary, until the pressure is as close to –50 pascals as possible.



House-to-attic pressure: *This commonly used measurement is convenient because it requires only one hose.*



Attic-to-outdoors pressure: *This measurement confirms the first because the two add up to –50 pascals. This test is preferred by many for accuracy.*

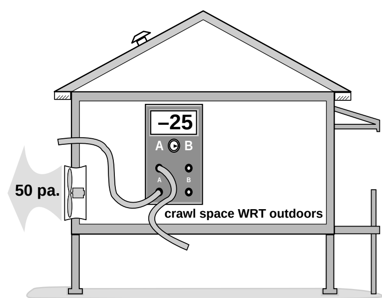
The *house-to-attic* pressure will be –50 pascals if the ceiling is airtight or if the roof has a large area of roof vents or if the ceiling's air leakage is insignificant compared to vents and air leaks in the roof.

- Readings of 25-to-50 pascals *house-to-attic pressure* mean that the ceiling is tighter than the roof.
- Readings of 0-to-25 pascals *house-to-attic pressure* mean that the roof is tighter than the ceiling.
- Readings around 25 pascals *house-to-attic pressure* indicate that the roof and ceiling are equally airtight or leaky.

2.3.4 Testing zones and building cavities

Use the following test procedures for measuring zone pressures in attics, crawl spaces, building cavities, and attached or tuck-under garages.

1. Set-up blower door for house air-leakage test.
2. Ensure that the hose to the outside will not be affected by the blower-door airflow.
3. Set-up a hose to measure pressure in a zone or building cavity. Make sure that end of hose extends beyond insulation, flooring or other barriers and well into the zone.
4. Close any openings (door, access hatch) between the intermediate zone and conditioned space, taking care not to pinch hose if it goes through the door or hatchway.
5. Connect hose from zone to input tap on manometer. Connect hose from the outside to reference tap.
6. Record pressure of zone with reference to the outside.



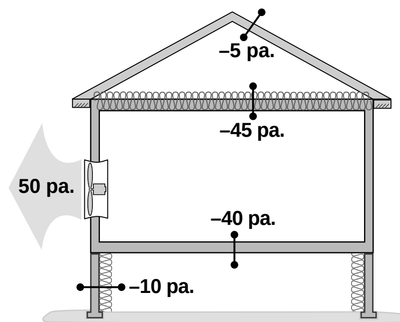
Crawl space-to-outdoors pressure: *Many homes with crawl spaces have an ambiguous thermal boundary at the foundation. Is the air barrier at the floor or foundation wall? Answer: In this case, both are an equal part of the air barrier.*

2.3.5 Interpreting zone pressures

Pressure readings between the zone and outside indicate whether the air barrier is aligned with the insulation. In all cases, both the air barrier and insulation should be in the same building section. Pressure readings also give clues about the amount of air-sealing work required.

Zone-to-outside readings of 0 to –25 pascals indicate that the air barrier between the living space and zone is tighter than the barrier between the zone and outside (for example, the ceiling is much tighter than the roof in an unfinished attic, shown here). This is good in that the primary air barrier is adjacent to the insulation. However, the air barrier (ceiling) can be made tighter if the pressure reading is more negative than –5 pascals. Pressure readings more negative than –5 pascals indicate that bypasses are present in the ceiling. Bypasses should be located and sealed. *See "Sealing bypasses" on page 3-3.*

Zone-to-outside readings of –25 pascals to –50 pascals indicate that the air barrier between the zone and outside is tighter than the air barrier between the living space and zone. For example, the floor is tighter than the crawl-space foundation walls, as shown here. If the crawl-space foundation walls are insulated, holes in the foundation wall should be sealed until the pressure difference between the crawl space and outside is more negative as high as you can get them. A leaky foundation wall renders the insulation much impaired.



Pressure measurements and air-barrier location: *The air barrier and insulation are aligned at the ceiling. The crawl-space pressure measurements show that the floor is the air barrier and the insulation is misaligned—installed at the foundation wall.*

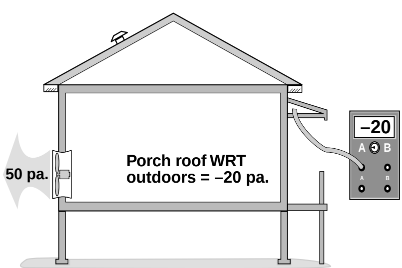
If instead, the floor above the crawl space were the insulated component, the air barrier and the insulation would be aligned.

Where to locate the thermal boundary, with its air barrier and insulation, is often a necessary retrofit decision, to be followed by appropriate air-sealing and insulation work.

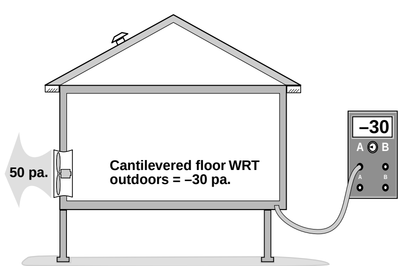
Zone-to-outside readings near –25 pascals indicate that the air barrier between the zone and conditioned space and the air barrier between the zone and outside are equally leaky. If there is currently no insulation, decide where the thermal boundary should be and perform appropriate air-sealing and insulation work accordingly. *See “Air-Sealing and Insulating” on page 3-1*.

Generally, the thermal boundary (air barrier and insulation) should be between the conditioned space and attic. The thermal boundary can be either the foundation walls or floor above crawl space. The thermal boundary should always be between the conditioned space and tuck-under or attached garage, to separate the living spaces from this unconditioned and often polluted zone.

Building cavities like wall cavities, floor cavities between stories, and soffits in kitchens and bathrooms can also be tested as described above to determine their connection to the outdoors as shown here.



Porch roof test: *We hope that the porch roof is outdoors because it is outside the insulation. We find, however, that it is partially indoors, indicating that it may harbor significant air leaks through the thermal boundary. If the porch roof were outdoors, the manometer would read near 0 pascals.*



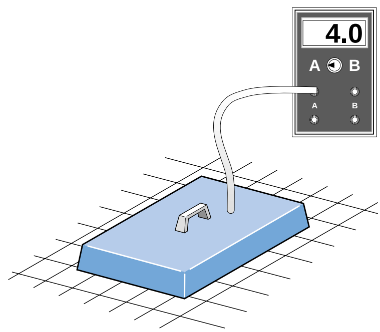
Cantilevered floor test: *We hope to find the cantilevered floor to be indoors. A reading of –50 pascals would indicate that it is completely indoors. A reading, less negative than –50 pascals, is measured here, indicating that the floor cavity is partially connected to outdoors.*

2.4 Duct airtightness testing

The blower door can be used for duct airtightness testing at the same time that it is testing house airtightness. The goal of the tests explained below is to roughly estimate duct leakage so that a decision can be made about the level of duct sealing necessary. *For information on sealing duct leaks, see "Duct air-tightness standards" on page 1-53.*

2.4.1 Pressure-pan testing

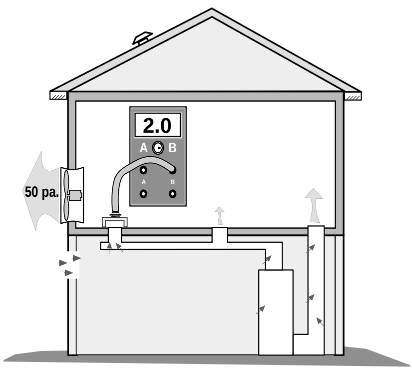
Pressure-pan tests can help identify leaky or disconnected ducts. With the house depressurized by the blower door to –50 pascals with reference to the outside, pressure-pan readings are taken at each supply and return register.



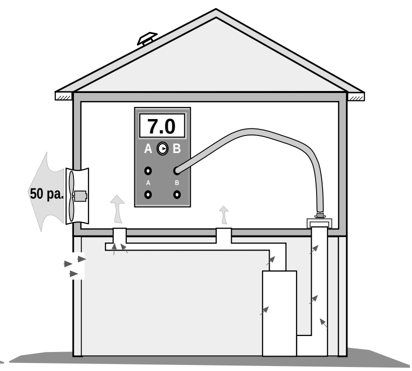
A pressure pan: *Blocks a single register and measures the air pressure behind it, during a blower door test. The magnitude of that pressure is an indicator of duct leakage.*

1. Install blower door and set-up house for winter conditions. Open all interior doors.
2. If the basement is conditioned living space, open the basement door. If the basement is considered outside the conditioned living space, close the basement door and open a basement window.
3. Turn furnace off. Remove furnace filter. Ensure that all grilles, registers, and dampers are fully open.
4. Temporarily seal any outside fresh-air intakes to the duct system. Seal all registers that are in unconditioned living spaces (supply registers in unconditioned basements, for example).
5. Open attics, crawl spaces, and garages as much as possible to the outside. If it has been determined that the basement is outside the conditioned living space, open basement windows or doors to the outside.

6. Connect hose between pressure pan and the input tap on the digital manometer. Leave the reference tap open.
7. With the blower door at –50 pascals, place the pressure pan completely over a grille or register to form a tight seal. Record the reading.
8. If a grille is too large or a supply register is difficult to access (under a kitchen cabinet, for example), seal the grille or register with masking tape. Insert a pressure probe through the masking tape and record reading.
9. Repeat test for each register and grille in a systematic fashion.



Pressure pan test: *A pressure-pan reading of 2 indicates moderate duct air leakage.*



Problem register: *A pressure reading of 7 pascals indicates major air leakage near the tested register.*

Basements are often considered part of the conditioned living space of a home. The door between a conditioned basement and living space should be open during pressure-pan testing and no opening need be made between the basement and outdoors. If instead, the basement is accessed from the outside and rarely used, the basement is usually considered outside the conditioned living space. In this case, a window or door between the basement and outdoors should be opened and the door between conditioned spaces and basement should be closed.

Pressure-pan duct standards

If the ducts are perfectly sealed with no leakage to the outside, no pressure difference (0.0 pascals) will be read during a pressure-pan test. The higher the pressure reading, the more connected the duct is to the outdoors.

- If three or more readings are greater than 2.0, examine duct system for leaks and repair, especially if ducts are located outside the conditioned living space.
- Following weatherization work, no more than three registers should have pressure-pan readings greater than 2.0 pascals. No single reading shall be greater than 4.0 pascals.
- The best weatherization providers won't accept readings greater than 1.0 pascals.

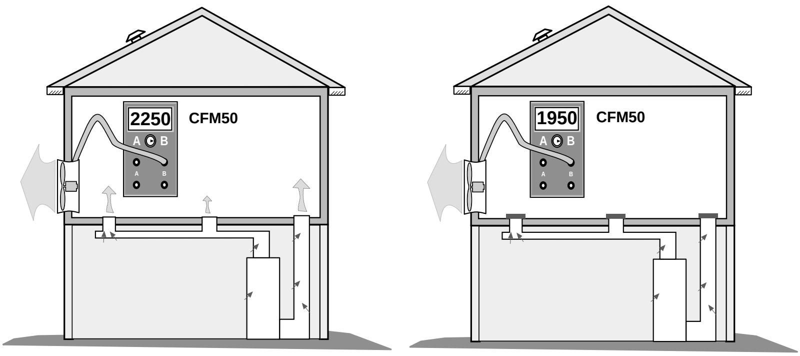
Attention should be given to registers connected to ducts that are located in areas outside the conditioned living space. These spaces include attics, crawl spaces, garages, and basements as described above. Attention should also given to registers attached to stud cavities or panned joists used as return ducts. Leaky ducts located outside the conditioned living space may show pressure-pan readings in excess of 30 pascals if they have large holes.

2.4.2 Blower-door subtraction

The blower door subtraction method employs two separate blower door tests: one test with registers open, and a subsequent test with registers blocked. The test assumes that the reduced blower door reading, after the registers are blocked, is due to the elimination of duct leakage from outdoors.

For best accuracy, the intermediate zone containing the ducts should be well-connected to the outdoors. If the *house-to-duct* pressure is –45 pascals or more, with the registers sealed, the test will be fairly accurate. If the *house-to-duct* pressure is a smaller negative number, this test will underestimate duct leakage. Correction factors, listed here make the test more accurate when the *house-to-duct* pressure is less negative than –45 pascals.

1. Take a standard blower door airflow reading (CFM_{50}) for house air leakage: *house WRT outdoors* = –50 pascals.
2. Tape over all supply and return registers and take another CFM_{50} reading.

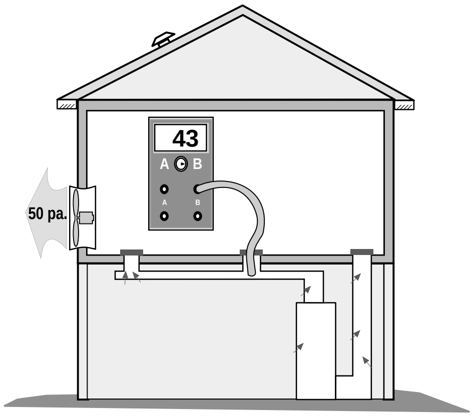


Blower door subtraction: *This test involves two blower door tests, one with the registers open and another with the registers taped closed. The difference between the two CFM_{50} readings is an rough indicator of duct leakage.*

3. Subtract the reading obtained in Step 2 from the reading in Step 1 to arrive at an estimate of duct leakage to the outdoors.
4. Measure the duct-to-house pressure through a hole in the tape at a central register or at a hole in a supply or return plenum.
5. Find the correction factor corresponding to the duct-to-house pressure measured in Step 4.
6. Multiply the correction factor times the duct leakage estimate from Step 3.

Blower-door subtraction standards

This test gives a very approximate duct-air-leakage measurement, which is not accurate for small-to-moderate duct leakage. The blower door measures large airflows, then subtracts them to get a much smaller figure for duct leakage. Small percentage errors between the two readings, due to wind or other variables, produce large errors in estimated duct leakage. The smaller the



Correction factor for blower door subtraction: *The pressure inside the sealed ducts serves as a correction factor to the CFM$_{50}$ difference. Match the duct pressure with the correction factors shown at right, which you multiply times your leakage*

House-WRT-Duct Pressure	Subtraction Correction Factor	House-WRT-Duct Pressure	Subtraction Correction Factor
50	1.00	30	2.23
49	1.09	29	2.32
48	1.14	28	2.42
47	1.19	27	2.52
46	1.24	26	2.64
45	1.29	25	2.76
44	1.34	24	2.89
43	1.39	23	3.03
42	1.44	22	3.18
41	1.49	21	3.35
40	1.54	20	3.54
39	1.60	19	3.74
38	1.65	18	3.97
37	1.71	17	4.23
36	1.78	16	4.51
35	1.84	15	4.83
34	1.91	14	5.20
33	1.98	13	5.63
32	2.06	12	6.12
31	2.14	11	6.71

Courtesy: The Energy Conservatory

duct leakage, the greater the error. Duct leakage of 200-to-500 CFM$_{50}$ is common in existing duct systems needing repair.

Setting realistic goals for blower door subtraction depends on the skill level of the technicians. The best technicians may be able to reduce CFM$_{50}$ duct leakage to around 2-to-3 percent of conditioned-floor area. Less experienced technicians may be satisfied with a blower door subtraction at CFM$_{50}$ of 10 percent of conditioned-floor area.

$$\textbf{BDS CFM}_{50} = \textbf{CFM}_{50}\ \textbf{difference} \times \textbf{Correction factor}$$

From the example: "Blower door subtraction" on page 2-23 and the Correction factor shown above, the calculation would go as follows.

$$\textbf{BDS CFM}_{50} = \textbf{300 CFM}_{50} \times \textbf{1.39} = \boxed{\textbf{417 CFM}_{50}}$$

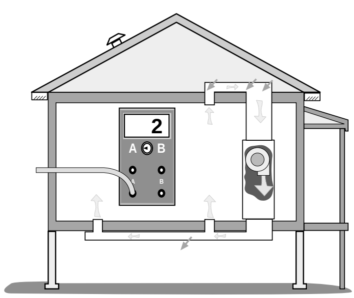
2.5 DUCT-INDUCED ROOM PRESSURES

An improperly balanced air-handling system can cause comfort, building-durability, and indoor-air-quality problems. Duct-induced room pressures can increase air leakage from 1.5 to 3 times compared to when the air handler is off.

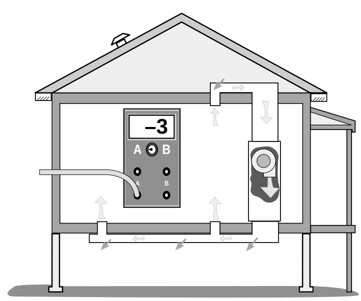
2.5.1 Measuring duct-induced room pressures

The following test measures pressure differences between the main body of the house and each room, including the combustion-appliance zone (or basement). Pressure difference greater than +3.0 pascals or more negative than –3.0 pascals should be corrected. *For information on reducing duct-induced room pressures, see "Improving duct-system airflow" on page 1-57.*

1. Set-up house for winter conditions. Close all windows and exterior doors. Turn-off all exhaust fans.
2. First, open all interior doors, including door to basement.
3. Turn on air handler.
4. Measure the house-to-outdoors pressure difference. This test indicates dominant duct leakage as shown here.



Dominant return leaks: *When return leaks are larger than supply leaks, the house shows a positive pressure with reference to the outdoors.*



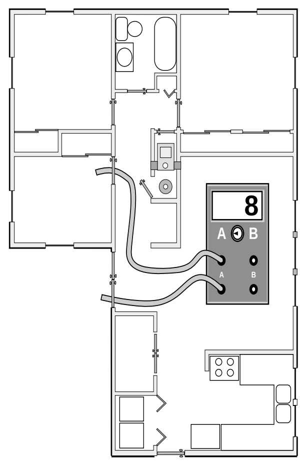
Dominant supply leaks: *When supply leaks are larger than return leaks, the house shows a negative pressure with reference to the outdoors.*

A positive pressure indicates that the return ducts (which pull air from leaky intermediate zones) is leakier than the supply ducts. A negative pressure indicates that the supply ducts (which push air into intermediate zones through their leaks) are leakier than return ducts.

5. Now, close interior doors.
6. Place hose from input tap on the manometer under one of the closed interior doors. Leave reference tap connected to outdoors.
7. Read and record this pressure measurement for each room. This pressure's magnitude indicates the degree to which the air-handler's airflow is unbalanced between supply and return.

If pressure difference is more than + or – 3.0 pascals with the air handler operating, pressure relief is necessary. To estimate the amount of pressure relief, slowly open door until pressure difference drops between +3.0 pascals and –3.0 pascals Estimate area of open door. This is the area required to provide pressure relief. Pressure relief may include undercutting the door or installing transfer grilles.

For information on the danger of depressurized combustion zones, see "Worst-case depressurization test" on page 1-24.

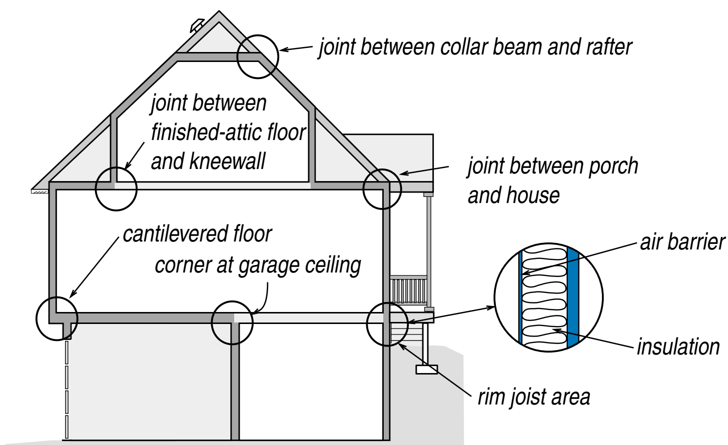


Blocked return path: *With interior doors closed, the large positive pressure in the bedroom is caused by the lack of a air return register in the bedroom. The airflow in this forced-air system is unbalanced, causing this pressure, which forces room air through the room's air leaks.*

3.0 AIR-SEALING AND INSULATING

These specifications address energy-efficiency measures designed to improve the building's thermal boundary. Perform air leakage testing and evaluation before beginning air-sealing or insulation work. *See "Assessing Air Leakage through the Building Shell and through Ducts" on page 2-1.*

Use visual inspection to determine the cost-effectiveness of adding insulating value to a building by installing insulation or window treatments. Reducing air leakage and adding insulation use the same general approach. The most needy areas are retrofitted first and then less needy areas are retrofitted as time and budget permit.



Thermal boundary flaws: *Corners in the thermal boundary are places where insulation and the air barrier may be incomplete.*

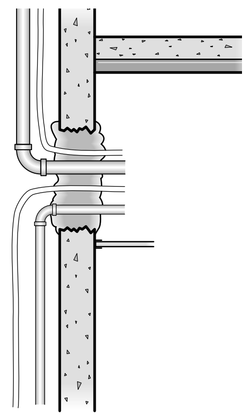
3.1 Reducing air leakage

Air leakage in homes represents from 5% to 40% of annual heating costs. Air-leakage reduction is one of weatherization's most important functions, and often the most difficult function. The four main functions of air-leakage reduction are to:

1. Save energy
2. Increase comfort
3. Protect insulation's thermal resistance
4. Avoid moisture migration into building cavities

Air leaks into and out of the building by three main ways:

1. Bypasses, which are significant flaws in the home's air barrier.
2. Seams between building materials.
3. The building materials themselves. *See "Air Permeance of Building Materials at 50 Pascals Pressure" on page 2-11.*



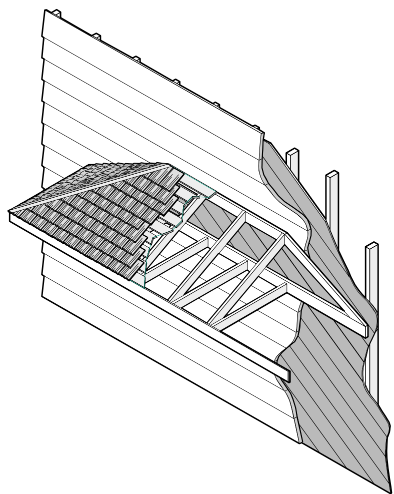
Large holes: *Tradesmen often knock large holes in concrete walls without patching them. These can be large air leaks.*

The ultimate goal of air leakage reduction is to establish an effective air barrier. Before air sealing, be aware of all air-pollution and house-pressure hazards. State and local governments may set standards for airtightness levels and ventilation. *See "Building tightness limits (BTL)" on page 2-9.*

Reference Title	Chapter / Section
Residential Energy: Cost Savings and Comfort for Existing Buildings, by John Krigger; Third Edition	Chapter 3, Air Leakage
Your Mobile Home: Energy and Repair Guide for Manufactured Housing, by John Krigger; Fourth Edition	Chapter 5, Air Leakage

3.1.1 Sealing bypasses

Bypasses are holes and gaps in the air barrier. The effort worth expending to seal a bypass depends primarily on its size. Bypasses will be found between the conditioned space and attic, crawl space, attached garages, and porch roofs.*For information on measuring and locating air leaks, see "Using manometers to test air barriers" on page 2-15.*

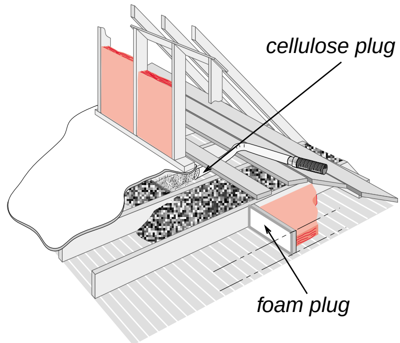


Porch air leakage: *Porches often create a substantial air leak because of all their joints and because there may be no siding or sheathing behind the porch.*

It is always preferable to use strong air-barrier materials like plywood or drywall to seal bypasses. These materials should be attached with mechanical and/or adhesive bonds. Strong materials with strong bonds are best practice because air barriers must be able to resist severe wind pressures.

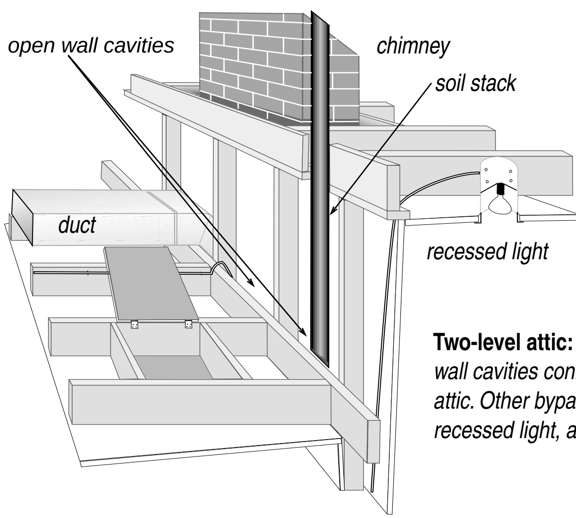
Sometimes bypasses are easily accessible and sometimes not. When they are not easily accessible, technicians sometimes blow densely packed cellulose insulation into surrounding cavities, hoping that the cellulose will resist airflow and clog cracks between building materials.

The following are examples of bypasses and how to seal them. All bypasses are to be sealed prior to insulating except where cellulose is also being used to seal bypasses.



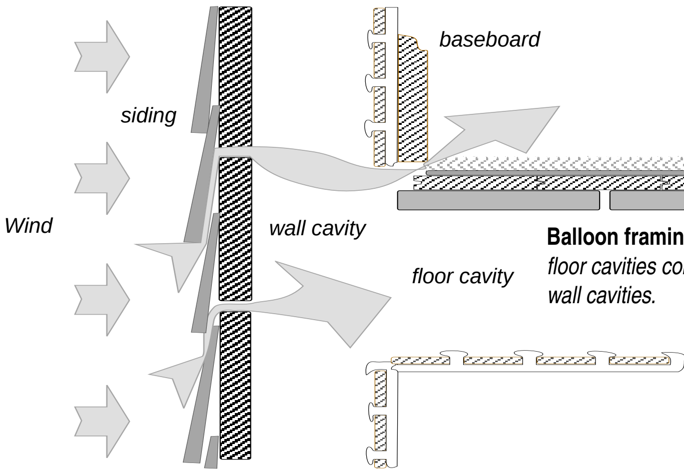
Cellulose or foam board plugs: *Seal these large air leaks between the ventilated attic and the interior floor cavity.*

- *Joist spaces under kneewalls in finished attic areas:* Connect plasterwall with the plaster ceiling of the floor below by creating a rigid seal under the kneewall or by blowing short sections of the floor cavity with densely packed cellulose.
- *Kitchen or bathroom interior soffits:* Seal the top of the soffit with plywood or drywall, fastened and sealed to ceiling joists and soffit framing.
- *Two-level attics in split-level houses:* Seal the wall cavity with a rigid material fastened to studs and wall material.



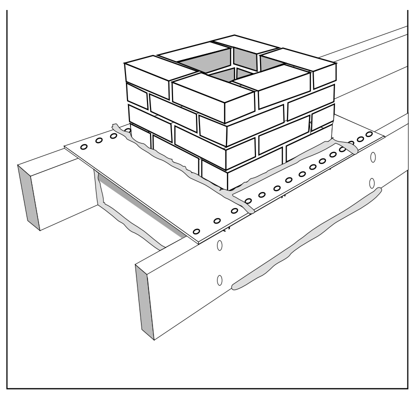
Two-level attic: *Split level homes create wall cavities connected to the ventilated attic. Other bypasses shown are duct, recessed light, and chimney.*

- *Tops and bottoms of balloon-framed interior partition wall cavities, missing top plates:* Seal with rigid barrier, like $^1/_4$-inch plywood or 1-inch foam sealed to surrounding materials with caulk or liquid foam.



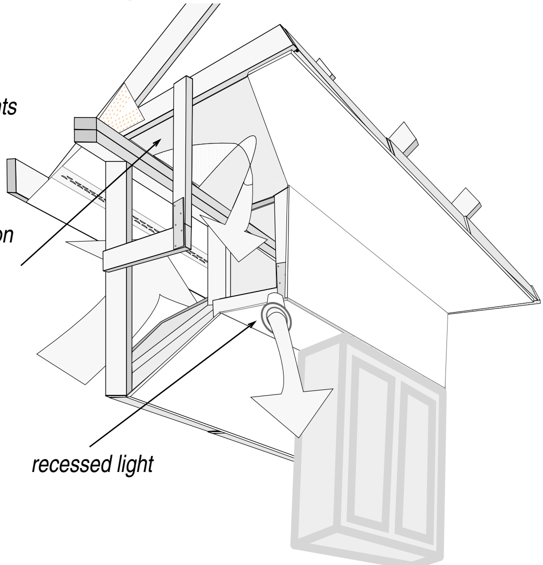
Balloon framing: *Leaves floor cavities connected to wall cavities.*

- *Chimney, Fireplace:* Seal chimney and fireplace bypasses with sheet metal (minimum 28 gauge thickness) and seal to chimney or flue and ceiling structure with a high temperature sealant or chimney cement.
- *Soil stacks, plumbing vents, open plumbing walls:* Seal joints with expanding foam or caulk. If joint is too large, stuff with fiberglass insulation and foam over the top to seal the surface of the patch.



Chimney chases: *Sealed with non-combustible sheet metal and high-temperature silicone sealant.*

- *Housings of exhaust fans and recessed lights:* Caulk joints where housing comes in contact with the ceiling.



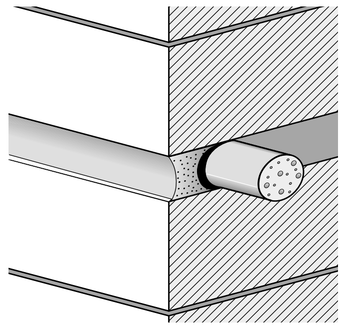
Kitchen soffits: *Are often open to both the wall cavity and ventilated attic. Any hole in the soffit creates a direct connection between the kitchen and attic.*

- *Duct boots and registers:* Caulk or foam joint between duct boot and ceiling, wall, or floor finish if ducts are located in attic, crawl space, or attached garage.
- *Wiring and conduit penetrations:* Seal penetration with caulk.
- *Duct chases:* If chase opening is large, seal with a rigid barrier such as plywood or drywall and seal the new barrier to ducts. Smaller cracks between the barrier and surrounding materials may be foamed or caulked.
- *Bathtubs and shower stalls:* Seal holes and cracks from underneath with expanding foam. Seal large openings with rigid materials caulked or foamed at edges.
- *Attic hatches and stairwell drops:* Weatherstrip around doors and hatches. Caulk around frame perimeter.
- *Other openings in the air barrier:* Seal with rigid material, caulk, or expanding foam depending upon size of opening.

3.1.2 General air sealing

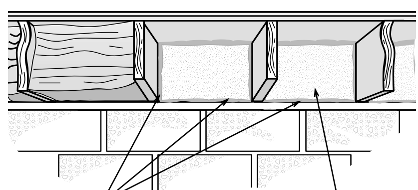
The following general infiltration measures may be done only if found to be cost effective as determined by sequential blower-door-guided air sealing.

- Cracks in exterior window and door frames should be sealed. If the crack is deeper than $^{5}/_{16}$-inch, it must be backed with a material such as flexible polyurethane, neoprene butyl rod, fiberglass, or sponge rubber specifically manufactured for this purpose and then sealed with caulk. Any existing loose or brittle material must be removed before being recaulked. Caulking should be applied in a manner that seals the area thoroughly and is neat in appearance.



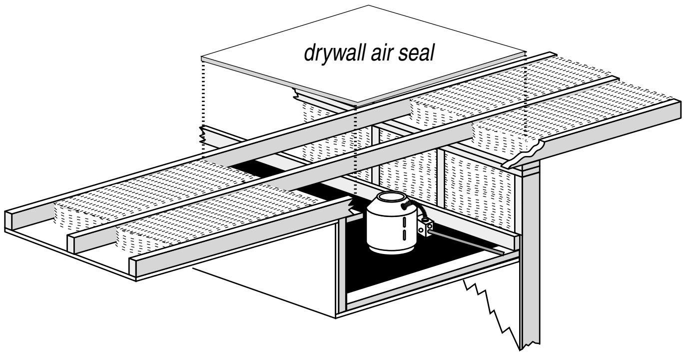
Backer rod: *Use it to support caulk for sealing uniform gaps, and use liquid foam for sealing irregular gaps.*

- Joints in sill plate (mud sill) and around utility openings in siding and foundation should be sealed in an appropriate manner. When a space between two metal surfaces is to be sealed, only a butyl or silicone caulk shall be used. Cracks between two masonry surfaces should be sealed with a cement patching compound or mortar mix. If the opening is deeper than $^{3}/_{8}$ inch, follow procedures described above.



Sealing rim joists: *Seal the joints with caulking before insulating with fiberglass batts. It's better to insulate the rim joist with foam board, cut to size with adequate clearances to seal edges with liquid foam.*

- Interior joints should be caulked. These joints include where baseboard, crown molding and/or casing meet the wall/ceiling/floor surfaces. Gaps around mounted or recessed light fixtures and ventilation fans shall be caulked.



Recessed light fixtures: *These are major leakage sites, but these fixtures must remain ventilated to cool their incandescent bulbs. Plug the top of the soffit with drywall.*

- Insulation gaskets are useful in trying to attain a tight interior air barrier, but not cost effective in every case.

3.2 INSTALLING INSULATION

The building shell's thermal resistance is increased by adding insulation. Insulation reduces heat transmission. Combined with the home's air barrier, insulation forms the thermal boundary. *Make sure that the air barrier and insulation will be aligned using procedures outlined in "Pressure-testing air barriers" on page 2-11.*

Insulation should cover the entire area intended for insulation without voids or edge gaps. Blown insulation should be installed at sufficient density to resist settling, according to manufacturer's instructions. Insulation should be protected from air migrating around and through it by an effective air barrier. Insulation should be protected from moisture.

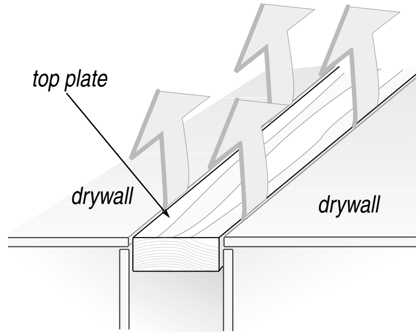
Wall cavities should be filled with insulation completely, from top to bottom and side to side. Observe lead-safe weatherization practices with all tasks that may disturb interior paint. *See "Lead-safe weatherization" on page 5-12.*

Reference Information on Insulation

Reference Title	Chapter / Section
Residential Energy: Cost Savings and Comfort for Existing Buildings, by John Krigger; Third Edition	Chapter 4,Insulation
Your Mobile Home: Energy and Repair Guide for Manufactured Housing, by John Krigger; Fourth Edition	Chapters 7, 8, and 10

3.2.1 Attic insulation

Air leakage testing and air sealing should always precede attic insulation because attic insulation is not itself an air barrier. Attic insulation needs an air barrier adjacent to it to be effective. Air moving through insulation reduces its R-value and can deposit moisture in the insulation. *See "Simple attic leak testing" on page 2-15 and "Sealing bypasses" on page 3-3 for more information.*



Top-plate leakage: *Even thin cracks between the top plate and drywall can be important air leaks because there are many linear feet of these cracks.*

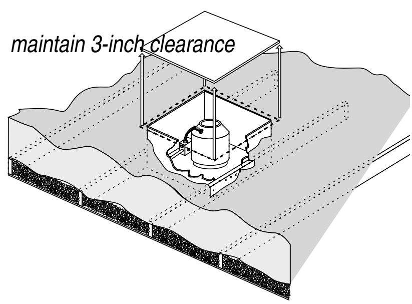
Safety

Comply with the following fire and electrical safety procedures before insulating.

✓ Box around recessed light fixtures and exhaust fans to prevent overheating and/or fire.

✓ Install collars or dams around masonry chimneys, B-vent chimneys, and manufactured chimneys after sealing bypass.

✓ All-fuel wood-stove chimneys should have ventilated insulation shields.



Covering recessed light fixtures: *Covering recessed light fixtures with fire-resistant drywall or sheet-metal enclosures reduces air leakage and allows insulation to be blown around the box.*

✓ If funds are available, attic knob-and-tube wiring may be replaced. Add insulation beneath knob-and-tube maintaining a one-inch air space between insulation and wiring. Or, create non-metallic barriers to retain minimum one-inch air space along side of knob-and-tube wiring.

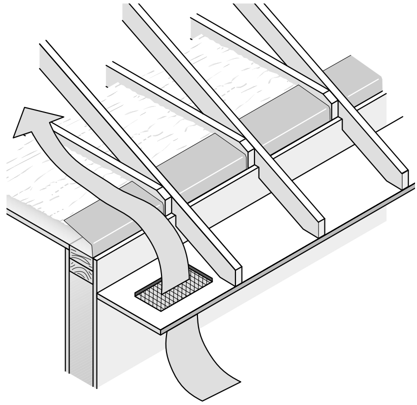
- ✓ In some cases, a home may have been rewired and the wiring left in place. The assessor must confirm that the knob-and-tube wiring is not in service before covering with insulation.
- ✓ Repair frayed wiring. Wiring splices must be enclosed in metal or plastic electrical boxes, fitted with cover plates.
- ✓ Covered electrical junction boxes may be covered with insulation, if appropriately marked.
- ✓ If rolled metal is used for as a barrier around heating producing devices or chimneys, it must be fastened securely to the attic joist in such a manner as to not allow the barrier to collapse. Barriers shall extend at least 4 inches above the insulation and be installed in such a fashion to keep insulation a minimum of 3 inches away from the heat-producing device.
- ✓ OSHA-approved respirators or dust masks should be worn when blowing insulation.

Preparation for attic insulation

Observe the following important preparatory steps before installing attic insulation.

- ✓ Repair all roof leaks before insulating attic. If roof leaks cannot be repaired, do not insulate attic.
- ✓ All kitchen and bath fans currently venting into the attic must be re-vented outdoors through roof fittings. Fans without operating backdraft dampers should be repaired, equipped with backdraft dampers, or the fan should be replaced. Check new fans for proper damper operation. Use rigid aluminum or galvanized pipe for venting whenever possible and insulate the pipe to prevent condensation.

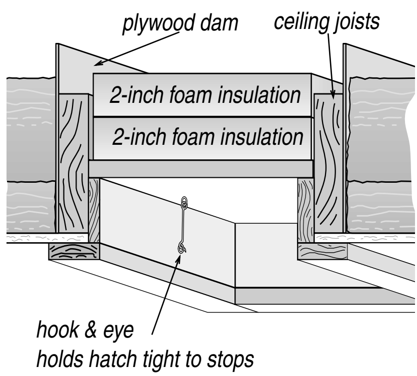
✓ Install chutes, dams or other blocking devices to prevent blown insulation from plugging air channels from soffit vents into the attic, to maximize amount of insulation that may be installed over top plates, and to prevent wind-washing of the insulation by cold air entering soffit vents.



Chute or dam: *Prevents wind washing and airway blockage by blown insulation.*

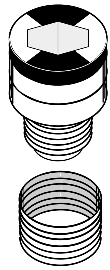
✓ Install an attic access hatch if none is present. This attic hatch should be at least 24 inches square if possible.

✓ Build an insulation dam around the attic access hatch. Build the dam with rigid materials like plywood or oriented-strand board. The dam's purpose is to prevent loose-fill insulation from falling out of the attic hatch when opened. Install latches, sash locks, gate hooks or other positive closure to provide substantially air-tight hatch closure where appropriate.



Insulated attic hatch: *Foam insulation prevents this area from being a thermal weakness. Building a dam prevents loose-fill insulation from falling down the hatchway.*

- ✓ Air leakage and convection can significantly degrade the thermal resistance of attic insulation. Before insulating attic, seal bypasses as described previously. If attic bypasses are not properly sealed, increasing attic ventilation may increase the air leakage rate of the home.



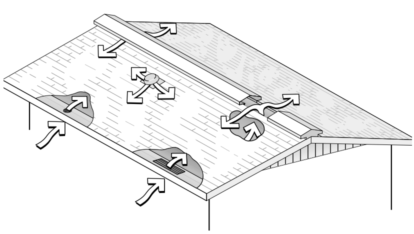
S-type fuse: *An S-type fuse won't allow residents to oversize the fuse and overload a knob-and-tube electrical circuit.*

- ✓ Within jurisdictions that allow insulating over knob-and-tube wiring, inspect fuse boxes to insure that the circuits aren't overloaded. Maximum ampacity for 14 gauge wire is 15 amps and for 12 gauge wire is 20 amps. Install S-type fuses where appropriate to prevent circuit overloading.

Attic venting

Attic ventilation is intended to remove moisture from the attic during the heating season and to remove solar heat from the attic during the cooling season.

Many building codes require a minimum ratio of one square foot of net free area to 150 square feet of attic area if a vapor barrier is not present. With a vapor barrier, one square foot per 300 square feet of attic area is required.

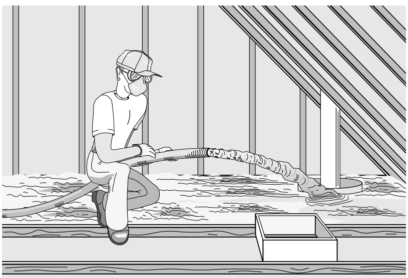


Low and high attic ventilation: *Creates effective air movement to keep attics dry and also help to keep them from overheating in summer.*

Many building scientists and technicians now believe that attic venting requirements are arbitrary and possibly excessive. Attic venting can increase air leakage by increasing the stack effect and ceiling air leakage. Ceilings should be thoroughly air-sealed to prevent ceiling air leakage from depositing moisture in the insulation.

Vents should be installed in a manner to prevent the entrance of snow, rain, insects and rodents. Vents shall be installed in accordance with manufacturers' instructions and sealed with an appropriate sealant.

3.2.2 Blowing attic insulation



Blown-in attic insulation: *Blown insulation is more continuous than batts and produces better coverage. Insulation should be blown at a high density to reduce settling.*

Blown insulation is preferred to batt insulation whenever possible because blown insulation forms a seamless blanket. Blowing attic insulation at the highest achievable density helps resist settling and prevent convection currents from moving within the insulation. The highest density is achieved by moving the most insulation 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.

Attic insulation should be installed to a cost effective R-value as determined by the climatic region. If the attic has a closed floor cavity, dense-pack the cavity between ceiling and flooring. Do not insulate cavity if live knob-and-tube wiring is present beneath attic flooring.

Insulation should be installed to a uniform depth according to manufacturers' specifications for proper coverage (bags per square foot ratio) to attain the desired R-value at settled density.

3.2.3 Installing batt insulation

Blown insulation is preferred to batt insulation because it covers better and is seamless. If batt insulation must be used, then it must be installed in such a manner to ensure tight fit between ceiling joists. Allow no voids or gaps between batts or between batts and ceiling joists, because these imperfections reduce R-value significantly. Insulation must fill joist cavity and provide uniform and complete coverage. If insulation has vapor barrier backing, the vapor barrier shall be toward heated space. When insulation with vapor barrier is installed over existing insulation, the vapor barrier should be removed, to allow drying of the insulation should it get wet.

3.2.4 Finished attics of Cape-Cod homes

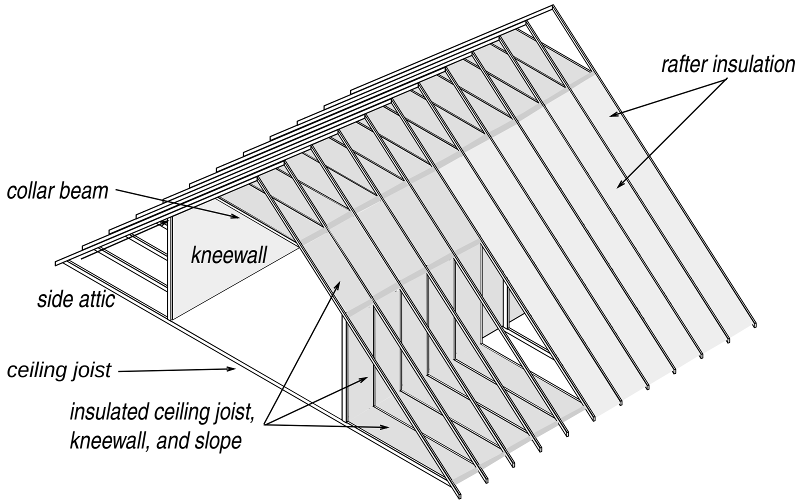
The finished attic consists of five sections.

1. Exterior finished attic walls (end walls of finished attic). *See "Wall insulation" on page 3-17.*
2. Collar beams (above finished attic)
3. Sloped roof (where wall/roof finish is installed directly to roof rafters)
4. Knee walls (between finished attic and unconditioned attic space).
5. Outer ceiling joists (between knee wall and top plate of exterior wall)

Consider the following specifications when insulating finished attics.

- ✓ Seal attic bypasses before insulating. Seal joist spaces under knee wall by creating a rigid seal under the knee-wall or by blowing cellulose insulation into the floor cavity until it plugs the cavity with a densely packed mass of insulation. *See "Sealing bypasses" on page 3-3.*

- ✓ Where possible, insulate sloped roof with dense pack cellulose.



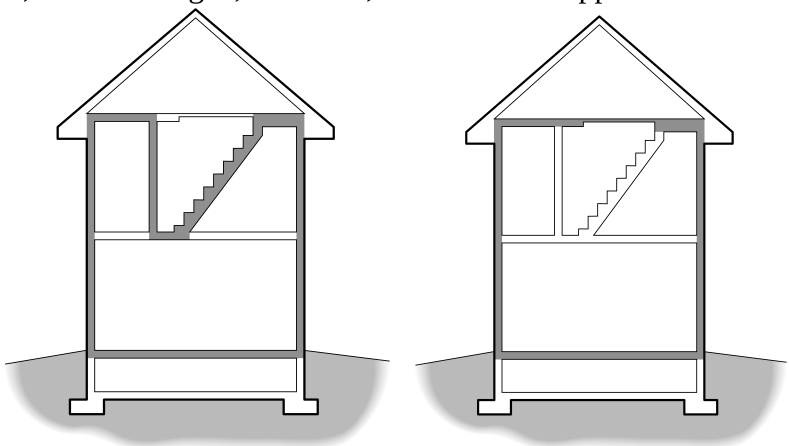
Finished attic: *This illustration depicts two approaches to insulating a finished attic. Either insulate the kneewall and side attic or insulate the rafters.*

- ✓ Insulate knee walls with maximum R-value as allowed by stud-cavity depth. Extend insulation down to ceiling of conditioned space below. Ensure that joist cavity has been air-sealed with a solid material.
- ✓ When knee-wall area is used for storage, cover insulation with a vapor-permeable material such as house wrap to prevent exposure to insulation fibers.
- ✓ Insulate knee-wall access hatches with minimum R-13 insulation. Insulate collar beam access hatches with minimum R-19 insulation. Weatherstrip and provide positive closure (latch, sash locks, gate hooks, etc.) to hatches where appropriate.

Option: Insulate rafter cavity with maximum R-value as allowed by rafter-cavity depth. The area where the rafter meets the ceiling joist should be air-sealed and insulated.

Walk-up stairway and door

Think carefully about how to establish a continuous insulation and air barrier around or over top of the attic stairway. If possible, install a hinged, insulated, and weatherstripped hatch door.



Attic stairway walls and stairs: *Insulating and air sealing these is one way of establishing the thermal boundary around such an attic access.*

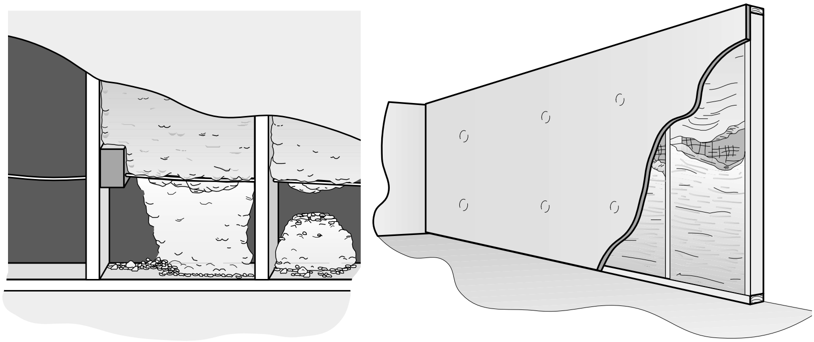
Insulating and weatherstripping the attic door: *Air sealing around the doorway is alternative way of establishing the thermal boundary here.*

If attic is accessed by a stairwell and standard vertical door, blow dense-packed cellulose insulation into walls of stairwell. Install threshold or door sweep, and weatherstrip door. Also blow packed cellulose insulation into the cavity beneath the stair treads and risers.

When planning to insulate walls and stairway, investigate barriers that might prevent insulation from filling cavities you want to fill and what passageways may lead to filling other areas (like closets) by mistake. Balloon-framed walls and deep stair cavities may prevent blown insulation from being cost-effective.

3.2.5 Wall insulation

Installing insulation with a uniform coverage and density is very important for wall insulation because wall cavities are like chimneys: convection currents or air leakage can significantly reduce insulation's thermal performance.



Blowing insulation using a directional nozzle: *Through one or two holes usually creates voids inside the wall cavity. Insulation won't reliably blow at an adequate density more than about one foot from the nozzle. This is why tube-filling is superior.*

Densely packed cellulose wall insulation reduces air leakage through cracks inside walls and other closed building cavities because the fibers are driven into the cracks by the blowing machine.

Where you find incomplete wall insulation, uninsulated walls, or uninsulated wall sections, insulation should be added to provide complete coverage for all the home's exterior walls.

Two methods for installing sidewall insulation are commonly used: dense-pack method (one-hole) or the two-hole method. The dense-pack method is preferred because it ensures that wall insulation achieves the correct coverage and density.

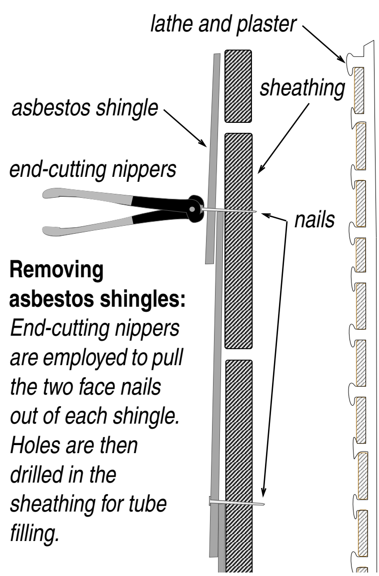
Preparation for wall insulation

✓ Inspect walls for evidence of moisture damage. If existing condition of the siding, sheathing, or interior wall finish indicates an existing moisture problem, no sidewall insulation should be installed until the moisture problem has been corrected.

✓ Seal gaps in external window trim and other areas that may admit rain water into the wall.

✓ Inspect indoor areas on exterior walls for places where blown insulation must not go. Examples are electric wall heaters, wall furnaces, pocket doors, closets, cabinets, wall ducts, and through unsealed tops and bottoms of balloon-framed walls.

- ✓ Inspect indoor areas on exterior walls to assure that they are strong enough to withstand the installation process.
- ✓ Inspect for interior openings from which insulation may escape, such as pocket doors, balloon framing and unbacked cabinets, soffits, and closets. Seal openings as necessary.
- ✓ Inspect walls for live knob-and-tube wiring. Insure that circuits, contained within walls, aren't overloaded. Maximum ampacity for 14 gauge wire is 15 amps and for 12 gauge wire is 20 amps. Install S-type fuses where appropriate to prevent circuit overloading. Don't insulate walls with live knob-and-tube wiring if forbidden by local codes.
- ✓ Avoid drilling through siding. Where possible, carefully remove siding and drill through sheathing.
- ✓ If siding cannot be removed, obtain homeowner's permission to drill through siding or interior finish. Practice lead-safe weatherization when drilling through interior walls. *See "Lead-safe weatherization" on page 5-12.*
- ✓ Asbestos shingles may be carefully removed by pulling the nails holding them to the sheathing or else nipping off the nailheads. Dampening the asbestos tiles slightly reduces the possibility of dust.

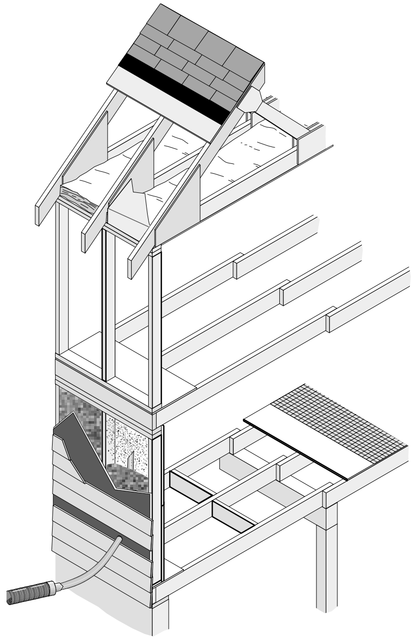


Removing asbestos shingles: *End-cutting nippers are employed to pull the two face nails out of each shingle. Holes are then drilled in the sheathing for tube filling.*

✓ Homes with brick veneer or blind-nailed asbestos siding may be insulated from the inside. Holes drilled for insulation must be finished and returned to condition as close to original as possible.

✓ Probe all wall cavities through holes, as you drill them, to identify fire blocking, diagonal bracing, and other obstacles.

✓ After probing, drill whatever additional holes are necessary to ensure complete coverage.

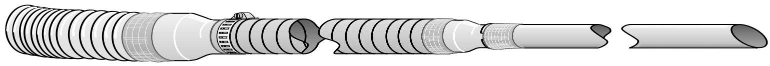


Tube-filling walls: *This method can be accomplished from inside or outside the home. It is the preferred wall-insulation method because it is the only reliable way for achieving a uniform coverage and density.*

Dense-packed wall insulation

1. Drill minimum 2-to-3-inch diameter holes to access stud cavity.
2. To prevent settling, cellulose insulation must be blown at a minimum of 3.5 pounds per cubic foot density. This minimum density translates into one pound per square foot in a 2-by-4 wall cavity. Blowing cellulose insulation this densely requires a fill-tube.
3. Dense-packed wall insulation is best installed using a blower equipped with separate controls for air and material feed.
4. Marking the fill-tube in one-foot intervals allows the person blowing insulation to verify the correct penetration of the tube into the wall.
5. Starting with several full-height, unobstructed wall cavities allows the crew to measure the insulation density. Start

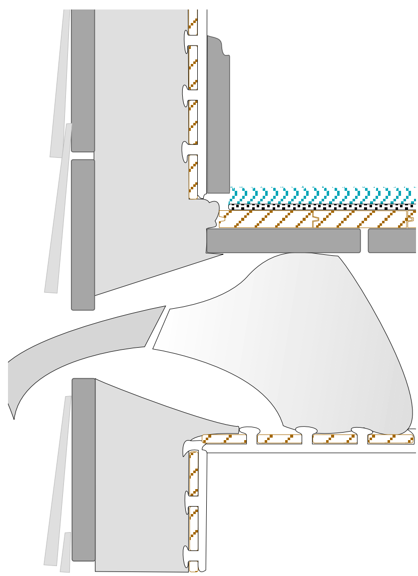
with an empty hopper. Fill the hopper with a bag you've weighed. An 8-foot cavity should consume a minimum of 10 pounds of cellulose insulation.



Insulation hoses, fittings, and the fill tube: *Smooth, gradual transitions are important to the free flow of insulation.*

6. Except as previously noted, fill all wall cavities.
7. Seal holes with plugs before replacing siding.

- If for some reason siding could not be removed, use wood plugs for patching holes. The wood plugs must be shaved flush, spackled and painted.
- Insulation should be installed in accordance with the manufacturers recommended application procedures.
- With balloon-framed walls, try to blow an insulation plug in each floor cavity to insulate the perimeter between the two floors and to seal the floor cavity against being a conduit for air migration.



Filling floor-joist cavities: *Reduces air leakage through balloon-framed homes.*

Two-hole method

The two-hole method is not a preferred wall-insulation method because voids and sub-standard density are common. When using this method, employ a powerful blowing machine, preferably one with a gasoline engine.

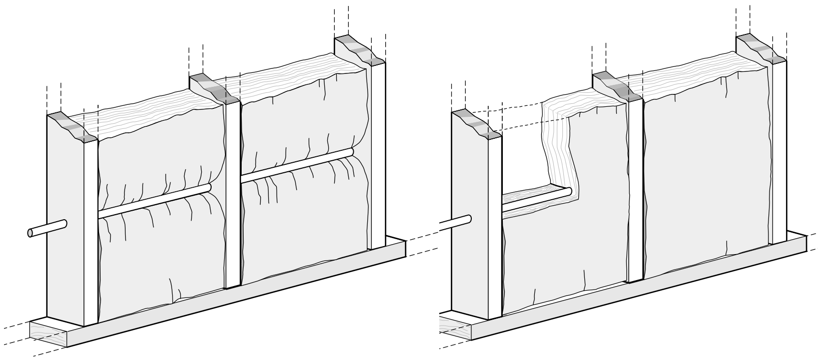
✓ Drill two one-inch diameter holes into each stud cavity.

- ✓ Holes are to be located no more than 2 feet between the top plate and the top holes; 2.5 feet between the bottom plate and bottom holes.
- ✓ Examine wall cavity with wire probe or steel tape to determine location of obstacles and cavities around window and door areas.
- ✓ All wall cavities around windows and doors should be filled with insulation.

Open-cavity wall insulation

Fiberglass batts achieve their rated R-value only when installed very carefully. If there are gaps between the cavity and batt at the top and bottom, the R-value can be reduced by as much as 30 percent. The batt should fill the entire cavity without spaces in corners or edges.

- ✓ If possible, use unfaced friction-fit batt insulation. Fluff to fill entire wall cavity.
- ✓ Staple faced insulation to outside face of studs—avoid inset stapling.
- ✓ Batt insulation must be cut to the exact length of the cavity. A too-short batt creates air spaces above and beneath the batt, causing convection. A too-long batt will bunch up, creating air pockets. Air pockets and convection currents significantly reduce insulation's thermal resistance. Each wall cavity should be completely filled with batt insulation.
- ✓ Split batt around wiring rather than letting the wiring bunch the batt to one side of the cavity.
- ✓ Insulate behind and around obstacles with scrap pieces of batt before installing batt.
- ✓ Install vapor retarder with permeability less than 1 on the warm in winter side of the insulation. Vapor retarder should be well fastened at all seams and edges.
- ✓ Installed fiberglass insulation exposed to the interior living space must be covered with minimum $^1/_2$-inch drywall or



Fiberglass batts, compressed by a cable: *Reduces the wall's overall R-value by creating a void between the wire and interior wallboard.*

Batt, split around a cable: *The void is avoided and the batt attains its rated R-value.*

other material that has an ASTM flame spread rating of 25 or less.

3.2.6 Floor insulation and foundation insulation

With heated, occupied basements, the obvious choice is to insulate the basement walls and to establish the air barrier at the walls. However, the choice between insulating the floor or the foundation is often not an easy one for homes with unused basements or crawl spaces. To establish an effective thermal boundary, the insulation and air barrier should be adjacent to each other. Establishing an effective air barrier—comparable to the air barriers in the house walls and ceiling—may be difficult.

Floor insulation is generally preferred where there are crawl-space moisture problems, the building has a relatively large perimeter and a relatively small floor area (mobile homes, for example) or where the foundation wall surface is too irregular to permit foundation insulation.

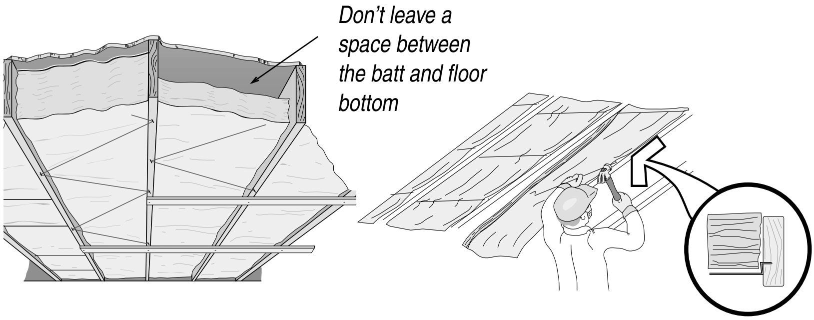
With either floor insulation or foundation insulation, install a ground air/moisture barrier.

Any ducts from exhaust fans that terminate in crawl spaces must be extended to the outside. New exhaust ducts must be galvanized metal or rigid PVC.

Floor insulation

All appropriate measures should be taken to establish an effective air barrier at the floor, to prevent air from passing through or around the insulation, prior to insulating the floor.

- ✓ Install minimum R19 insulation between floor joists.
- ✓ Insulation should be installed without voids, edge gaps, or end gaps.
- ✓ Insulation shall be fitted tightly around cross bracing and other obstructions.



Floor insulating with batts: *Use unfaced fiberglass batts, installed flush to the floor bottom, to insulate floors. The batt should fill the whole cavity if it is supported by lathe or plastic twine underneath. For batts that don't fill the whole cavity, use wire insulation supports.*

- ✓ Securely fasten batt insulation to framing with insulation hangers or other supporting material. Insulation must contact subfloor to prevent convecting air above the insulation from reducing its R-value.
- ✓ Faced insulation shall be installed with the foil or kraft facing placed up towards the floor sheathing.
- ✓ Ensure that floor insulation is in direct contact with rim joist. If balloon framed, air seal stud cavities prior to installing insulation.
- ✓ Insulation must not be installed over knob-and-tube wiring.
- ✓ If water pipes protrude below floor joist area, they should be insulated.

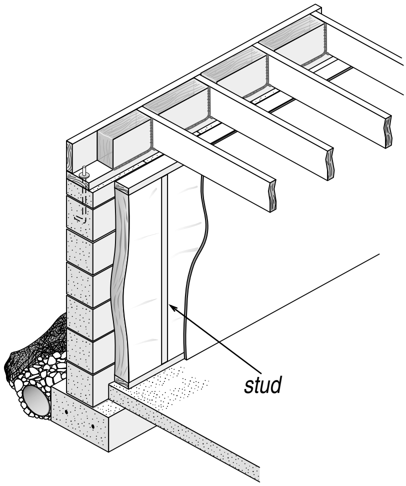
- ✓ If duct work protrudes below floor joist area, ducts are to be sealed and insulated.
- ✓ It is not necessary for open floor cavities to be completely filled with insulation as determined by the depth of the floor joist. Assure that no air space exists between insulation and subfloor. Closed cavities shall be completely filled with dense-pack insulation at 3.5 lbs./cu.ft.
- ✓ In crawl spaces, install a ground air-moisture barrier that runs up the foundation walls at least 6 inches.
- ✓ Consider eliminating foundation vents or making them operable (to be closed in winter).

3.2.7 Foundation insulation

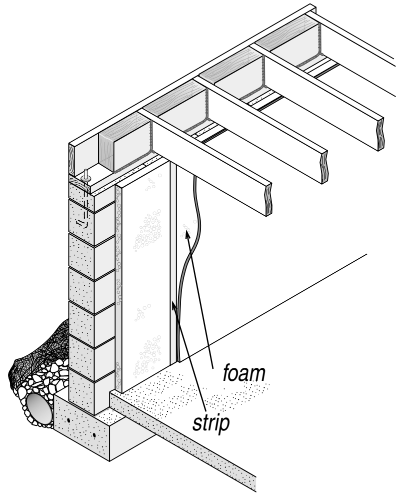
Extruded polystyrene insulation is the most appropriate insulation for flat concrete or concrete block walls. For rubble masonry walls, use 3-inch or 6-inch-thick, vinyl-faced, metal-building insulation.

- Foundation insulation should be minimum R10.
- Interior foundation insulation should be covered with a material that has an ASTM flame spread rating of 25 or less.
- Insulation should be attached to the entire inside wall surface with appropriate fasteners and/or adhesive.

- Install insulation with no significant voids or edge gaps.



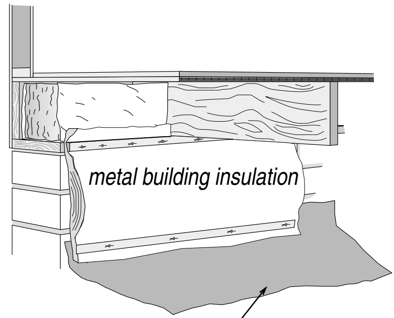
Batts and stud wall: *Insulating occupied basements with fiberglass batts requires building a stud wall. The rim joist must be sealed before it is insulated.*



2-inch foam board manufactured with plywood strips: *Insulates this basement. The strips facilitate fastening the foam to the wall and the drywall to the foam.*

- Metal-building insulation should be clamped to the sill plate by a wooden strip, nailed or screwed into the sill. The bottom of this batt insulation should be air-sealed to the wall with a strip of wood nailed into the foundation or by sealing the vinyl facing to the wall with caulk, or by any other effective method.

- If heating system is located in crawl space, precautions must be taken to assure that adequate combustion air is available.
- In crawl spaces, install a ground air-moisture barrier that runs up the foundation walls at least 6 inches. Outside access hatch shall be securely attached to foundation wall. Crawl space access hatch from conditioned space shall be insulated to R-value of foundation walls. A latch, sash lock, gate hook or other device should be installed to provide substantially airtight closure.



Fiberglass crawl-space insulation: *A vinyl-faced fiberglass blanket, called metal building insulation, can be used to insulate a crawl space. Every crawl space should have a ground moisture barrier.*

Ground moisture and air barriers

The ground is neither an air barrier nor a moisture barrier and can transport air-and-moisture into a crawl space from outdoors. Crawl-space moisture can lead to condensation, mold and rot. Air passing through the soil can also contain radon and pesticides. Covering the ground with an airtight moisture barrier establishes an air barrier and seals out moisture and soil gases.

Cover the ground completely with an air-moisture barrier such as 6 mil polyethylene without voids or gaps. Extend air-moisture barrier up foundation wall a minimum of 6 inches. Overlap air-moisture barrier at least 6 inches and seal with construction tape or acoustical sealant.

If the crawl space access is difficult or if the air barrier is at the floor, the polyethylene need not be sealed and is then referred to as a ground moisture barrier.

Crawl space ventilation

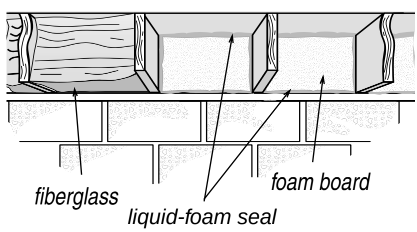
Crawl-space ventilation is generally not required if there are no signs of standing water, the crawl is dry, there is proper surface drainage and there is a properly installed ground air-moisture barrier.

If crawl space ventilation is required, install one square foot of net free ventilation area for every 1500 square feet of crawl space floor area. A minimum of two vents must be installed and should be located on opposite sides of the crawl space.

Rim insulation

Air-seal stud cavities in balloon framed homes before insulating rim. Air-seal other penetrations through rim before insulating. Polystyrene or polyurethane rigid-board insulation is preferred for insulating the rim-joist area. Fiberglass insulation is less effective than polystyrene or polyurethane. All joints in the rim-joist area should be sealed with caulk or foam before insulating with fiberglass batts.

- Insulate rim joist with 2 inches of polystyrene sealed on all sides with one part foam.
- Polystyrene insulation and the liquid-foam seal should create an airtight insulation block between floor joists, subfloor and mudsill.
- Longitudinal box sill cavities enclosed by a floor joist may be sealed and blown with wall insulation product unless moisture is present. In moist areas use rigid foam with a liquid-foam seal.



Fiberglass insulated: *Seal the joints with caulking first. Better, insulate the rim joist with foam board cut with adequate clearances to seal edges with liquid foam.*

3.3 WINDOWS AND DOORS

Windows and doors were once thought to be a major air-leakage problem. However, since the widespread use of blower doors and the realization that most homes have gaps in the air barrier large enough to put your hand through, window and door air-sealing has been de-emphasized.

Windows' energy efficiency is improved in two primary ways: increasing thermal resistance and reducing air leakage. The limiting factors to the application of window and door measures are cost and energy savings. In the past, window measures—especially storm windows and replacement windows—were over-emphasized.

Windows and doors remain very important building elements and their repair or replacement is often essential for a building's survival. Repairs that go beyond the cost-effective standards of the Weatherization Assistance Program should be limited to funds that are dedicated to repair work. All tasks relating to window and door repair should be accomplished using lead-safe weatherization methods. *See "Lead-safe weatherization" on page 5-12.*

Reference Information on Windows and Doors

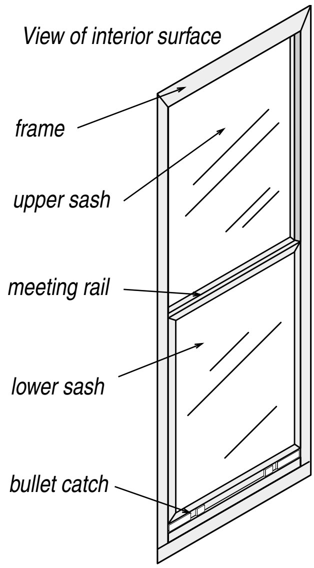
Reference Title	Chapter / Section
Residential Energy: Cost Savings and Comfort for Existing Buildings, by John Krigger; Third Edition	Chapter 5, Windows and Doors
Your Mobile Home: Energy and Repair Guide for Manufactured Housing, by John Krigger; Fourth Edition	Chapter 9, Doors and Windows

3.3.1 Exterior storm windows

Storm windows are only cost effective if purchased at the right price. If storm windows are to be installed, select metal exterior storm windows with the following qualities.

- Frame should have sturdy corners and not tend to rack out-of-square during transport and installation.

- The gasket sealing the glass should surround the glass's edge and not merely wedge the glass in place against the metal frame.
- Storm-window sashes must fit tightly in their frames.
- The window should be sized correctly and fit well in the opening.
- Storm windows shall be caulked around the frame at time of installation, except for weep holes that shall not be sealed. If weep holes are not manufactured into new storm window, weep holes shall be drilled into them.
- Storm-window sashes must be removable from indoors.
- New storm windows must not be used to replace existing storms if the existing storms are in good condition or can be repaired at a reasonable cost.
- Wood storm window inserts should fit neatly within window frame with the appropriate turn buttons, latches or closing hardware.
- Fixed storm windows must not restrict the existing capacity and access required for emergency exits.



Aluminum exterior storm windows: *Protect the primary window and add about an R-1 to the window assembly.*

3.3.2 Window repair and air-leakage reduction

With the exception of broken glass or missing panes, windows are rarely the major source of air leakage in a home. Window air-leakage measures are marginally cost-effective.

Window repair and weatherstripping should be accomplished using lead-safe weatherization practices. *See "Lead-safe weatherization" on page 5-12.*

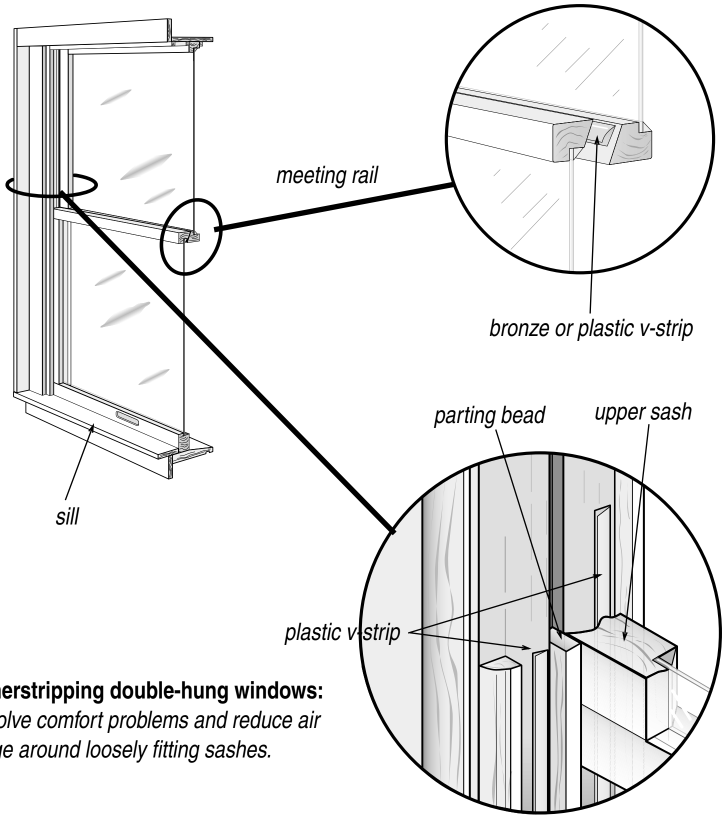
Repair measures may include the following measures:

- Replace missing or broken glass or glass that is cracked and noticeably separated that affects the structural integrity of the window. Use glazing compound and glazier points when replacing glass. Glass cracks that are not noticeably separated may be neglected.
- To prevent air leakage, condensation, and rain leakage, seal between window frame and other building materials on interior and exterior walls. Use sealants with rated adhesion and joint-movement characteristics appropriate for both the window frame and the building materials surrounding the window.
- Replace missing or severely deteriorated window frame components, such as, stops, jambs or sills. Wood exposed to the weather should be primed and painted.
- Re-glazing window sashes is best accomplished as part of a comprehensive window rehabilitation project. Re-glazing wood windows may not be a durable repair without scraping, priming, and painting.
- Window stops should be adjusted if large gaps exist between stop and jamb. Ensure that window operates smoothly following stop adjustment.
- Large gaps between sash and sill and sash and stops may be weatherstripped. Meeting rails may also be weatherstipped or planed. Window weatherstripping is typically not cost effective but may be installed to solve a comfort problem.
- Replace/repair missing or non-functional top and side sash locks, hinges or other hardware if such action will significantly reduce air leakage.

Avoid expensive or time-consuming window-repair measures, implemented to solve minor comfort complaints.

Weatherstripping double-hung windows

Wooden double-hung windows are fairly easy to weatherstrip. Window weatherstripping is mainly a comfort retrofit and a low



Weatherstripping double-hung windows: *Can solve comfort problems and reduce air leakage around loosely fitting sashes.*

weatherization priority. However, wooden double-hung windows are so common that some retrofitting tips follow.

Paint is the primary obstacle when weatherstripping double-hung windows. Often the upper sash has slipped down, and is locked in place by layers of paint, producing a leaking gap between the meeting rails of the upper and lower sashes. To make the meeting rails meet again, either break the paint seal and push the upper sash up, or cut the bottom of the lower sash off to bring it down. *See "Lead-safe weatherization" on page 5-12.*

To lift the upper sash, cut the paint around its inside and outside perimeter. Use leverage or a small hydraulic jack to lift the sash. Jack only at the corners of the sash. Lifting in the middle will likely break the window. Block, screw, or nail the repositioned upper sash in place.

To weatherstrip the window, you must remove the lower sash. Cut the paint where the window stop meets the jamb so the paint doesn't pop off in large flakes as you pry the stop off. Removing one stop is sufficient to remove the bottom sash.

Scrape excess paint from the sashes and the window sill. You may need to plane the sides so the window operates smoothly. Apply vinyl V-strip to the side jambs, and bronze V-strip to the meeting rail on the top sash. The point of the bronze V goes skyward. The weatherstrip is caulked on its back side and stapled in place, as shown in the illustration.

Window replacement

Window replacements are generally not cost-effective energy conservation measures. Replace windows only as emergency-repair measures when the window is missing, or damaged beyond repair, or found to be cost-effective.

Replacement windows should have a window unit U-value of 0.40 or less as rated by the National Fenestration Rating Council (NFRC) or approved equal.

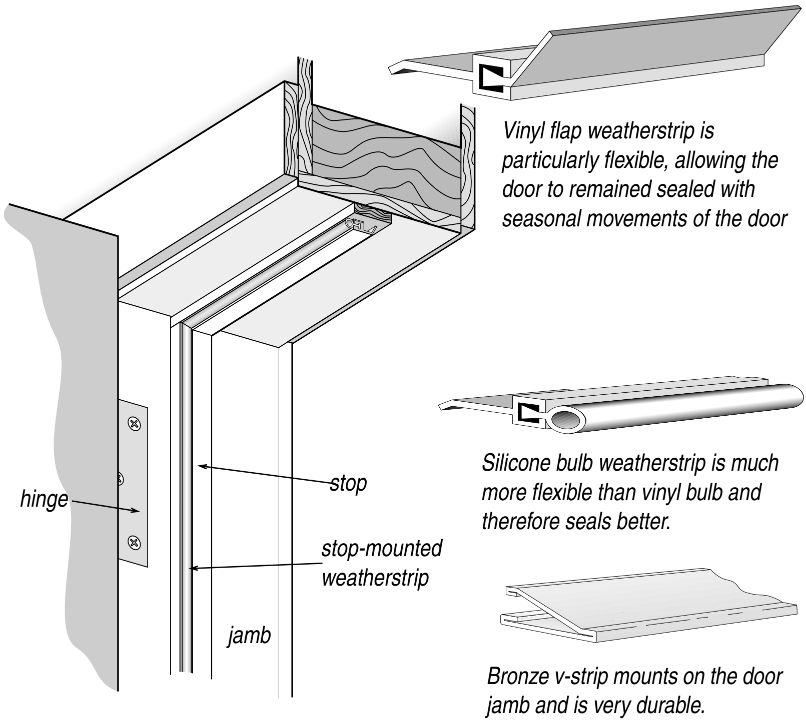
3.3.3 Door measures

Door measures are usually not cost-effective unless they have a very low cost. Doors have a small surface area and their air leakage is more of a localized comfort problem than a significant energy problem most of the time. However, door operation affects building security and durability, so doors are often an important repair priority.

Door weatherstrip, thresholds and sweeps

Door weatherstrip, thresholds and sweeps are marginally cost effective. These measures may be addressed if they are found to be cost effective.

Before installing weatherstripping, remove old weatherstrip. Tighten door hardware and adjust stops so door closes snugly against its stops.



Weatherstripping doors: *Weatherstripping doors is mainly a comfort retrofit. The door should be repaired before weatherstripping by tightening hinges and latches. The door stop should fit tightly against the door when it is closed.*

Use a durable stop-mounted or jamb-mounted weatherstrip material to weatherstrip the door. New weatherstrip must form a tight seal (no buckling or gaps) when installed. Door should close without rubbing or binding on the stops and jambs, especially in homes that may have lead paint. Doors that rub and crush paint on their jambs create lead dust. *See "Lead-safe weatherization" on page 5-12.*

Thresholds and door sweeps are installed to prevent air leakage and should not bind the door. Thresholds should be caulked at the sill and jamb junction.

Door replacement

Door replacements are rarely cost-effective energy conservation measures. Replace a door as an emergency-repair, when the door is damaged beyond repair. Tight uninsulated doors in good condition should not be replaced.

Observe the following standards when replacing exterior doors.

- All replacement doors must have a solid wood core or an exterior-grade foam core. Replace the door using a solid-core or insulated door-blank or a pre-hung steel insulated door. Replacing an exterior panel door with another panel door is not allowed. All replacement doors must have three hinges.
- Replacement door should not have glass panes. If homeowner is persistent, install smallest glass pane as possible or a door viewer.

Door repair

Door repair items improve home security and building durability.

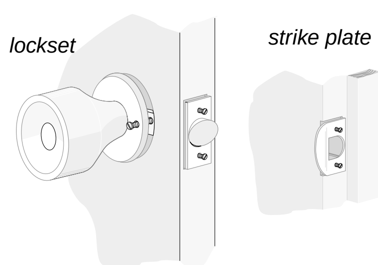
✓ Replace missing or inoperable lock sets.

✓ Reposition the lock set/ strike plate.

✓ Install a modernization kit so that the door can be held in a tightly closed position.

✓ Reposition stops if necessary.

✓ Seal gaps between the stop and jamb with caulk.



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

Storm doors

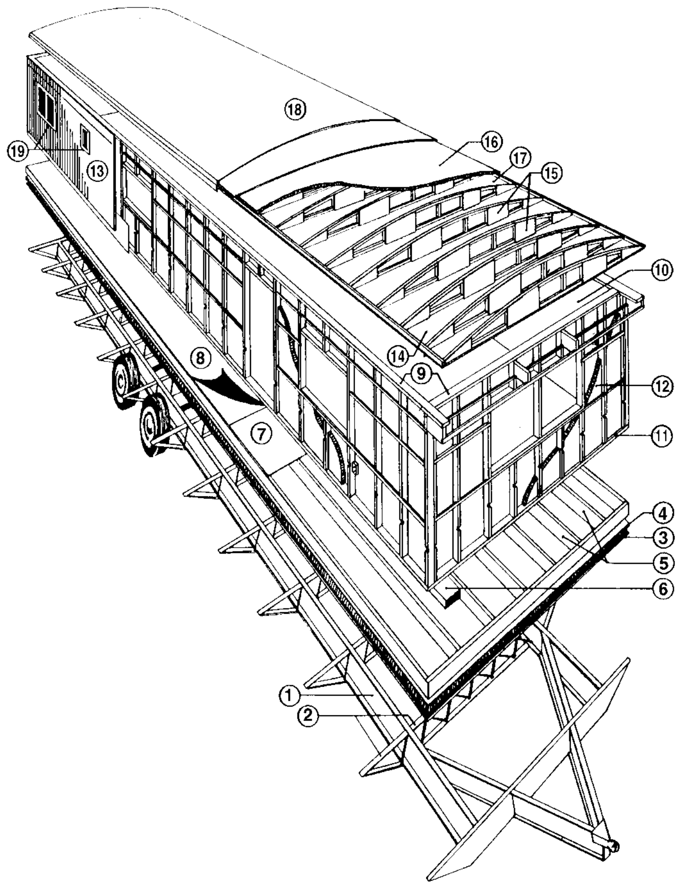
Storm doors are expensive per square foot of area and most weatherization programs don’t install them because all of the common measures described here are considerably more cost-effective. Storm doors can damage steel insulated doors by causing them to overheat.

4.0 MOBILE HOME STANDARDS

Mobile homes typically use more energy per square foot than conventional homes. Mobile homes are more similar to each other than conventional homes, making energy-waste reduction more predictable and straightforward. Insulation saves the most energy because the mobile home's thermal resistance is its weakest characteristic. Reducing air leakage by sealing shell air leaks and duct air leaks presents good opportunities for energy savings too.

Reference Information on Mobile Homes

Reference Title	Chapter / Section
Your Mobile Home: Energy and Repair Guide for Manufactured Housing, by John Krigger; Fourth Edition	Chapters 5 through 11 cover air leakage, insulation, and heating.



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.*

4.1 MOBILE HOME HEATING

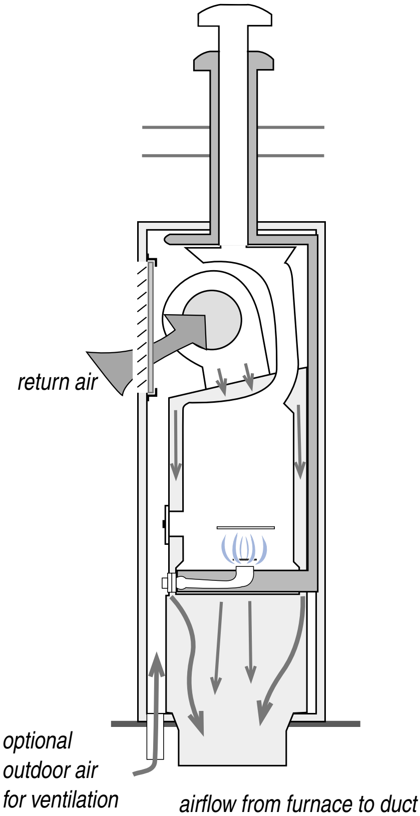
Mobile home furnaces are similar to furnaces for site-built homes in some ways and different in others. Gas furnaces are either the old atmospheric sealed-combustion type or the newer fan-assisted mid-efficiency furnaces (also sealed-combustion). Some older less-efficient furnaces had draft fans too.

Mobile-home oil furnaces are a close relative to oil furnaces in site-built homes. However, they should have a housing that fits around the burner air shutter and provides outdoor air to the burner. *See "Oil-burner safety and efficiency" on page 1-33 and "Direct combustion air supply to oil-fired heaters" on page 1-21.*

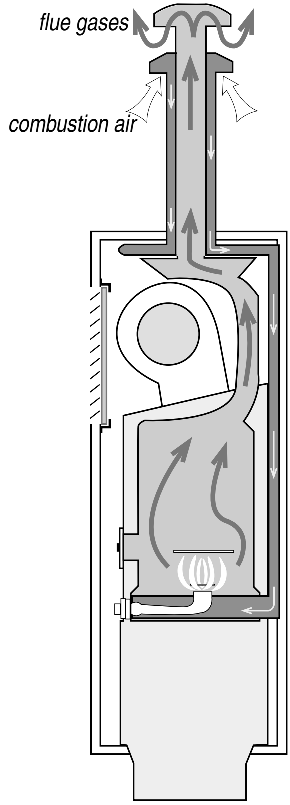
Mobile-home furnaces are different from conventional furnaces in the following ways.

- A great majority of mobile homes are equipped with downflow furnaces, designed specifically for mobile homes.
- Mobile home combustion furnaces are sealed-combustion units that use outdoor combustion air, unlike most furnaces in site-built homes.
- Gas-fired furnaces have kits attached, containing alternative orifices, to burn either propane or gas.
- Return air admitted to the furnace through a large opening in the furnace rather than return ducts.

Important Note: Only furnaces designed for mobile homes should be installed in mobile homes.



Mobile home furnace airflow: *Return air flows from the hallway through the furnace grill. The air is heated and distributed through the ducts.*



Mobile home furnace combustion: *Combustion air enters through the flue assembly on the roof and feeds the flame through a sealed passageway.*

4.1.1 Furnace maintenance and energy efficiency

Mobile home furnaces should comply with this guidebook's combustion safety and efficiency standards. *See "Gas burner safety and efficiency testing" on page 1-29 and "Oil-burner safety and efficiency" on page 1-33.*

4.1.2 Furnace replacement

Mobile home furnaces must be replaced by furnaces designed and listed for use in mobile homes. Mobile home furnaces may be replaced when any of the following is observed.

- The furnace has a cracked heat exchanger.
- Repair and retrofit exceed half of the replacement cost.
- The furnace is not operating and not repairable.

Mobile home furnaces require an outdoor source of combustion air. Mobile home furnaces have either a manufactured chimney that includes a passageway for combustion air or a combustion-air chute connecting the burner with the crawl space.

✓ When replacing mobile home furnaces, note the differences between old furnace and new in the way each supplies itself with combustion air.

✓ Install a new furnace base unless you are sure that the existing base exactly matches the new furnace.

✓ Install a new chimney that is manufactured specifically for the new furnace.

If a heat exchanger is available to replace the existing cracked heat exchanger, consider heat-exchanger replacement as a repair priority instead of replacing the furnace.

Follow manufacturer's installation instructions exactly. *See "Mobile-home furnace venting" on page 1-14.*

4.2 MOBILE HOME AIR SEALING

The locations and relative importance of air-leakage sites was a mystery before blower doors. Some homes are fairly airtight and some are incredibly leaky. It's recommended that a blower door be used to establish Building Tightness Limits and to guide air sealing work in mobile homes.

4.2.1 Air-leakage locations

The following locations have been identified by technicians using blower doors as the most serious energy problems. Window and door air leakage is more of a comfort problem than a serious energy problem.

- Plumbing penetrations in floors, walls, and ceilings. Water-heater closets with exterior doors are particularly serious air-leakage problems, having large openings into the bathroom and other areas.
- Torn or missing underbelly, exposing flaws in the floor to the ventilated crawl space.

Table 4-1: *Air Leak Locations and Typical CFM_{50} Reductions*

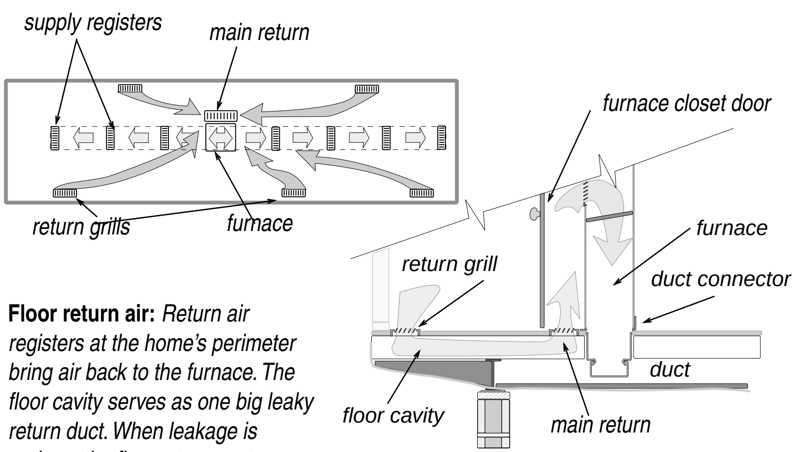
Air Sealing Procedure	Typical CFM_{50} Reduction
Caulking and weatherstripping	50–150
Installing tight interior storm windows	100–250
Sealing leaky supply ducts	100–500
Sealing leaky water-heater closet	200–600
Sealing floor as return-air plenum	300–900
Patching large air leaks in the floor, walls and ceiling	200–900

- Gaps around the electrical service panel box, light fixtures, fans, and flue pipes.
- Joints between the halves of double-wide mobile homes and between the main dwelling and additions.

4.2.2 Duct-leak locations

The following locations have been identified by technicians using blower doors and duct testers as the most serious energy problems.

- Floor and ceiling cavities used as return-air plenums. These return systems should be eliminated in favor of return-air through the hall or a large grill in the furnace-closet door.

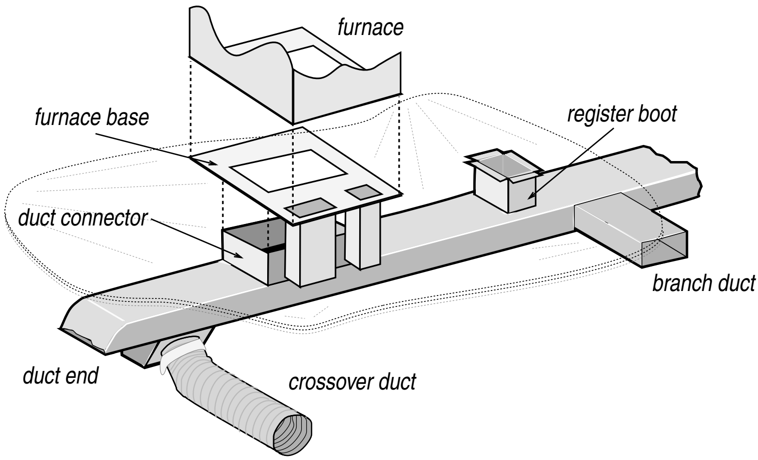


Floor return air: *Return air registers at the home's perimeter bring air back to the furnace. The floor cavity serves as one big leaky return duct. When leakage is serious, the floor return system should be eliminated.*

Note: When eliminating return air in the floor, take steps to remove restrictions to return airflow. For example, cut off interior doors or install grills in doors or walls.

- The joint between the furnace and the main duct. The main duct may need to be cut open from underneath to access and seal these leaks between the furnace, duct connector and main duct.

- Joints between the main duct and the short duct sections joining the main duct to the floor register.
- Joints between duct boots and floor.
- The end of the duct trunk is often very leaky.
- Disconnected, damaged or poorly joined crossover duct.



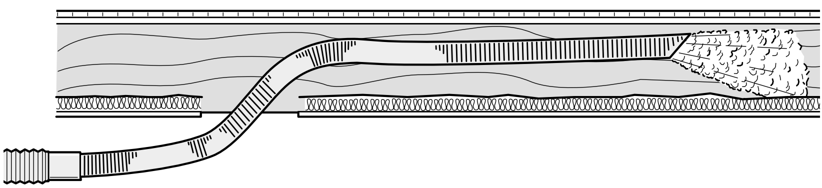
Mobile home ducts: *Mobile home ducts leak at their ends and wherever a joint occurs—especially at the joints beneath the furnace. The furnace base marries the furnace to the duct connector. Leaks occur where the duct connector meets the main duct and where it meets the furnace. Branch ducts are rare but easy to find because their supply register isn't in line with the others. Crossover ducts are found only in double-wide and triple-wide homes (A multi-section home has a single furnace, however each section has its own main duct. These main ducts are connected by the crossover duct.)*

4.3 MOBILE HOME INSULATION

Over the past 15 years, effective methods for insulating mobile homes have been developed by weatherization agencies. If your contractor or crew is trained in these methods, utilize the following standards for floor, wall and ceiling insulation. Remove all significant moisture problems before insulating. *See "Moisture problems" on page 5-5.*

4.3.1 Mobile home floor insulation

Mobile home floor insulation is a beneficial measure for cool climates. Existing insulation is fastened to the bottom of the floor joists, leaving the cavity uninsulated and subject to convection currents.



Blowing bellies: *A flexible fill tube, attached to the blower hose, blows fiberglass insulation through a hole in the belly from underneath the home.*

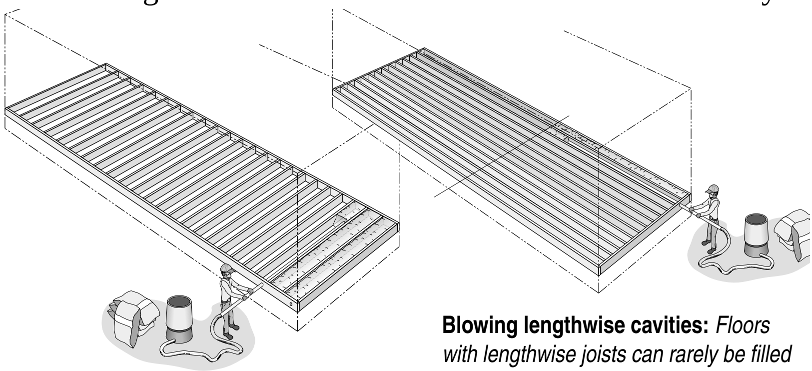
Preparing for mobile home floor insulation

Seal air leaks and ensure that all moisture problems are solved before insulating.

1. Tightly seal all holes in the floor.
2. Inspect the ducts and seal all significant holes in the ducts.
3. Install a ground moisture barrier in the crawl space.

Insulating the floor

Two methods of insulating mobile home floors are common. The first is drilling through the 2-by-6 rim joist and blowing through a rigid fill tube. The second is blowing fiberglass insulation through a flexible fill tube from holes in the underbelly.



Blowing crosswise cavities: *Blowing insulation into belly is easy if the floor joists run crosswise. However, the dropped belly requires more insulation than a home with lengthwise joists.*

Blowing lengthwise cavities: *Floors with lengthwise joists can rarely be filled completely from the ends because of the long tubing needed. The middle can be filled from underneath.*

Unfaced fiberglass batts may also be used to insulate floor sections where the insulation and belly are missing. The insulation may be supported by lathe, twine or insulation supports. *See "Floor insulation and foundation insulation" on page 3-23.*

4.3.2 Mobile home wall insulation

Mobile home walls are usually partially insulated. It is common for the existing insulation to fill only half of the cavity's thickness and to be poorly installed. Access to mobile home walls is from the bottom of the metal siding. Use fiberglass batts or fiberglass blowing wool. (Cellulose is not appropriate because it creates too much pressure blowing into the fragile wall cavities. Also, cellulose can absorb a lot of moisture in mobile home wall cavities with their exterior vapor barrier of metal siding.)

- ✓ Inspect interior paneling, making sure panels are well-fastened and sound.
- ✓ For vertically ribbed siding, remove the bottom row of screws for blowing and the bottom two rows for stuffing.

✓ With a short sheet-metal screw, fasten the vertical siding together at joints so that the difficult-to-refasten joint doesn't separate.

These two steps complete, a technician may insert a fill-tube or a batt-stuffer with a batt.

Note: Wall areas above windows and doors are difficult to access and may not be worth insulating.

Blowing mobile home walls

Additional insulation is blown between existing insulation and interior paneling. Make sure that interior paneling is sound.

✓ Insert tube with tip sliding against interior paneling.

✓ Avoid bulging the flexible exterior metal siding.

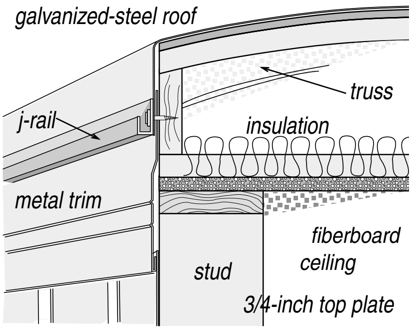
✓ To prevent over-filling the loosened wall cavity bottom, stop blowing and stuff an unfaced batt in the bottom of the cavity.

Batt-stuffing mobile home walls

A batt stuffer is made of quarter-inch clear acrylic or polycarbonate plastic, 13 inches wide and 96 inches long. It is a fast and effective tool for installing insulation in many mobile homes. This method works on about 50% of metal-sided mobile homes. It is faster than blowing the wall but blowing works on more sizes of wall cavities.

1. On the ground, lay a piece of plastic sheeting, measuring approximately the same size as the unfaced batt and the stuffer.
2. Lay the unfaced batt on the plastic and then lay the batt-stuffer on the batt.
3. Wrap 6 inches of the batt and plastic over the batt stuffer. This wrap keeps the batt on the stuffer as they move up the wall.
4. Stuff the batt up into the wall with the plastic sliding against the interior paneling.

4.3.3 Blowing mobile home roof cavities



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

Blowing a closed mobile home roof cavity is similar to blowing a closed wall cavity, only the insulation doesn't have to be as dense. Fiberglass blowing wool is used since cellulose is too heavy and it absorbs water too readily for use around a mobile home's lightweight sheeting materials. There are two common and effective methods for blowing mobile home roof cavities. The first is cutting a square hole in the metal roof and blowing fiberglass through a flexible fill-tube. The second is disconnecting the metal roof at its edge and blowing fiberglass through a rigid fill-tube.

Preparing to blow a mobile home roof

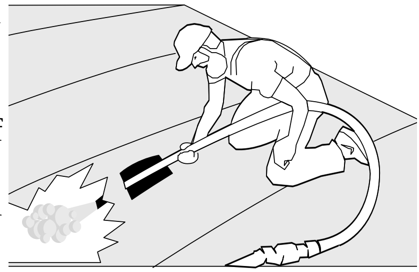
- ✓ Inspect the ceiling and seal all penetrations.
- ✓ Reinforce weak areas in the ceiling.
- ✓ Take steps to maintain safe clearances between insulation and recessed light fixtures and ceiling fans.
- ✓ Assemble patching materials such as metal patches, roof cement, sheet-metal screws, putty tape, and roof coating.

Blowing through the top

This procedure involves drilling large square holes that provide access to two complete truss cavities. If the roof contains a strongback running the length of the roof, the holes should be centered over the strongback, which is usually near the center of the roof's width.

1. Cut 10-inch square holes at the roof's apex on top of every second truss. Each square hole allows access to two truss cavities.

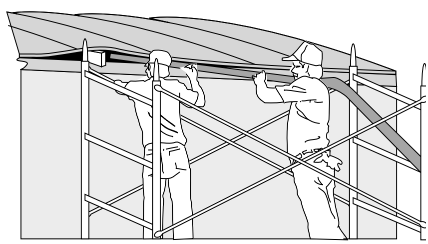
2. Use a 2-inch or 2-$^1/_2$-inch diameter fill-tube. Insert the fill-tube and push it forcefully out toward the edge of the cavity.
3. Blow fiberglass insulation into each cavity.
4. Stuff the area under each square hole with a piece of unfaced fiberglass batt so that the finished patch will stand a little higher than the surrounding roof.
5. Patch the hole with a 14-inch-square piece of stiff galvanized steel, sealed with roof cement and screwed into the existing metal roof.
6. Cover the patch with a second 18-inch-square patch made of a foil-faced butyl rubber.



Roof-top insulation: *Blowing fiberglass insulation through the roof top is effective at achieving good coverage and density on almost any metal roof.*

Blowing a mobile home roof from the edge

This procedure requires scaffold to be performed safely and efficiently. Mobile home metal roofs are usually fastened only at the edge, where the roof joins the wall.



Roof-edge blowing: *Using a rigid fill tube to blow insulation through the roof edge avoids making holes in the roof itself. However, this process requires much care in refastening the roof edge.*

1. Remove the screws from the metal j-rail at the roof edge. Also remove staples or other fasteners. Also scrape off putty tape.
2. Pry the metal roof up far enough to insert a 2-inch-diameter, 10-to-14-foot-long rigid fill tube.
3. Blow insulation through the fill-tube into the cavity. Turn down the air on the blowing machine when the tube is a

couple feet from the roof edge, in order to avoid blowing insulation out through the opening in the roof edge. Or, stop blowing a foot or two from the edge, and stuff the last foot or two with unfaced fiberglass batts.

4. Fasten the roof edge back to the wall using a new metal j-rail, new putty tape, and larger screws.

Blowing a mobile home roof from indoors

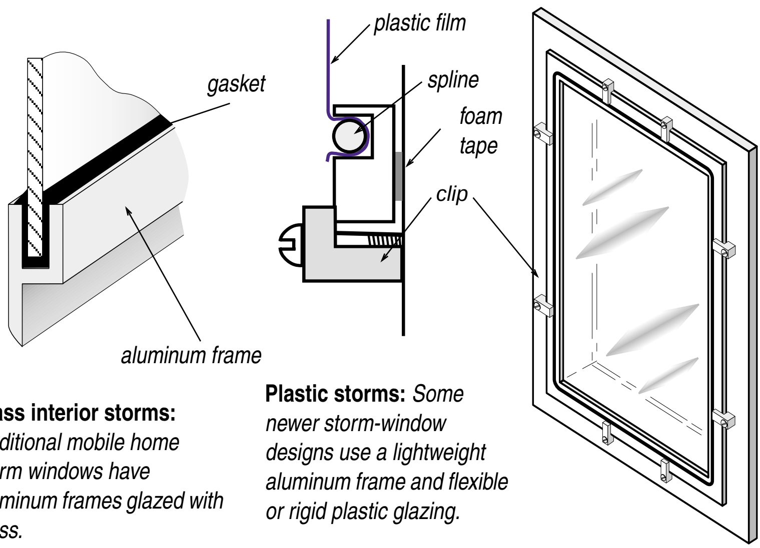
This procedure requires the drilling of straight rows of 3-inch or 4-inch holes and blowing insulation into the roof cavity through a fill tube.

1. Drill a 3-inch or 4-inch hole in an unseen location to discover whether the roof structure contains a strongback that would prevent blowing the roof cavity from a single row of holes.
2. Devise a way to drill a straight row of holes down the center of the ceiling. If a strongback exists, drill two rows of holes at the quarter points of the width of the ceiling.
3. Insert a flexible plastic fill tube into the cavity and push it as far as possible toward the edge of the roof.
4. Fill the cavity with tightly packed fiberglass insulation.

4.4 MOBILE HOME WINDOWS AND DOORS

Replacing windows and doors is generally not cost-effective and should only be done if repairs cannot hold together any longer. New jalousie or awning type windows are not acceptable as replacements. Replacement windows with an emergency release are available and one should be considered for bedrooms when replacing windows.

4.4.1 Mobile home storm windows



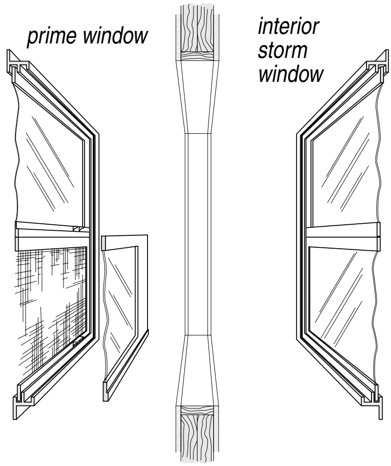
Glass interior storms: *Traditional mobile home storm windows have aluminum frames glazed with glass.*

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

Interior storm windows are common in mobile homes. Interior storms serve awning and jalousie windows and pair with exterior sliding prime windows.

- Interior storm windows double the R-value of a single-pane window and they reduce infiltration, especially in the case of leaky jalousie prime windows.
- Avoid replacing of existing storm windows unless the existing storm windows cannot be re-glazed or repaired.

- With sliding primary windows, use a sliding storm window that slides from the same side as the primary window. Sliding storm windows stay in place and aren't removed seasonally. They are therefore are less likely to be lost or broken.



Mobile-home double window: *In mobile homes, the prime window is installed over the siding outdoors and the storm window is installed indoors.*

4.4.2 Replacing mobile home windows

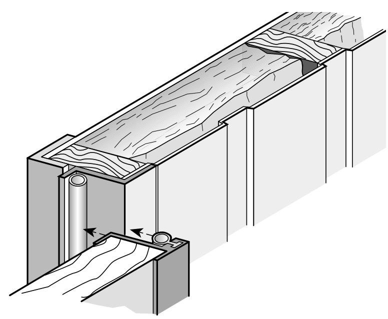
Inspect condition of rough opening members before replacing windows. Replace deteriorated, weak or waterlogged framing members.

Prepare replacement window by lining the perimeter of the inner lip with $^{1}/_{8}$-inch thick putty tape. Caulk exterior window frame perimeter to wall after installing window.

4.4.3 Mobile home doors

Mobile-home doors come in two basic types: the mobile-home door and the house-type door. Mobile home doors swing outwardly, and house-type doors swing inwardly.

Door replacement is an allowable expense only when the existing door is damaged beyond repair and constitutes a severe air-leakage problem.



Mobile home door: *Mobile home doors swing outwardly and have integral weatherstrip.*

4.4.4 Mobile home skirting

Installation and repair of mobile home skirting is seldom cost-effective as a weatherization measure. Skirting must usually be vented so there isn't much sense in insulating it. Insulation and air barrier are at the floor, so skirting is outside the thermal boundary.

5.0 HEALTH AND SAFETY INFORMATION

This chapter's purpose is to explain some of the most pressing hazards that your clients face in their homes and that you face at work as a weatherization specialist. Where this chapter strays from purely weatherization topics, the purpose is to provide balance and context.

Workers face a greater risk of injury at home than at work because they spend more time at home. Home is second only to the automobile as a dangerous place to be: household accidents kill 24,000 Americans and injure 3,500,000 each year. Families—especially children—may be at a greater risk because they spend more time at home or are unaware of danger. The three major cause of free-time injuries in order are:

1. Falls
2. Poisoning by solids and liquids
3. Smoke inhalation and burns from fires

Other common health hazards, related to weatherization, found in homes include.

1. Carbon monoxide
2. Lead-based-paint dust

When a weatherization agency finds a serious safety problem in a customer's home, the agency should inform the customer in writing about the hazards.

Reference Information on Health and Safety

Reference Title	Chapter / Section
Residential Energy: Cost Savings and Comfort for Existing Buildings, by John Krigger; Third Edition	Chapter 10, Avoiding Hazards
Your Mobile Home: Energy and Repair Guide for Manufactured Housing, by John Krigger; Fourth Edition	Chapter 4, Healthy Homes

5.1 CLIENT HEALTH AND SAFETY

Moisture problems, carbon monoxide, and lead-paint dust are problems related to weatherization work. When these problems are detected, inform the customer verbally and in writing as appropriate. Mitigating these problems should be a top priority for any funds budgeted for repair.

1. Test heating systems and homes for carbon monoxide and solve problems causing CO.
2. Find, communicate, and solve moisture problems as part of weatherization. Never make moisture problems worse. *See "Moisture problems" on page 5-5.*
3. Practice lead-safe weatherization. See *"Lead-safe weatherization" on page 5-12*

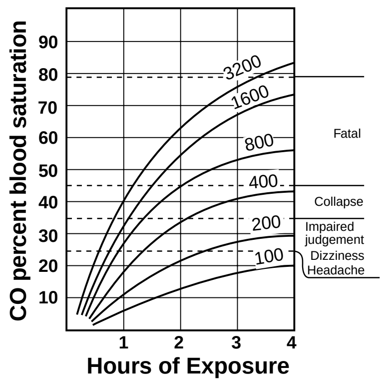
The following hazards aren't related to weatherization but are included here because they pose a great statistical danger to occupants. Encourage clients to prevent falls, poisoning, and fires by noticing obvious hazards and by practicing these 7 recommendations.

1. Pick up toys and obstacles that could cause slips and falls.
2. Install non-slip grip strips to bathtubs and showers and steps to prevent falls.
3. Make sure that sturdy step stools and ladders are handy where they may be needed for safe climbing.
4. Store poisons separately from medicines to prevent accidental poisoning.
5. Check smoke detectors regularly and make a fire escape plan for the family.
6. Repair or discard damaged pots and pans—having broken or insecure handles—for example.
7. Repair or replace faulty electrical cords and appliances.

5.1.1 Carbon monoxide

Carbon monoxide (CO) is released by combustion appliances, automobiles, and cigarettes as a product of incomplete combustion. CO is the largest cause of injury and death from gas poisoning, resulting in more than 500 deaths per year. Many more people are injured by high concentrations of the gas, or temporarily sickened by lower concentrations of 5-to-50 parts per million (ppm). The symptoms of low-level CO exposure are similar to the flu, and may go unnoticed.

CO blocks the oxygen-carrying capacity of the blood's hemoglobin, which carries vital oxygen to the tissues. At low concentrations (5-to-50 ppm), CO reduces nerve reaction time and causes mild drowsiness, nausea, and headaches. Higher concentrations (50-to-3000 ppm), lead to severe headaches, vomiting, and even death, if the high concentration persists. The effects of CO poisoning are usually reversible, except for exposure to very high levels, which causes brain damage.



Effects of CO Exposure: *CO is a major hazard, often encountered in homes.*

The EPA's suggested maximum 8-hour exposure is 9 ppm in room air. Room levels of CO at or above 9 ppm are usually associated with the use of malfunctioning combustion appliances within the living space, although proximity to parking and highways can also be related. Offending appliances include: unvented gas and kerosene space heaters; gas ranges; leaky wood stoves; and backdrafting, vented space heaters. Backdrafting furnaces and boilers may also lead to high levels of CO, but are less a problem because they aren't located in the living space. CO is a common problem in low-income housing, affecting 20 percent or more of residential buildings in some regions.

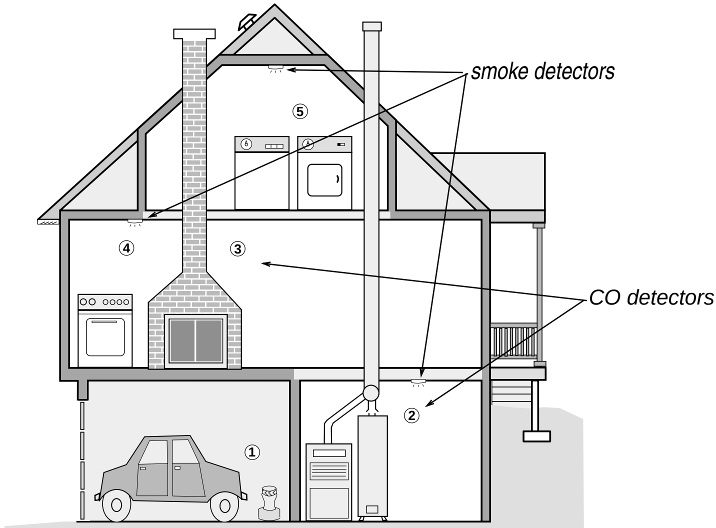
The most common CO-testing instruments are electronic sensors with a digital readouts in parts per million (ppm). Following manufacturers recommendations on zeroing the meter—usually by exposing the meter to clean air. CO testers usually need re-calibration every 6 months or so.

CO is normally tested near the flame or at the exhaust port of the heat exchanger. *See "Combustion safety and efficiency testing" on page 1-29.* CO is usually caused by one of the following:

- Flame interference by an object (a pan over a gas burner on a range top, for example) or moving air
- Flame interference from dirt and debris
- Misalignment of the burner
- Inadequate combustion air
- Backdrafting of combustion gases smothering the flame

CO and smoke detectors

All homes should have smoke detectors, one near combustion zone and one near the bedrooms. CO detectors are appropriate whenever the CO hazard is judged a likely occurrance.

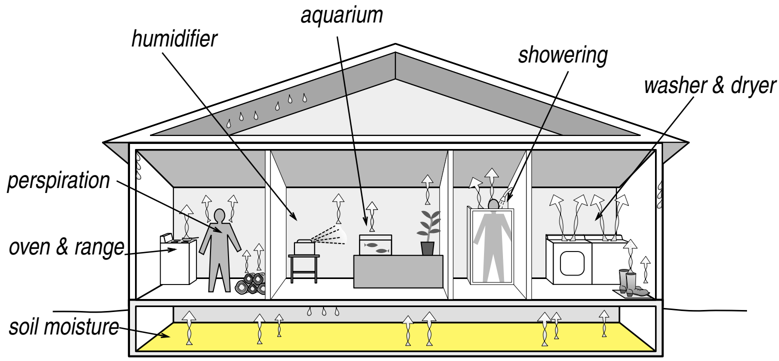


1. *The garage can contribute CO from car exhaust and space heaters. The garage is often a storage area for chemicals that may also affect air quality.*
2. *The mechanical room can contribute CO from backdrafting combustion appliances.*
3. *Fireplaces can backdraft CO and smoke.*
4. *Gas ranges and ovens can contribute large quantities of CO and moisture.*
5. *Gas dryers contribute combustion gases and moisture unless vented outdoors.*

Possible locations of smoke detectors and CO detectors: *CO can originate from a variety of sources around the home.*

5.1.2 Moisture problems

Moisture causes billions of dollars in property damage and high energy bills each year in American homes. Water damages building materials by dissolving glues and mortar, corroding metal, and nurturing pests, like mildew and dust mites. These pests, in turn, are the cause of millions of cases of respiratory distress annually. Water also reduces the thermal resistance of insulation and other building materials.



Moisture sources: *Moisture sources abound in many homes.*

The most prolific sources of moisture are leaky roofs and damp foundations. Other critical moisture sources include dryers venting indoors, unvented gas appliances like ranges or decorative fireplaces, showers and cooking appliances. Climate is also a major contributor to moisture problems. The more rain, extreme temperatures and humid weather a region has, the more its homes are threatened by moisture problems.

Reducing sources of moisture is the first priority for solving moisture problems. Next most important are air and vapor barriers to prevent water-vapor migrating through building cavities. Relatively airtight homes may need ventilation to remove accumulating water vapor. Adding insulation or installing storm windows helps eliminate cold areas where water vapor condenses.

Symptoms of moisture problems

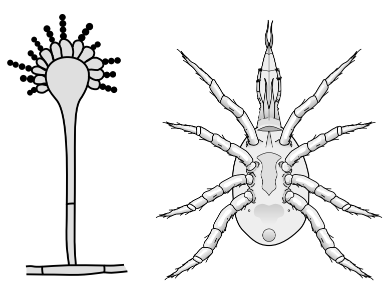
Condensation on windows, walls and other surfaces signals high relative humidity and the need to find and reduce moisture sources. During very cold weather or during rapid weather changes, condensation may inevitably occur, and this occasional condensation isn't a major problem. However, if window condensation is a persistent problem, reduce moisture sources,

Table 5-1: *The Most Potent Household Moisture Sources*

Moisture Source	Potential Amount Pounds or Pints
Ground moisture	0–3 per day
Unvented combustion space heater	0.3 per gal. propane
Seasonal evaporation from materials	0.25–0.70 per day
Dryers venting indoors	0.20–0.25 per load
Dishwashing	0.04 per meal
Cooking (meal for four)	0.015–0.020 per meal
Showering	0.02 per 5 min.

install storm windows, or consider other remedies. The colder the outdoor temperature, the more likely window condensation is to occur.

Moisture moves into a building during wet seasons and out during drier seasons. Moisture becomes a problem when the moisture content of building materials reaches a threshold where pests like termites, dust mites, rot, and fungus can thrive. Asthma, bronchitis and other respiratory ailments should be considered a possible symptom of moisture problems because mold, mildew, and dust mites are often the cause.



Fungus and dust mites: *Biological pests create dust known as bioaerosols that give many people allergies and asthma.*

Rot and wood decay indicate advanced moisture damage. Unlike surface mold and mildew, wood decay fungi penetrate, soften, and weaken wood when the wood remains wet.

Peeling, blistering or cracking paint may indicate that moisture, moving through a wall, is damaging the paint and possibly the building materials underneath.

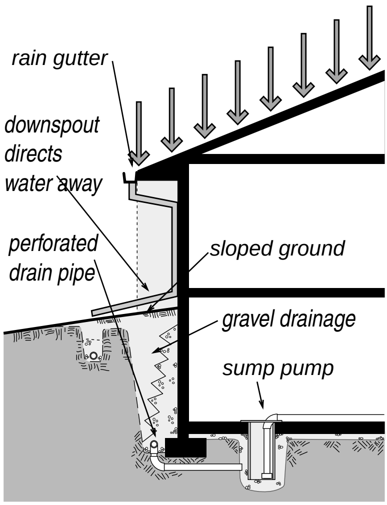
Corrosion, oxidation and rust on metal are unmistakable signs that moisture is at work. Deformed wooden surfaces may result as damp wood swells and then warps and cracks as it dries.

Concrete and masonry efflorescence is a white, powdery deposit left by water moving through a masonry wall and leaving minerals from mortar or the soil behind when it evaporates.

Solutions to moisture problems

Water moves easily as a liquid or vapor from the ground through porous building materials like concrete and wood. A high ground-water table can channel moisture into a basement or crawl space faster than anything short of a big roof leak. The most common ground-moisture problem is water vapor rising through the soil or liquid water moving by capillary action. To prevent this, all crawl spaces and dirt-floor basements should have ground moisture barriers. A ground moisture barrier is simply a piece of heavy plastic sheeting laid on the ground. Black or clear heavy plastic film is sold at hardware dealers on a roll. A more expensive plastic film with reinforcing fiber is appropriate for crawl spaces and dirt basements where the plastic may be crawled or walked on.

Serious ground-water problems may require excavating and installing drain pipe and gravel to disperse accumulations of groundwater—between the home and a nearby hillside, for example. A sump pump is the most common moisture eradicator, when ground water continually seeps into a basement or crawlspace and collects there as standing water. When building a new home on wet ground, use an engineered flood-resistant foundation.



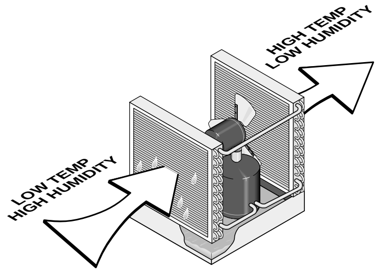
Stopping water leakage: *Choose from a variety of measures to protect homes from water leakage.*

Rainwater flowing from roofs often plays a major role in dampening foundations. Install rain gutters with downspouts and drain roof water into dry wells in rainy climates. Watering lawns and plants close to the house can also dampen the foundation. Avoid excessive watering around the home's perimeter. In wet climates, it's important to keep shrubbery away from the foundation to allow drying winds to circulate near the foundation.

Preventing moisture problems is the best way to guarantee a building's durability, and its occupant's respiratory health. Besides the all-important source-reduction strategies listed above, consider the following additional moisture solutions.

- Installing or improving air barriers and vapor barriers to prevent air leakage and vapor diffusion from transporting moisture into building cavities.
- Adding insulation to the walls, floor, and ceiling of a home to keep the indoor surfaces warmer and less prone to condensation. During cold weather, well-insulated homes can tolerate higher humidity, without causing condensation, than poorly insulated homes. *See "Installing insulation" on page 3-9 and "Windows and doors" on page 3-29.*
- Ventilating the home with drier outdoor air to dilute the more humid indoor air. Ventilation helps evaporate wetness and exhaust excess water vapor.

- Removing moisture from indoor air by cooling the air to below its dew point, with refrigerated air conditioning systems (summer) and dehumidifiers (winter).



Dehumidifiers: *In damp climates, dehumidifiers protect many homes from excessive moisture.*

Vapor barriers

Vapor barriers are most important for homes in cold climates or hot and humid ones, where the difference in humidity between cool, dry air and warm, moist air creates a very large vapor pressure. Vapor barriers should face toward the indoors in cold climates and toward the outdoors in hot, humid climates.

Vapor-barrier paints are often the only practical way to achieve a vapor barrier in an existing home. Almost any oil-based primer and many water-based primers act as vapor barriers.

In milder climates or climates with both hot and humid weather and cold, dry weather, it may be best not to install a vapor barrier but instead to allow building cavities to dry by purging their moisture toward either indoors or outdoors, whichever happens to be drier.

Mechanical ventilation

Ventilation is an important health and safety concern in fairly airtight homes. Fairly airtight homes have a blower-door-measured air leakage rate lower than the Building tightness limit discussed in *"Building tightness limits (BTL)" on page 2-8*. Ventilation is also important in homes with pollutant sources: smoking, new furniture, new carpet, etc. Homes with a natural air-change rate lower than the Building tightness limit should have mechanical ventilation systems, however many don't.

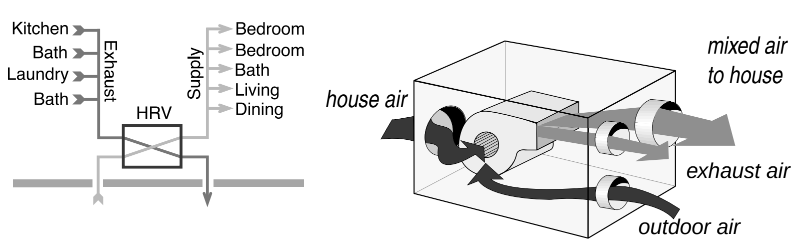
The choice comes down to ventilating the whole house or providing spot-ventilation in the kitchen and bathroom where most moisture and odors are generated. Ideally all kitchens and bathrooms should be equipped with exhaust fans. Kitchen fans should always be vented to outdoors and not just recirculate air through a filter. Bathroom exhaust fans should always vent outdoors, never into crawl spaces or attics.

Exhaust fans should have tight-sealing backdraft dampers. Backdraft dampers are located in the fan housing, in the vent duct, or in the termination fitting in the roof or wall.

A low noise level (rated in sones) is important in encouraging occupants to use fans. The sone rating varies from about 8 sones for the noisiest residential exhaust fans to about 1.5 sones for the quietest fans. The success of spot ventilation and whole-house ventilation depends on how much noise the fan makes. Occupants may decide not to use the fans or to disconnect automatic controls if the fans are too noisy.

Exhaust fans can also provide whole-house ventilation. Make-up air comes from outdoors through the homes air leaks. Manual switches, dehumidistats, and timers are used to control exhaust fans for whole-house ventilation. Exhaust fans typically run from 2 to 6 hours per day, when providing whole-house ventilation.

The best home-ventilation strategy for very airtight is balanced ventilation using a ventilator powered by one or two fans. Two types of balanced whole-house ventilators are appropriate: air-to-air heat exchangers and ventilators without energy recovery. The less expensive mixing-box type ventilator (no heat recovery) is the best choice to complement low-income weatherization. Air-to-air heat exchangers are generally too expensive.



Mixing-box ventilator: *This one-fan balanced ventilator is on of the cheapest ways to achieve balanced ventilation in a tight home. The installation can be fully ducted or can use the home's return plenum for distribution of mixed air.*

5.1.3 Lead-safe weatherization

All dust is dangerous but lead dust is particularly dangerous because lead is a poison. Children are more vulnerable than adults because of their greater hand-to-mouth behavior. Take all necessary steps, outlined here, to protect customers and their children from lead dust.

Lead-safe weatherization (LSW) is a group of safe practices, used by weatherization technicians when they know or suspect the presence of lead paint. LSW practices are little more than very careful dust-prevention and housekeeping precautions. Lead-safe weatherization is required when workers will disturb painted surfaces by cutting, scraping, drilling, or other dust-creating activities.

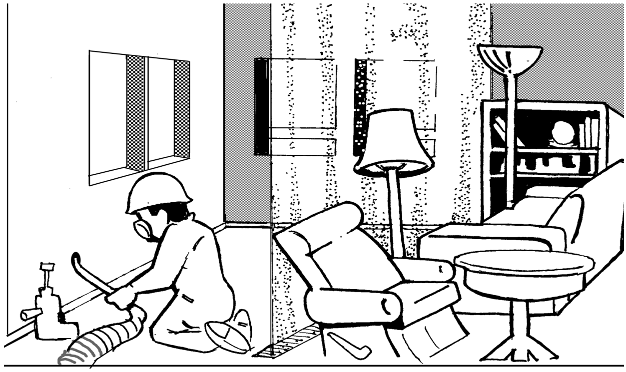
Technicians may either assume the presence of lead paint or else test to detect lead paint. Lead paint was commonly used in homes built before 1978, the year lead paint was outlawed. Weatherization activities that could disturb lead paint and create lead dust include the following.

- Glazing, weatherstripping, or replacing windows.
- Weatherstripping, repairing, or replacing doors.
- Drilling holes in the interior of the home for installing insulation.
- Removing trim or cutting through walls or ceilings to seal air leaks, install ducts, replace windows etc.

When engaging in these activities, take the following precautions.

1. Wear a tight-fitting respirator and coveralls to protect yourself from breathing dust or soiling your street clothes with dust.
2. Seal your work area within the home with tape and plastic. Cover furniture and carpet in the work area with tarps.
3. Spray water on the affected painted surfaces to keep dust down—out of the air.

Protective tarp: *Protect clients and their belongings with tarps when, drilling, scraping, cutting, or blowing insulation.*



4. Clean up as you work. Sweep carefully and wet mop all affected surfaces, daily. Avoid tracking dirt from the affected area to other parts of the house.
5. Keep children away from the work area.

5.2 Worker health and safety

Injuries are the fourth leading cause of death in the United States. Long-term exposure to toxic materials contributes to sickness, absenteeism, and death of workers.

The personal health and safety of each employee is vitally important. Preventing injuries on the job is weatherization's highest priority. Workplace standards established by the Occupational Safety and Health Administration (OSHA) as well as other standards established by the construction trade must be observed by weatherization staff and their contractors. Safety always has precedence over other factors affecting weatherization operations. The following hazards merit special attention of weatherization agencies and their contractors because of their statistical prominence.

Safety meetings: *Safety education and safety meetings are essential parts of a successful safety program.*

1. Driving
2. Falls
3. Back injuries
4. Hazardous materials
5. Electrical and tool hazards
6. Repetitive stress

5.2.1 Commitment to safety

Workers tend to become complacent about their health and safety if it is not continually stressed. Weatherization agencies must:

- Arrange regular health and safety training,
- Conduct regular safety meetings,
- Keep equipment in good condition, and
- Observe all state and federal standards relating to worker health and safety.

Safety requires communication and action. To protect themselves from injury and illness, workers are encouraged to recognize hazards, communicate with co-workers and supervisors, and take action to reduce or eliminate hazards.

5.2.2 New employees

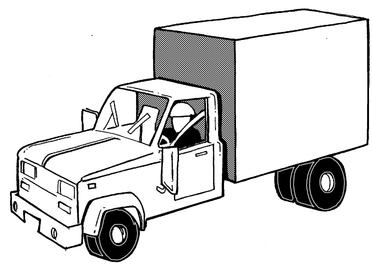
New hire: *New hires are several times more likely to be injured as experienced workers.*

New employees are several times more likely to injure themselves on the job compared to experienced workers. Before their first day on the job, new employees should learn about safety basics such as proper lifting, safe ladder usage, and safe operation of the power tools they will use on the job. New employees should be taught how to use safety equipment such as respirators, safety glasses, hearing protection, and gloves. They should also be instructed in proper dress for the job—short pants, sandals, and tank tops are usually not appropriate.

Supervisors must inform new employees about hazardous materials they may encounter on the job, and teach them to read the Material Safety Data Sheets (MSDS) required by OSHA for each material.

Alcohol and drugs should be banned from the job. Encourage staff and coworkers to refrain from smoking and to stay physically fit.

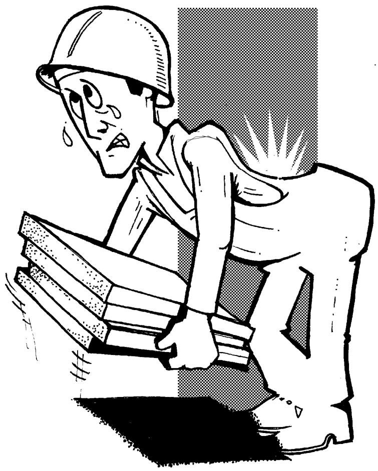
5.2.3 Driving



Safe vehicles: *Maintain vehicles in good repair. Drivers and passengers should always wear seat belts.*

According to the Bureau of Labor Statistics (BLS), one-third of all occupational fatalities in the United States occur in motor-vehicle accidents. Supervisors and workers should plan and organize their errands and commuting to the job site to minimize vehicular travel. Vehicles should be kept in good repair. Brakes, horns, steering gear, headlights, directional signals, backup lights, and backup signals (when present) will be regularly inspected and repaired if necessary. Workers should always wear seat belts, which should be kept in working order.

5.2.4 Lifting and back injuries



Awkward loads: *Ask for help when moving heavy or awkward loads.*

Back injuries account for one out of every five workplace injuries. Four out of five back injuries are to the lower back; three out of four are the result of improper lifting. Workers often injure their backs by lifting heavy or awkward loads improperly or without help.

Workers must be instructed in proper lifting techniques—lifting with their legs, keeping a straight back whenever possible. To avoid back injury, employees are encouraged: to get help before trying to lift heavy or awkward loads, to stay in good physical condition, and to control their weight through proper diet and exercise. Supervisors should identify workers with limited lifting abilities because of weakness or prior injury and instruct them to avoid heavy lifting.

Approaches for prevention also include:

1. Redesigning work activities: adapting equipment and minimizing awkward movement on the job site.
2. Administrative controls: strength-testing workers and setting lifting limits and providing training for all workers on the causes and prevention of back injuries.

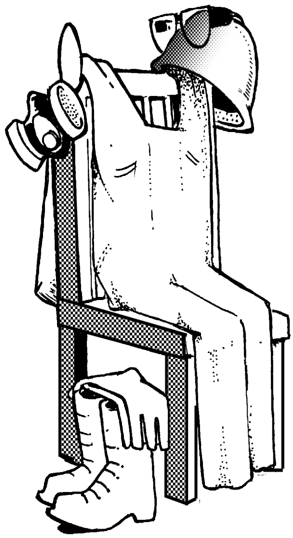
5.2.5 Respiratory health

Common household construction and insulation dust can be full of toxins including asbestos, fiberglass, metals, and chemicals. Weatherization work can stir up toxic dust, which may then be inhaled. Drilling, demolition, and sanding can also fill the air with toxic dust. Workers are also exposed to dust from the insulation they install. Dust that clings to clothes worn on the job travels home, where it may be inhaled by family members. Cigarette smokers have the greater risk for respiratory disease as the result of dust inhalation. Organic vapors are also a health risk when using paints, sealants, and cleaning solutions.

Workers should be instructed about the dangers of dust, gases, smoke, vapors, and oxygen-deficient environments. Employees are encouraged to wear a respirator when working in a dusty environment. Workers with beards, facial scars, and thick temple bars on eyeglasses must take special care to get a good seal when putting on a respirator. The seal can be tested by putting on the respirator, closing the exhalation valve, and exhaling gently. There should be no leakage of air around the face.

Workers are encouraged to wear coveralls when entering attics or crawl spaces and to launder them frequently. Workers should be taught how to recognize asbestos insulation that may be installed around older furnaces and boilers. The danger of carrying dust into their own home on their clothing should be stressed. Weatherization contractors and agency staff should be taught how to keep dust out of client's homes by erecting temporary barriers when they are doing work that may release toxic dust into a client's home.

5.2.6 Hazardous materials

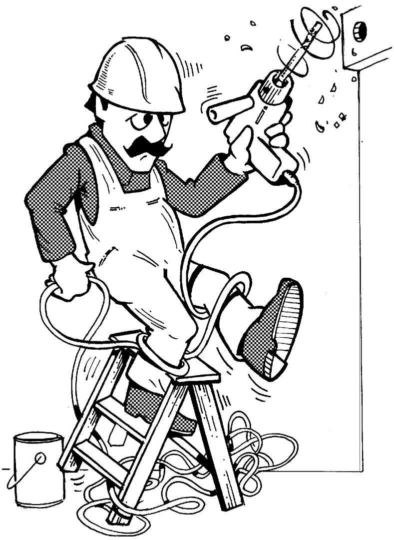


Personal protective equipment: *Employees should own and maintain protective equipment to protect themselves from hazardous materials.*

Workers' health and safety can be threatened by hazardous materials used on the job. Workers often fail to protect themselves from hazardous materials because they don't recognize them and understand their health effects. Breathing hazardous materials, absorbing them through the skin, and eye contact with hazardous materials are common ways workers are affected.

OSHA regulations say employers must notify and train employees about hazardous materials used on the job. OSHA requires that a Material Safety Data Sheet (MSDS) for every workplace hazardous material be readily available to employees. Copies of MSDSs are obtained from manufacturers or their distributors, and employees must have easy access to them. Employees must know where MSDSs are kept and how to interpret them. Employees must be instructed how to avoid exposure to hazardous materials used on the job and how to clean up chemical spills. Employees must be instructed on appropriate protective equipment. Employees must wear appropriate protective equipment recommended by the MSDS while working with any hazardous material.

5.2.7 Falls



Ladders: *Ladders are the most dangerous tools workers use.*

Falls off ladders and stairs cause 13% of workplace injuries according to the National Safety Council. Falls from the same elevation such as slips and trips account for approximately 7% of workplace injuries.

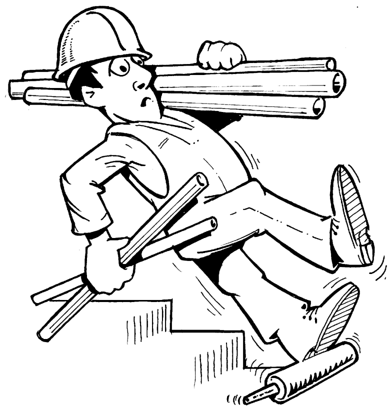
Broken ladders and ladders that slip because they haven't been anchored properly are both major causes of on-the-job falls. Worker carelessness and using the wrong ladder for a particular job is also a common cause of falls. Step ladders, for instance, are often used for work that is too far off the ground, forcing workers to stand on the top step or to reach too far.

OSHA regulations say extension ladders should extend at least three feet above the roof or landing they access and shouldn't have a pitch steeper than four feet of rise for each foot the base is away from the building. Any change in elevation greater than 19 inches must be served by a ladder or stairway.

Ladders must be blocked or tied firmly in place at the top and bottom when the above rule cannot be observed. Portable metal ladders should not be used where they may come in contact with electrical conductors. All ladders should be kept in good repair, and should be replaced if they have missing steps or cracked side-rails. Broken ladders should be removed from the equipment storage area.

Ladders must be maintained free of oil, grease, and other slipping hazards. They must not be loaded beyond the maximum intended load for which they were built. Workers should avoid carrying heavy loads up ladders and operating power tools from ladders.

Scaffolding must be used when working above-ground for sustained time periods. Scaffolds should be built plumb and level. Each leg should be stabilized so that it supports equal weight as other legs. This is especially important on unlevel ground. Planks should be secured to the structure and handrails provided on the sides and ends of the walkway.



Good housekeeping: *Good housekeeping is essential to protect workers and clients alike from falls.*

Workplaces should be policed regularly to remove slipping and tripping hazards. Workers carrying loads should establish a debris-free walkway.

5.2.8 Tool safety

The tools used in construction work are dangerous if used improperly. About 90,000 people hurt themselves with hand tools each year. One moment of inattention is all it takes to suffer an injury that will change a worker's life permanently.

Five basic safety rules can reduce hazards associate with the use of hand and power tools:

1. Keep all tools in good condition with regular maintenance.
2. Use the right tool for the job.
3. Inspect tools for damage before using them.
4. Operate according to the manufacturer's instructions.

5. Provide and use appropriate personal protective equipment.

Electrical safety: *Cords should be maintained in good condition. Special ground-fault-interrupter cords or outlets should be used in wet conditions.*

Index

C

D

E

F

G

H

I

K

L

M

N

O

P

R

S

T

V

W

Z