Southeast Weatherization Field Guide

Funded by the Department of Energy's
Weatherization Assistance Program

Weatherization Works

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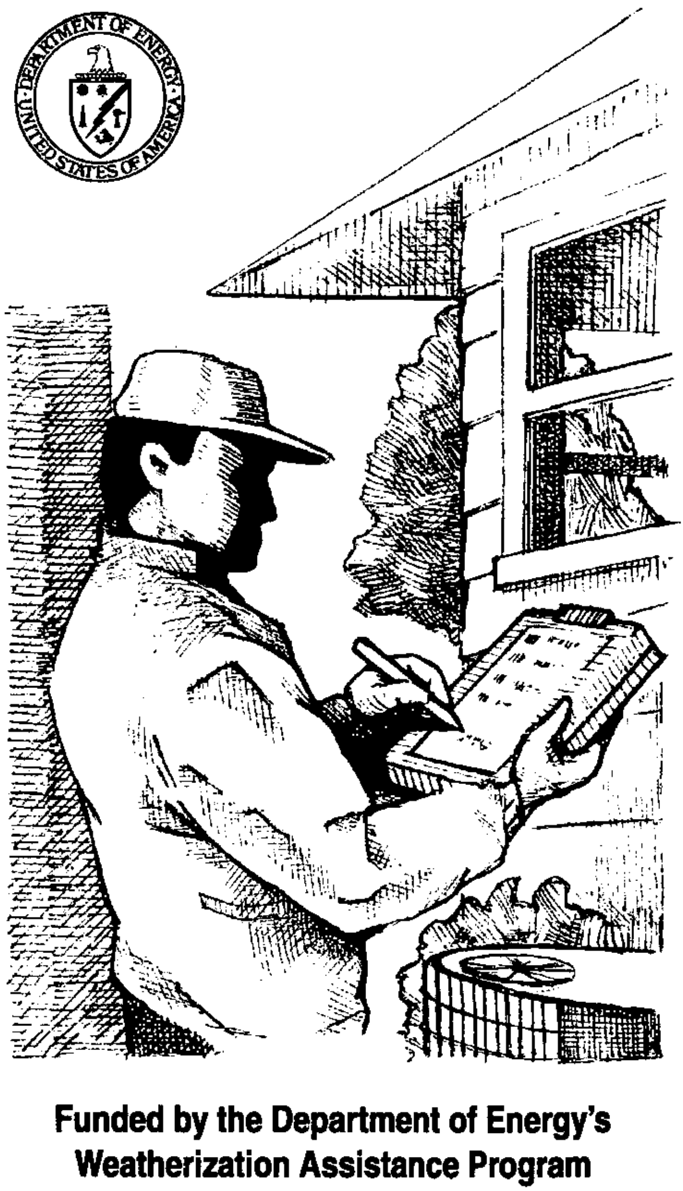

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Published for the Department of Energy's Weatherization Assistance Program in the Southeastern States

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FOREWORD

Greetings from the Atlanta DOE Support Office and the State Weatherization programs in the Southeastern United 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 Southeast. 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 safety leads off this Guide as Chapter 1. Safety for workers and clients in Job #1 in weatherization. Mechanical systems are discussed in Chapter 2, covering more content than any other chapter. The next two chapters cover diagnosing and treating the building shell. Chapter 5 covers special considerations for mobile homes.

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, the project coordinators, and the technical reviewers hope that this Guide is useful to you. Criticism and comments are encouraged and should be directed to the author.

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1.0 Health and Safety Information

This chapter's purpose is to explain some of the most pressing hazards that your clients face in their homes, as well as those you face at work as a weatherization specialist. Where this chapter strays from 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 and are less aware of danger than adults. 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
3. Moisture problems

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 and make suggestions about how to eliminate these 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

1.1 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.

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 1-8.*
3. Practice lead-safe weatherization. See *"Lead-safe weatherization" on page 1-14*

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.

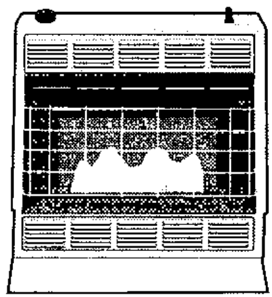
1. Pick up toys and obstacles that could cause slips and falls.
2. Install non-slip grip strips to bathtubs and showers and steps to prevent falls.
3. Make sure that sturdy step stools and ladders are handy where they may be needed for safe climbing.
4. Store poisons separately from medicines to prevent 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.

1.1.1 *Safety for gas ranges and unvented space heaters*

Unvented combustion space heaters and combustion ranges and ovens are the most dangerous household appliances found in southern homes. Regular maintenance and client education are important to reducing the risk of air pollution and fire. Both unvented space heaters and ranges deplete oxygen from the indoor air, may produce carbon monoxide, and

Unvented space heaters

Unvented combustion space heaters use an open flame and combustion gases to heat the home. If the combustion process is perfect, combustion gases consist of carbon dioxide (CO_2) and water vapor. If combustion isn't perfect, poisonous carbon monoxide (CO) can be released, putting occupants in grave danger.



Unvented space heaters: *These heaters pose a great danger to occupants from fire and carbon monoxide poisoning.*

Causes of CO in unvented space heaters relate to dust and dirt on burners, or on ceramic infrared-heating elements. The dust and dirt interfere with the flame or the flow of combustion air and combustion gases. A thorough cleaning can often stop this CO release.

Consider the following specifications related to unvented space heaters.

- ✓ Never air-seal a home heated by unvented space heaters.
- ✓ Test all unvented space heaters for CO.
- ✓ Clean heaters found to be producing CO and retest.
- ✓ Replace heaters that continue to produce CO after cleaning.
- ✓ Install a CO alarm near each space heater to alert occupants of dangerous CO levels.

Educate occupants using unvented space heaters about the following dangers.

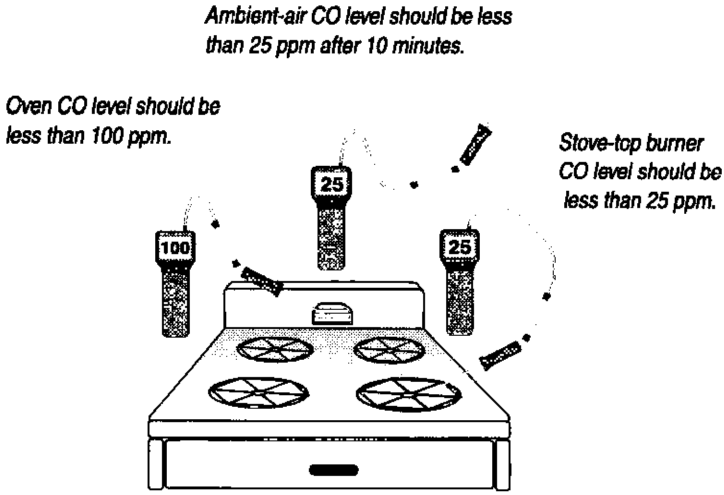
- ✓ Never fill a kerosene space heater in the home. Take the space heater outdoors to fill it.
- ✓ Keep the space heater away from furniture and drapes to prevent fire.
- ✓ Alert children to the danger of heat and flame.
- ✓ Open nearby windows at least one inch to provide adequate fresh air for combustion.
- ✓ If a space heater with a oxygen-depletion pilot safety extinguishes its flame during heating, open windows to admit fresh air before relighting.

Gas ranges and ovens

Gas ranges and ovens can produce significant quantities of CO in a kitchen. Overfiring, dirt buildup, and foil installed around burners are frequent causes of CO. Oven burners are likely to produce CO even when not obstructed by dirt or foil. Test the range and oven for safety following these steps and take the recommended actions before or during weatherization.

1. Test each stove-top burner separately, using a digital combustion analyzer or CO meter and holding the probe about 8 inches above the flame.
2. Clean and adjust burners producing more than 25 parts per million (ppm). Burners may have an adjustable gas control.
3. Turn on the oven to bake on high temperature. Sample the CO level in exhaust gases at the oven vent and in the ambient air after 10 minutes.
4. If the CO reading is over 100 ppm or if the ambient-air reading rises to 25 ppm or more during the test, take action to reduce these levels. Actions include cleaning the oven,

removing aluminum foil, adjusting the burner's adjustable gas control, or replacing the range and oven.



Testing ranges and ovens for CO: *Observe specifications shown here for CO-testing.*

Most range and oven burners are equipped with adjustable needle-and-seat valves. Most ranges also have an adjustable gas regulator that services the entire unit.

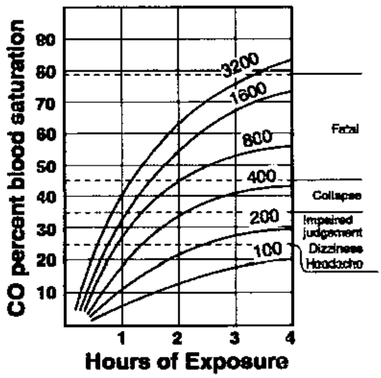
Advise the occupants of the following important operating practices.

- ✓ Never install aluminum foil around a range burner or oven burner.
- ✓ Never use a range burner or gas oven as a space heater.
- ✓ Open a window and turn on the kitchen exhaust fan when using the range or oven.
- ✓ Keep range burners and ovens clean to prevent dirt from interfering with combustion.
- ✓ Burners should display hard blue flames. Yellow or white flames, wavering flames, or noisy flames should be investigated by a trained gas technician.
- ✓ Buy and install a CO alarm, and discontinue use of the range and oven if the CO level rises above 9 ppm.

1.1.2 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 can cause 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 cigarette smoking or automobile exhaust ar also common causes.

Offending appliances include: unvented gas and kerosene space heaters; gas ranges; leaky wood stoves; and backdrafting, vented space heaters. Backdrafting furnaces 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% or more of residential buildings in some regions.

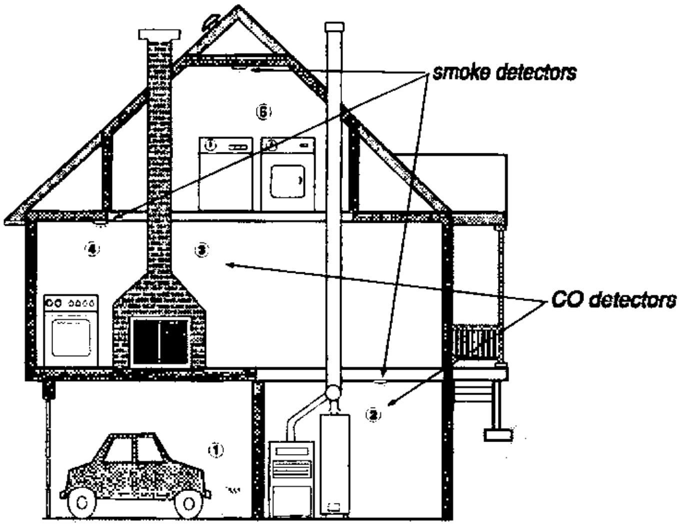
The most common CO-testing instruments are electronic sensors with a digital readouts in parts per million (ppm). Following manufacturers recommendations on zeroing the meter—usually by exposing the meter to clean air. CO testers usually need re-calibration every 6 months or so, using factory-specified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

CO is normally tested near the flame or at the exhaust port of the heat exchanger. See *"Combustion safety and efficiency testing" on page 5-32*. CO is usually caused by one of the following:

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

CO and smoke detectors

All homes should have smoke detectors, one near combustion zone and one near the bedrooms. CO alarms are appropriate whenever the CO hazard is considered 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 indoor air quality.

2. The mechanical room can contribute CO from backdrafting combustion appliances.

3. Fireplaces can backdraft CO and smoke.

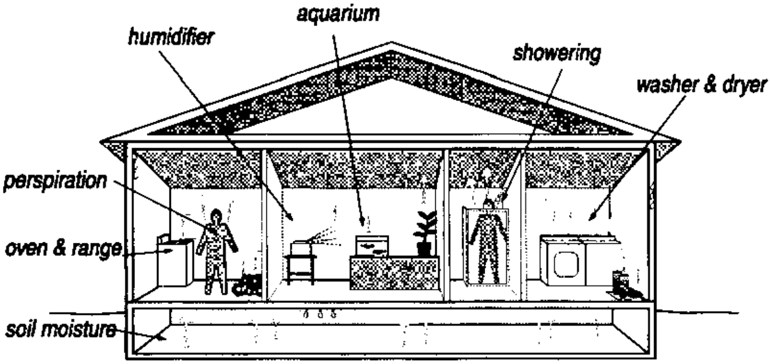
4. Gas ranges and ovens can contribute large quantities of CO and moisture.

5. Gas dryers contribute combustion gases and moisture, unless vented outdoors.

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

1.1.3 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, cause 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 typical homes.*

The most prolific sources of moisture are leaky roofs and damp foundations. Other critical moisture sources include dryers venting indoors, showers, cooking appliances, and unvented gas appliances like ranges or decorative fireplaces. 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 1-1: The Most Potent Household Moisture Sources

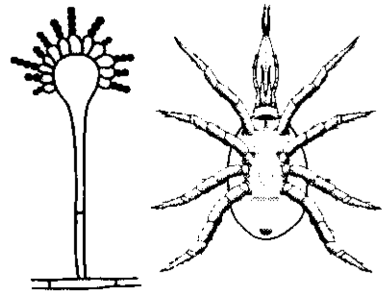
Moisture Source	Potential Amount Pounds or Pints
Ground moisture	0–3 per day
Unvented combustion space heater	0.3 per gal. propane
Seasonal evaporation from materials	0.25–0.70 per day
Dryers venting indoors	0.20–0.25 per load
Dishwashing	0.04 per meal
Cooking (meal for four)	0.015–0.020 per meal
Showering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

add insulation, install storm windows, or consider other remedies. The colder the outdoor temperature, the more likely condensation is to occur, especially if the residents heat with unvented space heaters.

Moisture moves into a building during wet seasons and out during drier seasons. Moisture problem arise 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 respiratory ailments.

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.



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

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.

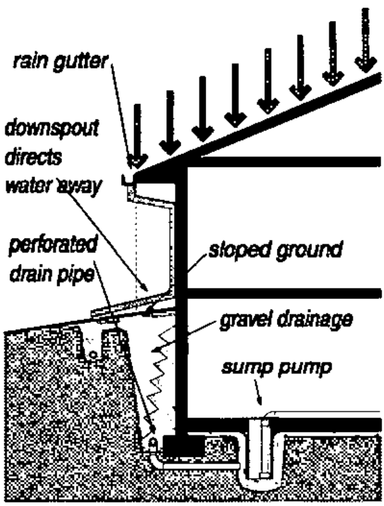
Concrete and masonry efflorescence is a white, powdery deposit left by water moving through a masonry wall, leaving minerals from mortar or the soil behind as it evaporates.

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 home 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 up through the soil 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 slightly more expensive plastic film, reinforced with fiber is appropriate for crawl spaces and dirt basements where the plastic may be crawled or walked on.

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



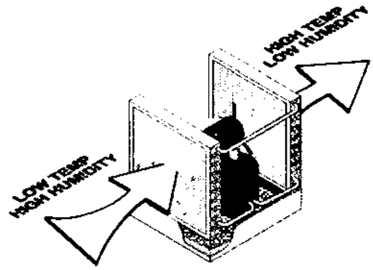
Stopping water leakage: *Choose from a variety of measures to protect homes from water leakage.*

Rainwater flowing from roofs often plays a major role in dampening foundations. In rainy climates. install rain gutters with downspouts and drain roof water into dry wells. Avoid excessive watering around the home's perimeter. Watering lawns and plants close to the house can dampen its foundation. In wet climates, 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. Adding insulation to low-income homes in the Southeast reduces the run-time of unvented space heaters, reducing the amount of water vapor they release. See *"Installing insulation" on page 3-9* and *"Windows and doors" on page 3-30.*

- Ventilating the home with drier outdoor air to dilute the more humid indoor air. Ventilation exhausts excess water vapor and helps evaporate wetness.
- 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.*

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 2-12*. 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 ones) is important in encouraging occupants to use exhaust fans. The one 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 home's 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. Running a round duct from the outdoors to the furnace is also a common way to provide ventilation air to the home.

1.1.4 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.

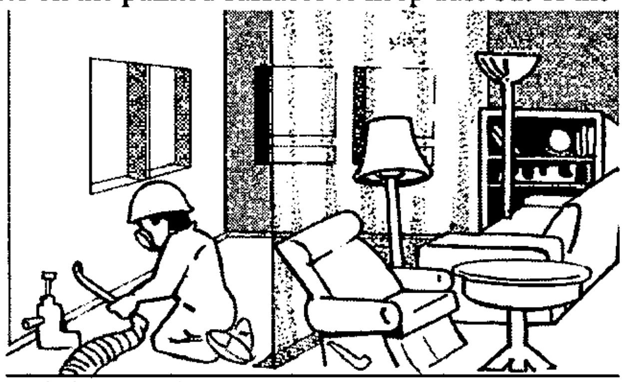
Lead-safe weatherization (LSW) is a group of safe practices, used by weatherization technicians when they know or suspect the presence of lead paint. LSW practices are little more than very careful dust-prevention and housekeeping precautions. Lead-safe weatherization is required when workers will disturb 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 until it was outlawed 1978. 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. Confine your work area within the home to the smallest possible floor area. Seal this area off carefully with floor-to-ceiling barriers made of tape and disposable plastic sheeting. Cover furniture and carpet in the work area with disposable plastic sheeting.
3. Spray water on the painted surfaces to keep dust out of the air, during drilling, cutting, or scraping painted surfaces.



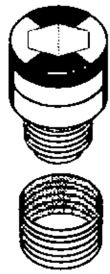
Protective tarp: *Protect clients and their belongings with disposable plastic sheeting when, drilling, scraping, cutting, or blowing*

4. Use a dust-containment system with a HEPA vacuum when drilling holes indoors.
5. Clean up as you work. Vacuum affected areas with a HEPA vacuum and wet mop these surfaces, daily. Don't use the customer's cleaning tools or leave the customer with lead dust to clean up.
6. Wear boot covers while in the work area and remove them to avoid tracking dirt from the work area to other parts of the house.Wear disposable coveralls, or else vacuum cloth coveralls before leaving the work area. Avoid taking lead dust home on clothing, shoes, or tools.
7. Wash thoroughly before eating, drinking, or quitting for the day.
8. Keep children and pets away from the work area.

1.1.5 Electrical safety

Electrical safety is a basic housing need affecting home weatherization and repair. Consider the following specifications for electrical safety in existing homes.

- Don't surround live knob and tube wiring with insulation. Instead, replace knob and tube wiring with modern nonmetallic cable before insulating.
- All home electrical systems should be grounded, either to a grounding rod or to a water pipe that has an uninterrupted electrical connection to the ground.
- #14 copper or #12 aluminum wiring should be protected by a fuse or breaker rated for no more than 15 amps. #12 copper or #10 aluminum should be protected by a fuse or breaker rated at no more than 20 amps.



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

  Install S-type fuses where appropriate to prevent occupants from installing oversized fuses.
- Wiring splices must be enclosed in metal or plastic electrical boxes, fitted with cover plates.

1.2 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 safety 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 priority over other factors affecting weatherization operations. The following hazards merit special attention of weatherization agencies and their contractors because of their statistical importance.

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

1.2.1 Commitment to safety

Workers tend to become complacent about their health and safety if it is not continually stressed. Weatherization agencies should do the following to encourage safety.

- 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.

1.2.2 New employees

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

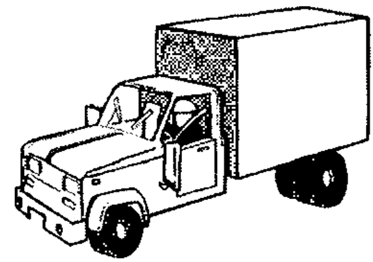
New employees are several times more likely to injure themselves on the job compared to experienced workers. Before their first day on the job, new employees should learn about safety basics such as proper lifting, safe ladder usage, and safe operation of the power tools they will use on the job. New 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.

1.2.3 Driving

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.



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

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.

1.2.4 Lifting and back injuries

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 should be instructed in proper lifting techniques—lifting with their legs and 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.

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

Supervisors should identify workers with limited lifting abilities because of weakness or prior injury and instruct them to avoid heavy lifting.

Other 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.

1.2.5 Respiratory health

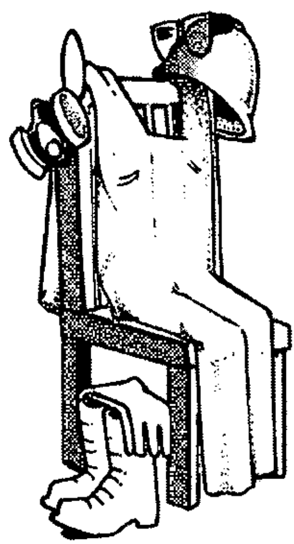
Common household construction and insulation dust can be full of toxins including asbestos, fiberglass, metals, and chemicals. Drilling, cutting, scraping can stir up toxic dust, which may then be inhaled. Workers are also exposed to dust from the insulation they install. Dust that clings to clothes worn on the job travels home, where it may be inhaled by family members.

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.

1.2.6 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.



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

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. Employees should know where MSDSs are kept and how to interpret them. Employees should know how to avoid exposure to hazardous materials used on the job and how to clean up chemical spills. Employees should be instructed on appropriate protective equipment. Employees should wear appropriate protective equipment recommended by the MSDS, while working with any hazardous material.

1.2.7 Falls

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. Any change in elevation greater than 19 inches must be served by a ladder or stairway.

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

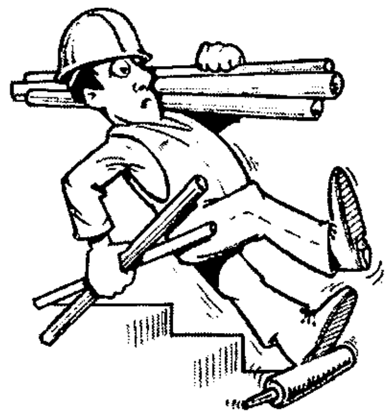
Broken ladders and ladders that slip because they haven't been anchored properly are both major causes of on-the-job falls. Worker carelessness and using the wrong ladder for a particular job is also a common cause of falls. Step ladders, for instance, are often used for work that is too far off the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

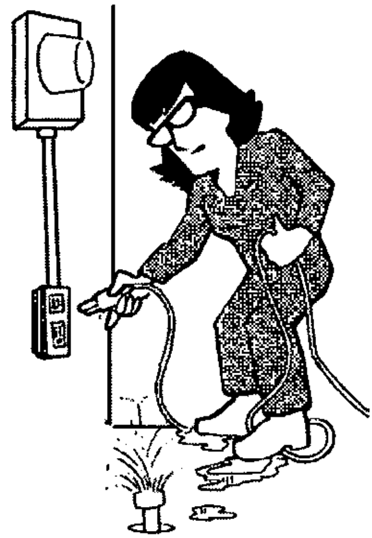
1.2.8 Tool safety

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 can cause 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 tools 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.*

2.0 Assessment, Diagnosis and Baseload Measures

Before deciding which weatherization measures to install in a particular home, understand how the home uses energy. This chapter begins with an overview of the information and procedures necessary for good decision-making. Attic insulation has been proven in numerous studies to be the best measure for reducing heating and cooling costs. Wall insulation is also a very good insulation measure, especially in the cooler parts of the Southeast region. The only analysis necessary for insulation is determining existing insulation levels and applying a policy or computer program like NEAT to judge cost-effectiveness.

Reducing air leakage through the building shell and ducts can be very cost-effective but requires analysis. Procedures for analyzing shell leakage and duct leakage are found in this chapter.

Some measures, which reduce baseload consumption, are cost-effective energy savers for most homes and don't require much analysis. They are covered at the end of this chapter.

2.1 Understanding Energy Usage

Energy usage can be divided into two categories: baseload and seasonal energy use. Baseload includes water heating, lighting, and the refrigerator. Seasonal energy use includes heating and cooling. In the Southeast, energy consumption is more evenly distributed than in the northern states, where heating dominates.

All electric homes show this even distribution on energy usage because all energy is measured in the same units: kilo-watt-hours.

Table 2-1: Baseload Energy Consumption

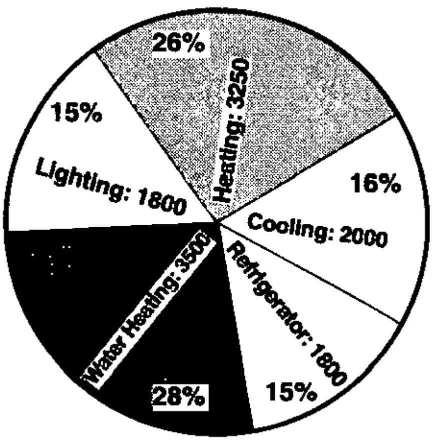
Baseload	kWh/yr	$/yr	%
Water heating	3500	$315	37%
Lighting	1800	$162	18%
Refrigerator	1800	$162	18%
Clothes dryer	1300	$117	13%
Other	1400	$126	14%
Total	9800	$882	100%

Seasonal energy consumption is highly variable between different parts of the Southeast and between individual households. Values for heating and cooling energy consumption are best expressed in ranges. The following table recognizes that there are two separate choices for heating and cooling a home. The first and most common is the combination of room heaters and room air conditioners. The second is a central furnace with central air conditioning or a heat pump, which both heats and cools the home.

Next, let's look at the regional round-number averages for baseload and seasonal energy usage combined in a pie chart to give a picture of the relative importance of each of the major energy uses.

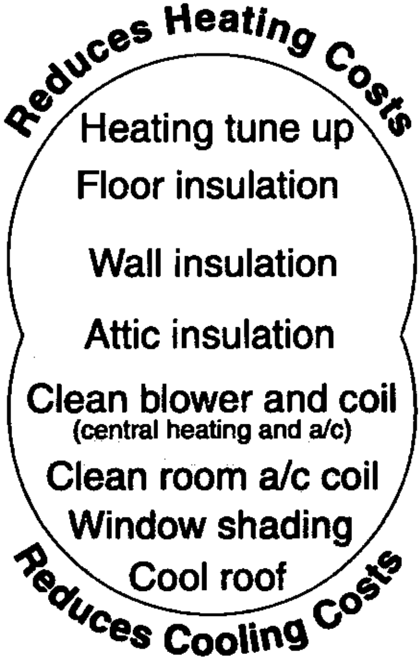
Table 2-2: Seasonal Energy Consumption

Seasonal Load	kWh/yr	$/yr	Ave. kWh–$/yr
Space heating	1000–4000	$90–$360	2500–$225
Space cooling	500–2000	$45–$180	2000–$180
Space Total	2000–7000	$180–$630	4500–$405
Central heating	2000–6000	$180–$540	4000–$360
Central cooling	1000–4000	$90–$360	2500–$225
Central Total	3000–10,000	$270–$900	6000–$540



Improvable baseload and seasonal energy uses: *In the Southeast, it's necessary to attack energy waste on at least five fronts, represented by the five pie slices shown here.*

Seasonal energy use is much more variable and difficult to reduce than baseload energy use. Procedures installed to reduce heating costs may or may not reduce cooling costs and vice versa. Floor insulation is mainly a heating energy-saver and cool roofs are a cooling energy-saver, of course. Cleaning the blower and indoor coil of a central heating and air-conditioning system improves both heating and cooling efficiency. Attic insulation is perhaps the best heating and cooling measure. Air-sealing and duct sealing also produce good savings in both seasons.



Reducing seasonal energy use: *Not all energy measures, installed to reduce heating costs, also reduce cooling costs. The diagram here shows heating measures, cooling measures, and measures that reduce both heating and cooling costs.*

The energy-use analysis, presented here, suggests a balanced energy-saving strategy to address each of the five major areas of the reduce-able energy consumption. The table shown next lists the five end-use areas with proven and reliable weatherization measures for each. These measures are listed in each area in order of priority.

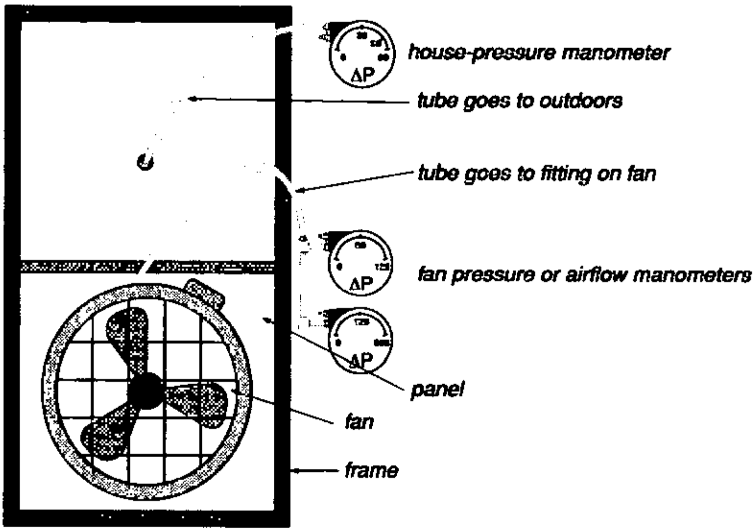
Table 2-3: Suggested Weatherization Measures for the Southeast

Usage sector	Suggested measures
Heating	Air-seal ceiling and floor: *page 3–2.* Insulate attic: *page 3–11.* Insulate walls (except mobile homes): *page 3–19.* Seal ducts in central systems: *page 5–57.*
Water heating	Adjust hot-water temperature: *page 2–27.* Install low-flow shower head: *page 2–28.* Wrap water heater: *page 2–29.* Insulate first five feet of water pipe: *page 2–28.*
Cooling	Air-seal and insulate attic: *page 3–11.* Improve window shading: *page 3–30.* Solve moisture problems: *page 1–8.* Clean coils, filters, and fans: *page 5–67.* Install cool roof (mobile homes and flat roofs): *page 4–15.* Seal ducts in central systems: *page 5–57.*
Lighting	Replace incandescents with CFLs: *page 2–34.*
Refrig-erator	Replace refrigerator: *page 2–33.* Adjust refrigerator and freezer temperatures: *page 2–33.* Clean condenser coil if refrigerator stays: *page 2–33.*

2.2 House airtightness testing

Air leakage reduction is less important in the Southeast than in the North. The Southeast has many homes heated by unvented space heaters, which creates a safety issue for air sealing. The air-sealing goals set forth in this chapter reflect these concerns.

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.*

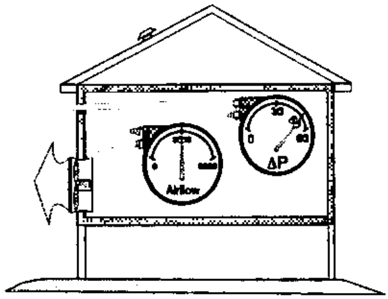
The blower door also allows the technician to test parts of the home's air barrier to locate air leaks. Testing air barriers with a blower door isn't always necessary. Sometimes air leaks are obvious. Other times the leaks are hidden, and the technician wants to obtain clues about their location without 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.

2.2.1 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 1-1 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 air-sealing materials would likely be removed.
2. Moisture has caused structural damage, rot, mold or mildew growth.
3. Fire hazards place the building's life and occupants' safety in jeopardy.
4. Measured carbon monoxide level exceeds suggested action levels.
5. Combustion-zone pressure exceed -4 pascals, during a worst-case test.
6. Chimney drafts of combustion appliances do not meet minimum standards.
7. Unvented space heaters will be used after air-sealing work.
8. Infestations, vermin, or other sanitary issues are observed.
9. The building is already at or below its Building Tightness Limit and no mechanical ventilation exists or is planned.

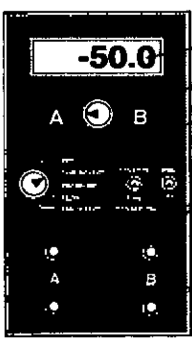
2.2.2 Blower-door testing



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

The blower door creates a 50-pascal pressure difference across the building shell and measures airflow (CFM_{50}), in order 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 3-2.*

Measuring pressure and airflow

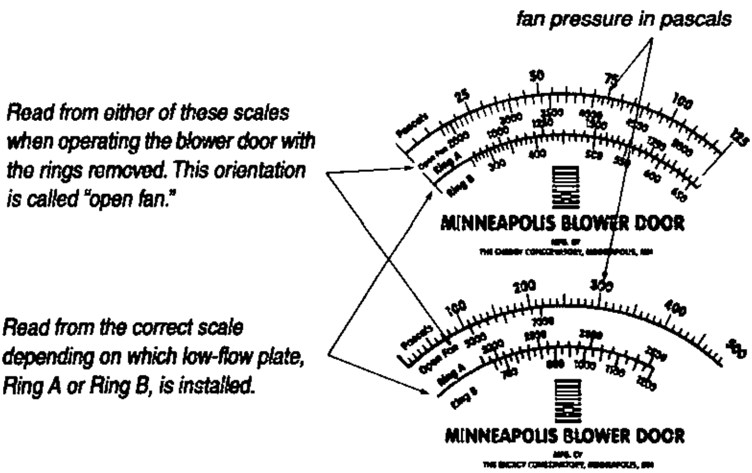


Digital manometers: *Are popular for diagnosing zone pressures and duct pressures because of their convenience and accuracy.*

Connecting the manometer's hoses correctly is essential for accurate 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. The reference zone is considered to be the zero point on the pressure scale. 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.

During the blower-door test, the airflow is measured through the fan. This airflow is directly proportional to the surface area of the home's air leaks. For the blower door to measure airflow accurately, the air must be flowing at an adequate speed. Tighter buildings don't have enough air leakage to create an adequate airspeed. This necessitates using one of three low-flow plates provided with the blower door to reduce the fan's opening and increase air speed through the fan.

When using one of these low-flow plates, you must read the correct scale on the analog gauges, shown below. When using a digital gauge, follow the manufacturer's instructions for selecting the proper fan configuration with the correct low-flow plate.



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

Some homes are so leaky that the blower door isn't powerful enough to pressurize them to 50 pascals. In these cases, you must apply a factor to the airflow you measure at a lower pressure. Those factors are listed in *"'Can't Reach Fifty' Factors" on page 2-11*. Use these factors only when absolutely necessary because they result in inaccurate air leakage estimates.

2.2.3 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.

2.2.4 Blower door test procedures

Follow these general instructions when performing a blower-door test.

1. Install blower door frame, panel, and fan in an exterior doorway, having a clear path to outdoors.
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 2-4: *'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 ensure that blower door testing did not extinguish them.

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

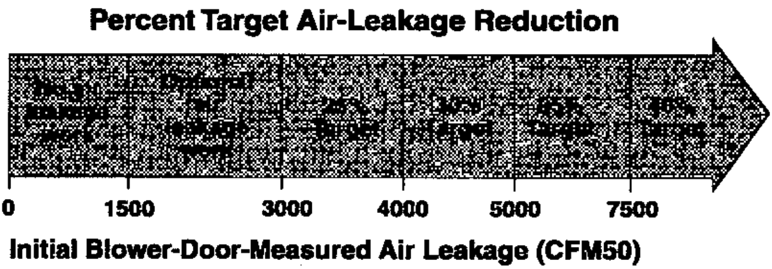
Approximate leakage area

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.

$$\text{ALA} = \text{CFM}_{50} \div 10$$

2.2.5 Target air-leakage reductions

Depending on the initial blower-door test reading in CFM50, follow the prescribed percentage target air-leakage reduction specified below.



Target air-leakage reduction: *The target reduction depends on the initial leakiness of the home. Don't air-seal homes heated by unvented space heaters.*

2.2.6 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 means of fresh air intake and pollutant removal. Follow these steps to determine the building tightness limit (BTL).

1. Determine 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. *Use the table titled "Building tightness limits (CFM50)" on page 2-13 to determine building tightness limits.*

Table 2-5: Building tightness limits (CFM_{50})

Wind shielding	Number of stories: 1	2	3
5 Occupants			
Shielded	2100	1650	1500
Normal	1750	1500	1500
Exposed	1550	1500	1500
6 Occupants			
Shielded	2500	2000	1750
Normal	2100	1700	1500
Exposed	1850	1500	1500
7 Occupants			
Shielded	2950	2300	2050
Normal	2450	1950	1700
Exposed	2150	1750	1550
8 Occupants			
Shielded	3350	2650	2300
Normal	2800	2250	1900
Exposed	2500	2000	1750

These Building Tightness Limits for zones 3 and 4, from methodology by Lawrence Berkeley Laboratory and George Tsongas.

2. Or, 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, however, may still be important to prevent humid indoor air from migrating into attics and building cavities.

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

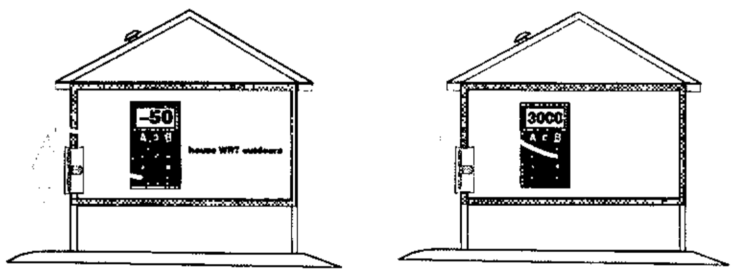
- Are sources of moisture like ground water, humidifier, water leaks, unvented clothes dryer, or unvented space heater causing indoor air pollution, high relative humidity, or moisture damage? *See "Solutions to moisture problems" on page 1-11*
- Do occupants complain or show symptoms of building-related illnesses?

Pollutant sources combined with tight houses produce poor indoor air quality. Educate residents about removing pollution sources and ventilating their homes. Take appropriate steps during weatherization to reduce pollutants and to install mechanical ventilation if needed. If pollutant sources can't be removed during weatherization, perform no air-sealing. See also *"Mechanical ventilation" on page 1-13*.

2.2.7 Leak-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.



Leak-testing air barriers involves a series of techniques, applied during a blower-door test with the house at a negative pressure of 50 pascals with reference to outdoors. This house has 3000 CFM50 of air leakage. Testing air barriers can help determine where that leakage is coming form.

- 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.

When you're planning to identify and improve a home's air barrier, consider the leakage characteristics of the building components. Creating an effective air barrier in an existing home involves choosing existing building components to act as air barrier and air-sealing their border regions. Chances are that you'll find two or more of these components adjacent to one another so that they combine to form a better air barrier compared to being considered alone. The classification below includes only the component itself, not seams and border areas where it meets other components.

Table 2-6:* *Building Components Compared by Air Permeance at 50 Pascals

Good air barriers (<2 CFM_{50} per 100 ft.^{2})	**Fair air barriers** (2–10 CFM_{50} per 100 ft.^{2})	**Poor air barriers** (10–1000 CFM_{50} per 100 ft.^{2})
5/8" oriented strand board	15# perforated felt	5/8" tongue-and-groove wood sheeting
1/2" drywall	concrete block	6" fiberglass batt
4-mil air barrier paper	rubble masonry	1.5" wet-spray cellulose
Asphalt shingles and perforated felt over 1/2" plywood	7/16" asphalt-coated fiberboard	wood siding over plank sheathing
1/8" tempered hardboard	1" expanded polystyrene	wood shingles over plank sheathing
painted uncracked lathe and plaster	brick veneer	blown fibrous insulation

Based on information from: "Air Permeance of Building Materials" by Canada Mortgage Housing Corporation and estimates of comparable assemblies by the author

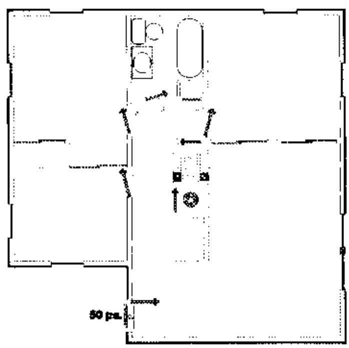
Primary versus secondary air barriers

The air barrier should be a material that is continuous, sealed at seams, and is itself relatively impermeable to airflow. Together the air barrier and insulation form the thermal boundary. The most airtight air barrier is the primary air barrier and the least airtight is the secondary air barrier. The primary air barrier should be adjacent to the insulation to ensure the insulation's effectiveness. Therefore, testing is important to verify that insulation and primary air barrier are together. 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. For example, the roof may be the primary air barrier instead of the top-floor ceiling as assumed.

Intermediate zones are unconditioned spaces, sheltered within the exterior shell of the house. Intermediate zones can be included inside the home's primary air barrier or outside it. Intermediate zones include: unheated basements, crawl spaces, attics, enclosed porches, and attached garages. 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.

Very simple pressure tests

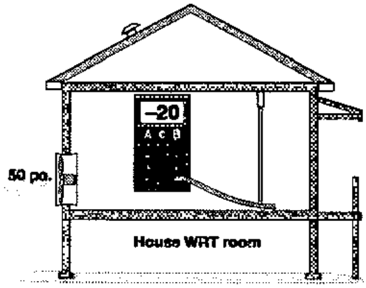
You can find valuable information about the relative leakiness of rooms or sections of the home with closable interior doors during a blower-door test. Listed below are 4 simple methods



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 the outdoors through 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. *Room pressure difference:* Check the pressure difference between a closed room or zone and the main body of a home. Larger pressure differences indicate larger potential air leakage within the closed room or else a tight air barrier between the room and main body. A small pressure difference means little leakage to the outdoors through the room or a leaky air barrier between the house and room.



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. This test can determine whether or not a confined combustion zone is connected to other rooms.*

3. *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.
4. *Observing smoke movement:* Pressurize the home to 50 pascals and observe the movement of smoke through the house and out of its air leaks.

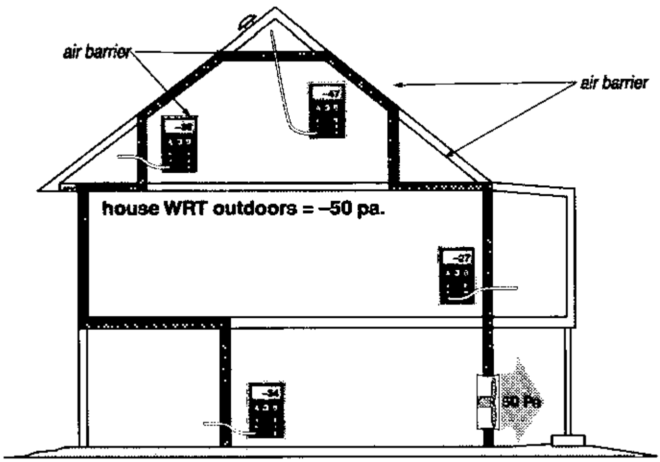
Tests 1,2, and 4 are mainly just observations. Feeling airflow with your hand or observing smoke are mere observations, but these simple techniques have helped identify many air leaks that could otherwise have remained hidden. Closing doors to leakier rooms will usually produce a greater reduction in CFM_{50} than closing doors to tighter ones.

Air leakage, restricted by closing a door, may have alternative indoor paths rendering test 2 inaccurate. Only practice and experience can guide your decisions about the applicability and usefulness of these tests.

Using manometers to test air barriers

A manometer, used for blower door testing, also can measure pressures between the house and its intermediate zones during blower-door tests.

The blower door, when used to create a house-to-outdoors pressure of –50 pascals, also creates house-to-zone pressures of between 0 and –50 pascals in the home's intermediate zones. The amount of depressurization depends on the relative leakiness of the zone's two air barriers.



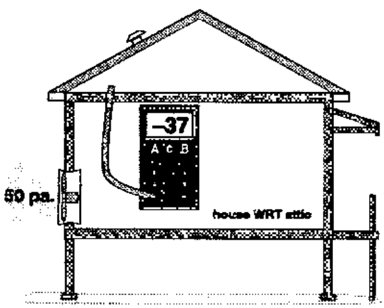
Pressure-testing building parts: *Measuring the pressure difference across the assumed thermal boundary tells you whether the air barrier and insulation are aligned. If the manometer reads close to –50 pascals, they are aligned, assuming the tested zones are well-connected to outdoors. Lesser negative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

For example, in an attic with a fairly airtight ceiling and a very well-ventilated roof, the attic will indicate that it is mostly outdoors by having a house-to-zone pressure of –45 to –50 pascals. The leakier the ceiling and the tighter the roof, the smaller the negative house-to-zone pressure will be. This holds true for other intermediate zones like crawl spaces, attached garages, and basements.

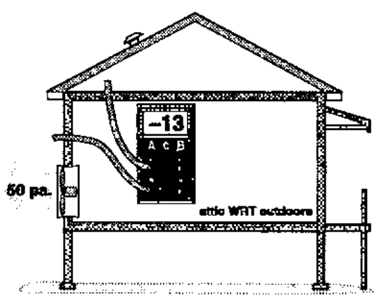
Zone leak-testing

This next procedure illustrates the general testing principles introduced above.

1. Depressurize house to –50 pascals with a blower door.
2. Find an existing hole or drill a hole through the floor, wall, or ceiling between the conditioned space and the intermediate zone.
3. Connect the reference port (digital manometer) or the low-pressure port (analog manometer) to a hose connected into the zone.
4. Leave the input port (digital manometer) or the high-pressure port (analog manometer) open to the indoors.
5. Read the negative pressure given by the manometer. This is the house-to-zone pressure, which will be –50 pascals if the air barrier between house and zone is airtight and the zone is open to outdoors.
6. If the reading is significantly less negative than –45 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.



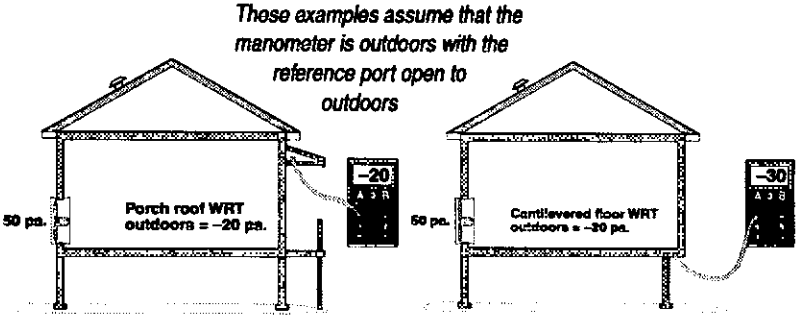
House-to-attic pressure: *This commonly used measurement is convenient because it requires only one hose.*



Attic-to-outdoors pressure: *This measurement confirms the first because the two add up to –50 pascals.*

Leak-testing building cavities

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

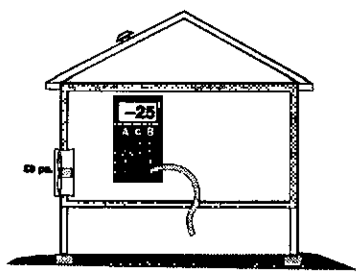


Porch roof test: *If the porch roof were outdoors, the manometer would read near 0 pascals. We hope that the porch roof is outdoors because it is outside the insulation. We find, however, that it is partially indoors, indicating that it may harbor significant air leaks through the thermal boundary.*

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.*

2.2.8 Decisions about crawl spaces

The importance of creating an effective air barrier at the foundation walls or floor depends on how much of the home's air leakage is coming through the foundation or floor. Air leakage from the crawl space is a leading cause of moisture problems.



House-to-crawl space 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.*

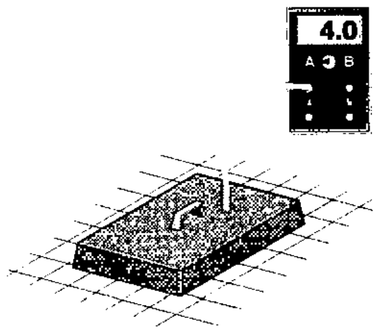
During a blower door test, check the difference in CFM_{50} when the crawl-space hatch is closed compared to when it is open. You will probably have to adjust the blower door after opening the interior or exterior crawl-space hatch to restore 50 pascals house pressure. This technique works well for basements and crawl spaces with interior access hatches.

2.2.9 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 5-57.*

Pressure-pan testing

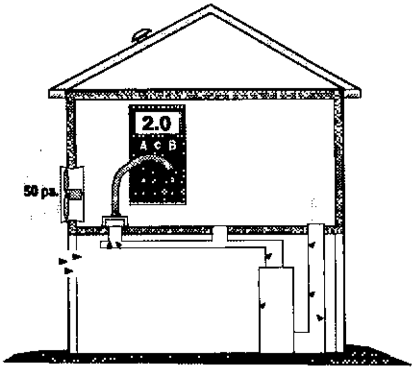
Pressure-pan tests can help identify leaky or disconnected ducts. With the house depressurized by the blower door to –25 pascals with reference to outdoors, pressure-pan readings are taken at each supply and return register.



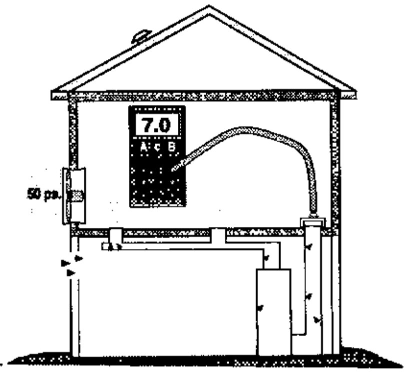
A pressure pan: *Blocks a single register and measures the air pressure behind it, during a blower door test. The magnitude of that pressure is an indicator of duct leakage.*

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 –25 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. In this case, pressure-pan testing isn't necessary, although air-sealing the return ducts for safety is still recommended. If instead, the basement is accessed from the outside and rarely used, the basement may be considered outside the conditioned living space. In this case, a window or door between the basement and outdoors should be opened and any door or hatch 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 measured 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.

Pay particular attention to registers connected to ducts that are located in areas outside the conditioned living space. These spaces include attics, crawl spaces, garages, and unoccupied 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.

2.2.10 Duct-induced room pressures

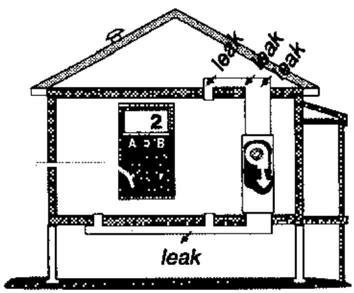
An improperly balanced air-handling system can cause comfort, building-durability, and indoor-air-quality problems. Duct-induced room pressures can increase air leakage through the building shell from 1.5 to 3 times compared to when the air handler is off.

Measuring duct-induced room pressures

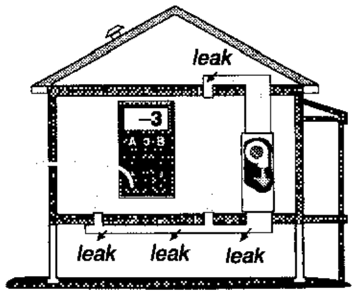
The following test measures pressure differences between the main body of the house and each room, including the combustion-appliance zone (or basement). Pressure difference greater than +4.0 pascals or more negative than –4.0 pascals should be corrected. *For information on reducing duct-induced room pres-*

sures, see "Duct improvements to increase airflow and improve comfort" on page 5-62.

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.*



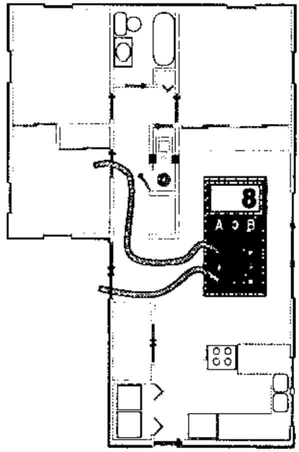
Dominant supply leaks: *When supply leaks are larger than return leaks, the house shows a negative pressure with reference to the outdoors.*

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. A pressure at or near zero indicates equal supply and return leakage or else little duct leakage.

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 ± 4.0 pascals with the air handler operating, pressure relief is necessary. To estimate the amount of pressure relief, slowly open door until pressure difference drops to between +4.0 pascals and –4.0 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 draft and pressure test" on page 5-27.



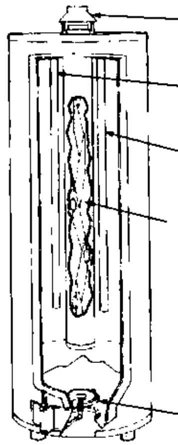
Blocked return path: *With interior doors closed, the large positive pressure in the bedroom is caused by the lack of a air return register in the bedroom. The airflow in this forced-air system is unbalanced, causing this pressure, which forces room air through the room's air leaks.*

2.3 Baseload Energy Measures

The following baseload energy measures can be applied to most homes and are reliable energy savers.

2.3.1 Water heating

Gas-, propane-, and oil-fired water heaters must be tested, maintained, and repaired as described in the sections on burners and venting. See *"Combustion safety and efficiency testing" on page 5-32.*



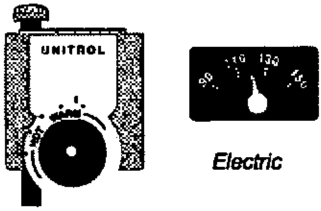
Standard gas water heater: *Is an open combustion appliance often troubled by spillage and backdrafting.*

✓ A water heater 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 with an external insulation blanket unless water-heater label gives specific instructions not to insulate or the water heater is already insulated.

✓ Water heater insulation must not obstruct draft diverter, pressure relief valve, thermostats, hi-limit switch, plumbing pipes, or element/thermostat access plates.

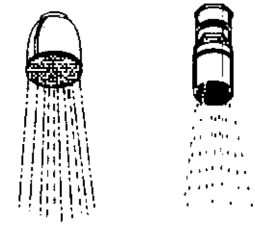
✓ Install a non-misting water-saving shower head. A non-misting model is preferred to prevent the shower from being too steamy and causing moisture problems in the bathroom.



Gas

Electric

Setting hot-water temperature: *Getting the temperature between 115 and 120°F can take a few adjustments and temperature measurements.*



Non-misting

Misting

Water-saving shower heads: *The non-misting type produces small streams of water rather than a mist.*

- ✓ Adjust water temperature between 115° and 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.
- ✓ Inspect faucets for hot-water leaks and repair leaks if found.

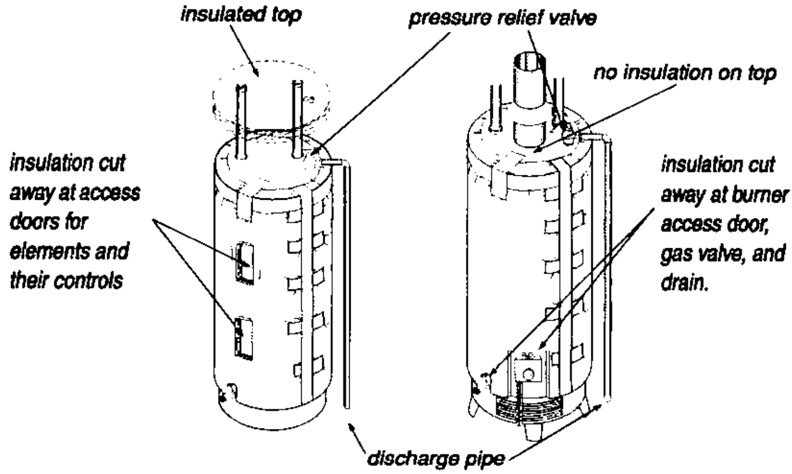
Pipe insulation

- ✓ Insulate the first 5 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.

Gas- and oil-fired water-heater insulation

- Keep insulation at least 2 inches away from the burner or gas valve.

- 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 access plates to heating elements and their thermostats.

2.3.2 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 5-2.*
- *"Combustion air" on page 5-18*
- *"Combustion safety and efficiency testing" on page 5-32.*

2.3.3 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 5-2*, *"Combustion air" on page 5-18*, and *"Heating-system replacement specifications" on page 5-44*.

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

- *"Oil-fired heating installation" on page 5-45*.
- *"Minimum Combustion Standards for Oil-Burning Appliances" on page 5-39*.

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

- *"Gas-fired heating installation" on page 5-46*.
- *"Gas burner safety and efficiency testing" on page 5-33*.

2.3.4 Electric water–heater safety and efficiency

✓ Electric water heaters should be serviced by a dedicated electrical circuit.

✓ Replace damaged wiring and correct loose or improper wiring connections.

✓ 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.

2.3.5 Gas and oil 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 or oil water heater must have an energy factor of at least 0.61 or have a minimum of 2 inches of foam insulation. Replacement water heaters should be wrapped with external insulating blankets for additional savings, 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 the water heater installed in a living space.

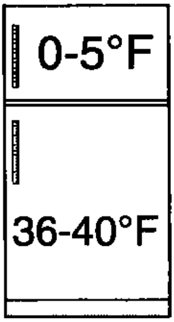
2.4 Appliances and Lighting

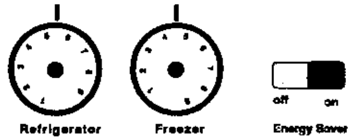
The importance of lights and appliances to residential energy-conservation programs is increasing with the increasing cost of electricity.

Refrigerator adjustments and coil-cleaning

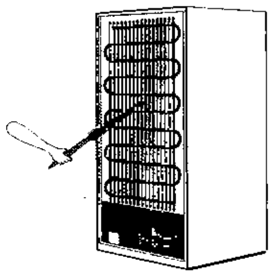
The most important issue for operating any refrigerator, existing or new, is the temperature setpoint of the refrigerator and freezer compartments. The refrigerator temperature should be 38–40°F and the freezer should be 2–5°F for optimal energy efficiency. It's helpful to use a two-channel digital thermometer that can measure refrigerator and freezer temperature at the same time.

Dust accumulates around refrigerator coils and reduces air-flow and heat transfer from the refrigerator to the air around it. This wastes energy. Clean existing refrigerator coils with a soft bristle brush, designed for this purpose. If the refrigerator has an ice maker, be sure not to damage the water tubing connected to the refrigerator.





Refrigerator settings: *Adjust refrigerator and freezer dials to achieve the temperature range shown. Turn the energy-saver switch on and explain its operation to the occupants.*



Cleaning refrigerator coils: *Dust and dirt built up on refrigerator coils can reduce efficiency by reducing airflow and heat transfer.*

2.4.1 Refrigerator assessment and replacement

Refrigerators that are more than 10 years old usually consume between 1000 and 1400 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.

2.4.2 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 compressor-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 kilowatt-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.

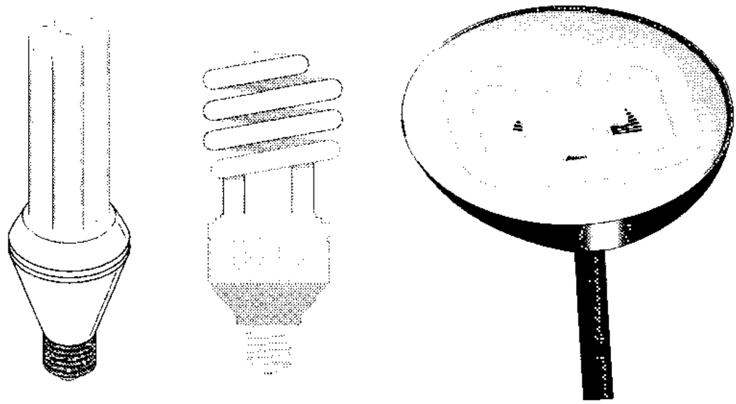
Refrigerators that are replaced should be taken to a facility, licensed to reclaim their refrigerant. No refrigerator, taken out of service, should be returned to service by sale, barter, or for free.

2.4.3 Lighting assessment and replacement

Most low-income homes have 6-to-12 lamps that burn for more than an hour per day. Incandescent lamps that burn for more than one hour per day should be replaced by more-efficient compact fluorescent lamps (CFLs). The CFL should be sized at approximately one-third of the wattage of the incandescent lamp they replace. This easy retrofit has as good an economic return as any retrofit mentioned in this field guide.

Compact fluorescent lamps are still a little bigger than the incandescents they replace. In many fixtures there is extra room and the size difference isn't an issue. In other fixtures, standard-sized compact fluorescents won't fit. To address this size problem, the lighting industry has recently created a smaller size of compact fluorescent lamp known as sub-compact fluorescent. A weatherization agency would be wise to stock both the more common and less expensive compact fluorescents and also the more expensive and versatile sub-compact models.

Halogen (incandescent) torchieres are inefficient and dangerous. Replace halogen torchieres with fluorescent torchieres.

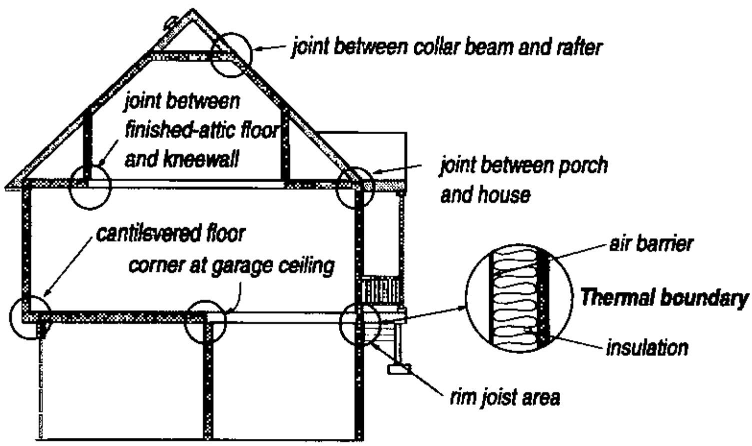


Compact fluorescent lamps: *These advanced lamps use about one-third of the electricity of the incandescent lamps they replace.*

3.0 AIR-SEALING, INSULATING, WINDOWS AND DOORS

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 *"Assessment, Diagnosis and Baseload measures" on page 2-1*.

Use visual inspection to determine the cost-effectiveness of adding thermal resistance to a building. 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: *The thermal boundary contains the air barrier and insulation, which should be adjacent to each other. Corners in the thermal boundary are places where insulation and the air barrier may be incomplete.*

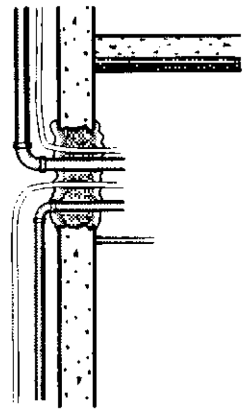
3.1 Reducing Air Leakage

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.*

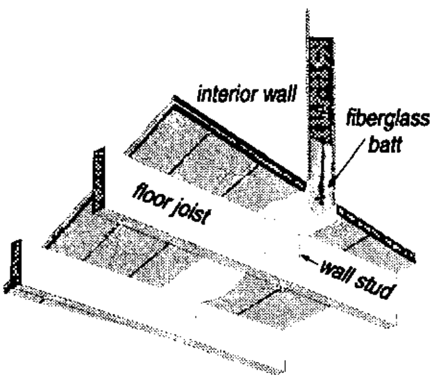
The ultimate goal of air leakage reduction is to establish an effective air barrier. Before air sealing, be aware of all air-pollution and house-pressure hazards. State and local governments may set standards for airtightness levels and ventilation. *See "Building tightness limits (BTL)" on page 2-12.*

3.1.1 Sealing bypasses

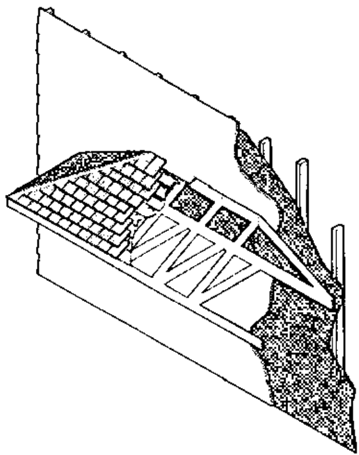
Bypasses are holes and gaps in the air barrier. The effort worth expending to seal a bypass depends primarily on its size. Bypasses will be found between the conditioned space and attic, crawl space, attached garages, and porch roofs. For information

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

on measuring and locating air leaks, see *"Using manometers to test air barriers" on page 2-19.*



Balloon-framed interior walls: *These wall cavities can be open to both the attic and basement.*

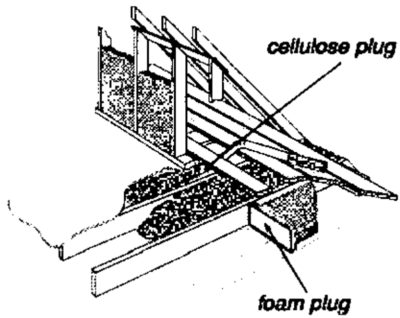


Porch air leakage: *Porches often create a substantial air leak because of all their joints and because there may be no siding or sheathing behind the porch.*

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.

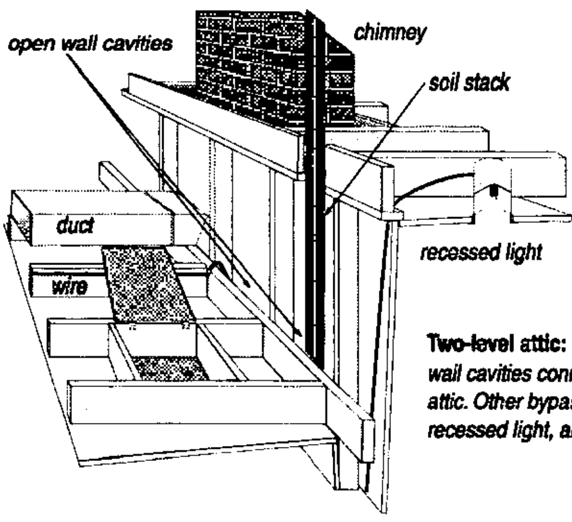
Sometimes bypasses are easily accessible and sometimes not. When they are not easily accessible, technicians sometimes blow densely packed cellulose insulation into surrounding cavities, hoping that the cellulose will resist airflow and plug cracks between building materials.

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.



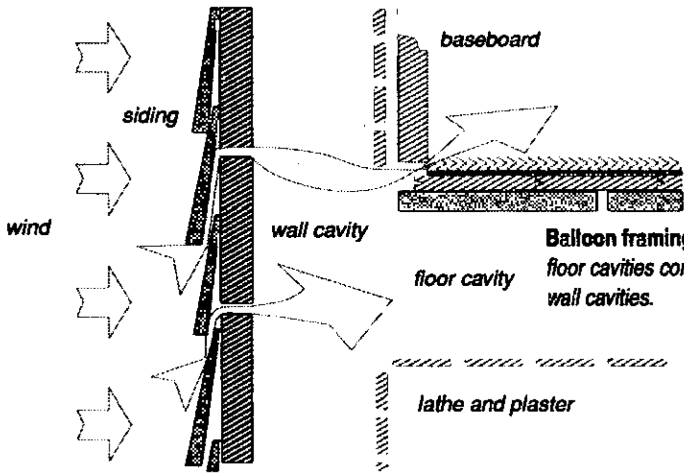
Cellulose or foam board plugs: *Seal these large air leaks between the ventilated attic and the interior floor cavity.*

- *Joist spaces under knee-walls in finished attic areas:* Connect knee-wall 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.



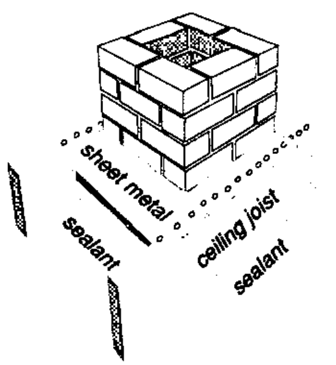
Two-level attic: *Split level homes create wall cavities connected to the ventilated attic. Other bypasses shown are duct, recessed light, and chimney.*

- *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.



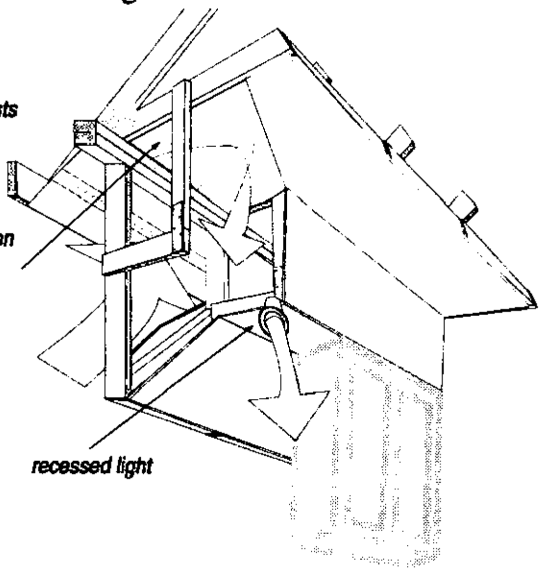
Balloon framing: *Leaves floor cavities connected to wall cavities.*

- *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 with spray foam.



Chimney chases: *Seal around masonry and metal chimneys 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.



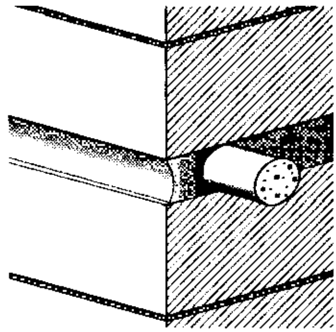
Kitchen soffits: *These framing flaws are often open to both the wall cavity and ventilated attic. Any hole in the soffit creates a direct connection between the kitchen and attic.*

- *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.

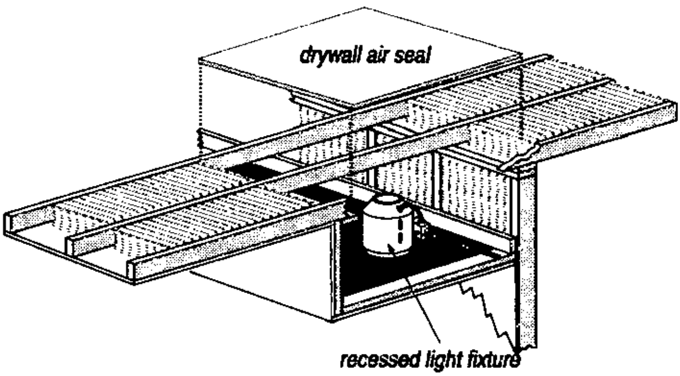
- Cracks in exterior window and door frames should be sealed to keep water out. If the crack is deeper than $^5/_{16}$-inch, it must be backed with a material such as backer rod and then sealed with caulk. Any existing loose or brittle material should be removed before the crack is recaulked.

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

  Caulking should be applied in a manner that seals the area thoroughly and is neat in appearance.
- Joints in sill plate (mud sill) and around utility openings in foundation should be sealed.
- Holes and cracks in masonry surfaces should be sealed with a cement patching compound or mortar mix.
- Interior joints should be caulked if blower-door testing indicates substantial leakage. These joints include where baseboard, crown molding and/or casing meet the wall/ceiling/floor surfaces. Gaps around surface-mounted or recessed light fixtures and ventilation fans should also be caulked.

- Insulating switch and outlet gaskets are useful in trying to attain a tight interior air barrier, but not always cost-effective.



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.*

3.2 Installing Insulation

Insulation is probably the most familiar weatherization measure and it's effectiveness in reducing utility costs is unquestioned. Insulation may still be the most reliable and cost-effective weatherization measure. For the Southeast, attic insulation is especially cost-effective because it reduces both heating and cooling costs. Cool roof coatings can also produce large cooling-energy savings. See *"Cool roofs for mobile homes" on page 4-15*.

Wall insulation gives excellent savings during the heating season and is somewhat less important during the cooling season. Floor or foundation insulation is less important than wall insulation and may not be cost-effective in the warmer parts of the Southeast region.

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 *"Leak-testing air barriers" on page 2-14*.

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 1-14*.

Approximate R-Values per inch for materials

Material	R-value/inch
Concrete	0.1
Wood	1.0
Fiberglass or rock wool batts and blown	2.8–4.0[1]
Cellulose blowing wool	3.0–4.0[2]
Vermiculite loose fill	2.2
White expanded polystyrene foam (bead-board)	3.9–4.3[1]
Polyurethane/polyisocyanurate foam	5.5–6.5[3]
Extruded polystyrene (usually blue, yellow, or pink)	5.0

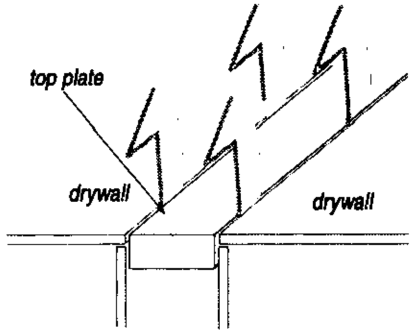
1. Varies according to density (increases with increasing density).
2. Varies according to density (decreases with increasing density).
3. Varies according to age and formulation.

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 *"Zone leak-testing" on page 2-19 and "Sealing bypasses" on page 3-2* for more information.

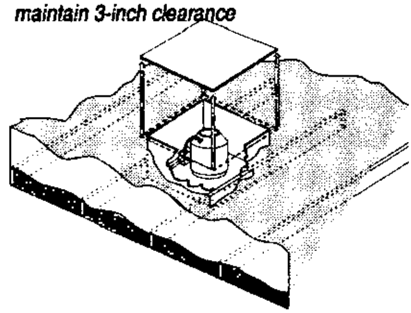


Top-plate leakage: *Even thin cracks between the top plate and drywall can be important air leaks because there are many linear feet of these cracks.*

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.



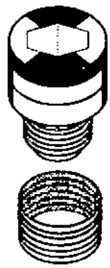
Covering recessed light fixtures: *Covering recessed light fixtures with fire-resistant drywall or sheet-metal enclosures reduces air leakage and allows insulation to be blown around the box.*

- ✓ If funds are available, attic knob-and-tube wiring may be replaced. In many cases, a home will be rewired and the old wiring left in place.

✓ If you plan to cover an electrical junction box with insulation, mark its location with a sign or other means.

✓ If rolled metal is used for as a barrier around heating producing devices or chimneys, it must be fastened securely to the ceiling joist so the barrier won't collapse. Barriers should extend at least 4 inches above the insulation and be secured to keep insulation a minimum of 3 inches away from the heat-producing device.

✓ Insulating over and around live knob-and-tube wiring is usually forbidden. Within jurisdictions that allow insulating over knob-and-tube wiring, inspect fuse boxes to insure that the circuits aren't overloaded.



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

✓ 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.

✓ OSHA-approved respirators or dust masks should be worn when blowing insulation.

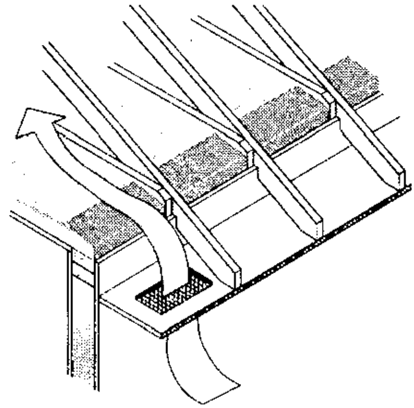
Preparation for attic insulation

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.

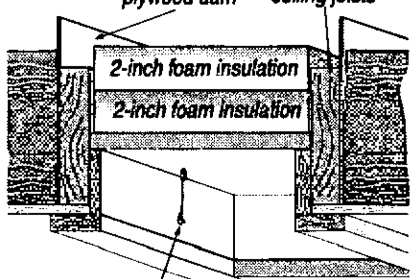
✓ All kitchen and bath fans, currently venting into the attic, must be re-vented outdoors through roof fittings. Fans without operating backdraft dampers should be repaired, equipped with backdraft dampers, or the fan should be replaced. Check new fans for proper damper operation. Use rigid aluminum or galvanized pipe for venting whenever possible and insulate the pipe to prevent condensation.

- ✓ Install chutes, dams, tubes, or other blocking devices to prevent blown insulation from plugging air channels from soffit vents into the attic. These chutes or other devices maximize amount of insulation that may be installed over top plates, and help 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 22 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 the 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.

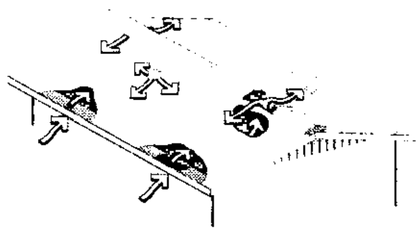
Attic venting

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. Adding attic ventilation during weatherization, however, is seldom necessary.

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, only one square foot per 300 square feet of attic area is required.

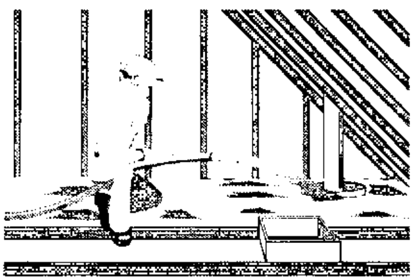
However, preventing moisture from entering the attic is now recognized as a best practice, superior in results to attic-venting for keeping attic insulation dry. Ceilings should be thoroughly air-sealed to prevent leakage of moist indoor air through the ceiling, which deposits moisture in the insulation during cold weather.

Many building experts now believe that attic venting requirements are arbitrary and possibly excessive. Attic venting can increase ceiling air leakage by increasing the stack effect. Attics, cooled by radiation into the night sky, can condense water out of ventilating air in some climates.



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

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 should 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.

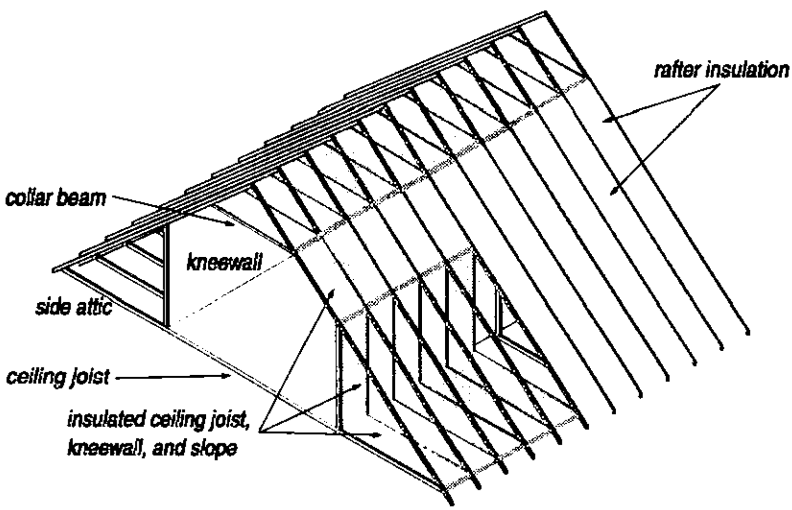
3.2.4 Finished attics of Cape-Cod homes

The finished attic consists of five sections.

1. Exterior finished attic walls (end walls of finished attic). *See "Wall insulation" on page 3-19.*
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. See also *"Sealing bypasses" on page 3-2.*

✓ Seal attic bypasses before insulating.

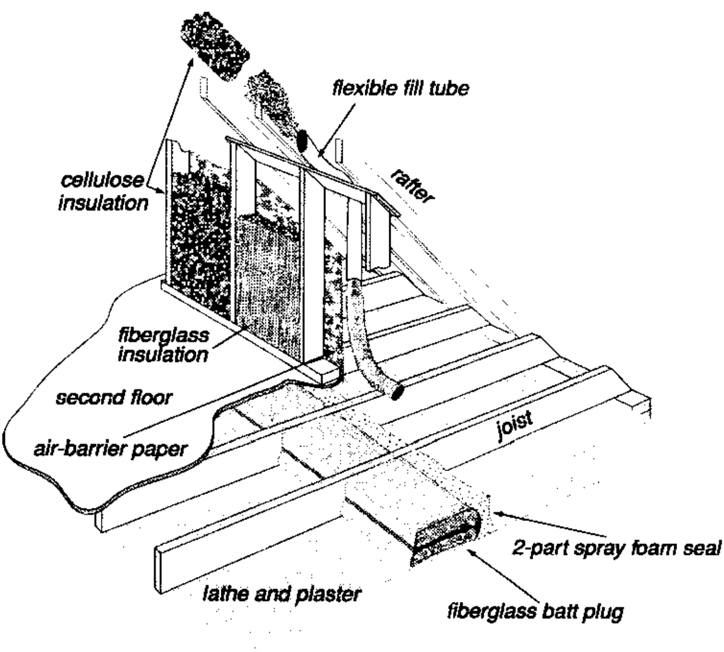


Finished attic: *This illustration depicts two approaches to insulating a finished attic. Either insulate the kneewall and side attic or insulate the rafters.*

✓ Create an airtight and structurally strong seal in the joist space under the knee-wall. Best practice is usually to seal these areas with plastic foam insulation. Consider these options for sealing the joist space.

1. Cut 2-inch-thick foam sheets an inch short in length and width and foam their perimeters with one-part foam.
2. Insert a fiberglass batt to block the empty space and foam the opening and its perimeter with two-part spray foam.
3. Blow cellulose insulation into the floor cavity until it plugs the cavity with a densely packed mass of insulation. Although acceptable, the air-seal and its structural strength aren't as good as the foam seals.

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



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

- ✓ Insulate knee walls with densely packed cellulose or fiberglass. Prepare the knee wall for blowing by nailing air-barrier paper to the knee wall with large-headed nails or stapling the paper through a strip of cardboard or thin wood. Or, insulate the knee wall with high-density batts and apply air-barrier paper to the attic side of the wall to prevent convection and air leakage.
- ✓ 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 and collar-beam access hatch with 2 or more inches of rigid foam insulation. Weatherstrip and provide positive closure (latch, sash locks, gate hooks, etc.) to hatches where appropriate.

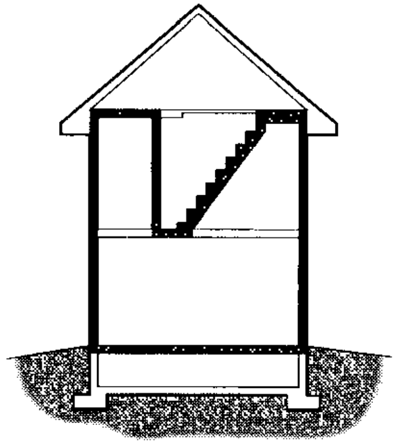
Option: Insulate rafter cavity with high-density fiberglass batts or dense-packed cellulose or fiberglass. The area where the rafter meets the ceiling joist should be air-sealed and insulated with 2-part foam.

Walk-up stairway and door

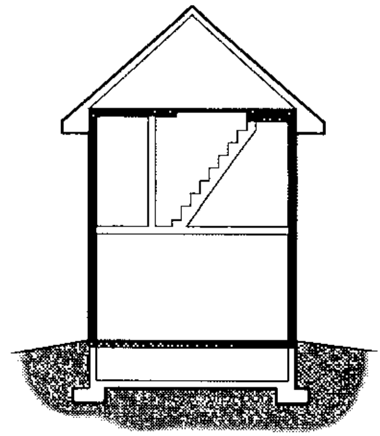
Think carefully about how to establish a continuous insulation and air barrier around or over top of the attic stairway. If possible, install a hinged, insulated, and weatherstripped hatch door.

If attic is accessed by a stairwell and standard vertical door, blow dense-packed 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.



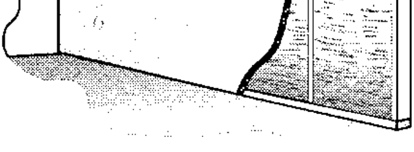
Attic stairway walls and stairs: *Insulating and air sealing these is one way of establishing the thermal boundary around such an attic access.*



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

3.2.5 Wall insulation

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



Blowing insulation using a directional nozzle: *Blowing insulation 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 the existing walls uninsulated or partially insulated, 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 multi-hole method. The dense-pack method is preferred because it ensures that wall insulation achieves the correct coverage and density.

Inspecting walls

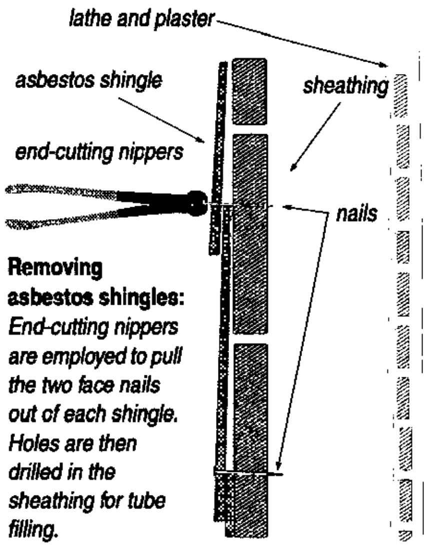
- ✓ Inspect walls for evidence of moisture damage. If existing condition of the siding, sheathing, or interior wall finish indicates an existing moisture problem, no sidewall insulation should be installed until the moisture problem has been identified and corrected.
- ✓ Seal gaps in external window trim and other areas that may admit rain water into the wall.
- ✓ Inspect indoor areas on exterior walls to assure that they are strong enough to withstand the insulation blowing.
- ✓ Inspect for interior openings from which insulation may escape, such as pocket doors, balloon framing, un-backed cabinets, interior soffits, and closets. Seal openings as necessary to prevent insulation from escaping.
- ✓ Inspect walls for live knob-and-tube wiring. Don't insulate walls with 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. See *"Electrical safety" on page 1-16.*

Removing siding and drilling

✓ Avoid drilling through siding. Where possible, carefully remove siding and drill through sheathing. (The sheathing isn't painted with lead paint and so isn't a hazard to drill. Inserting a fill tube through the sheathing is easier than inserting it through both siding and sheathing.)

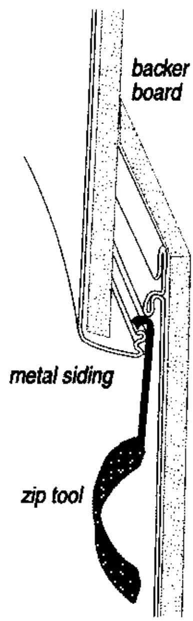
✓ If siding cannot be removed, obtain homeowner's permission to drill through siding or interior finish. Practice lead-safe weatherization when drilling through interior walls. *See "Lead-safe weatherization" on page 1-14.*

✓ 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 keeps dust down.



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.*

Zip tool: *A zip tool separates the joint in metal siding.*



✓ Metal or vinyl siding may be removed with the aid of a zip tool.

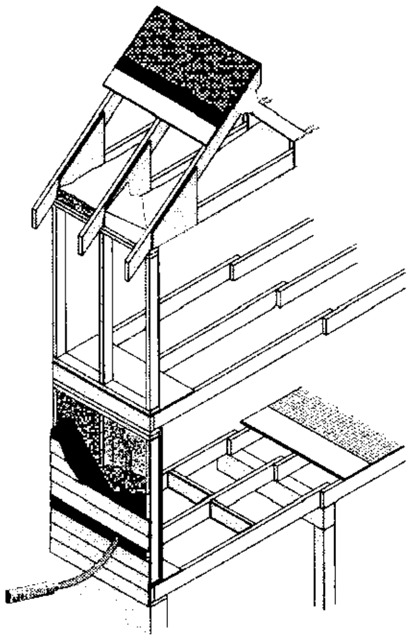
✓ Homes with brick veneer or blind-nailed asbestos siding may be insulated from the inside. Holes drilled for insulation must returned to an appearance as close to original as possible or satisfactory to the customer.

✓ 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.

Dense-packing 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 inserting a fill-tube through a single hole or drilling multiple holes (at least 3 holes per 8-foot cavity).



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.*

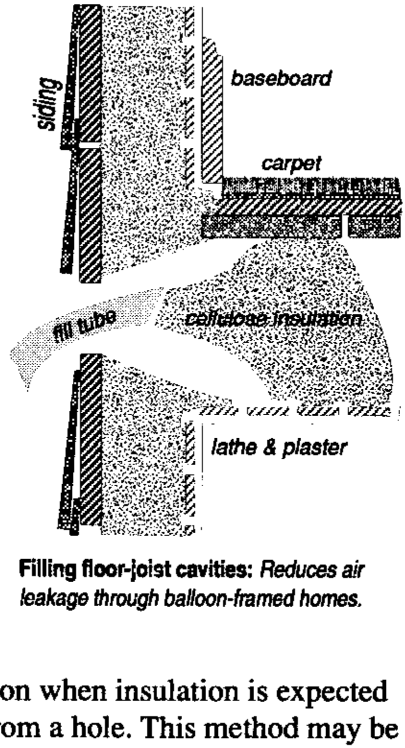
3. Dense-packed wall insulation is best installed using a blower equipped with separate controls for air and material feed.
4. Marking the fill-tube in one-foot intervals allows the person blowing insulation to verify the correct penetration of the tube into the wall.
5. Starting with several full-height, 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. Seal holes with plugs before replacing siding.

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. Placing a plastic bag over the end of the fill tube and blowing the insulation into the bag will limit the amount of insulation it takes to plug this area if the process is requiring too much insulation.



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

Multi-hole method

The multi-hole method is not a preferred wall-insulation method because voids and sub-standard density are common when insulation is expected to travel more than 20 inches from a hole. This method may be effective if three holes are drilled in each 8-foot cavity. When using this method, employ a powerful blowing machine, preferably one with a gasoline engine.

✓ Drill three holes into each stud cavity large enough to admit a directional nozzle. The top hole should be located no more than 12 inches below the top plate. The bottom hole should be no more than 20 inches above the bottom plate. The third hole should be drilled halfway between these other two.

✓ Examine wall cavity with wire probe or steel tape to determine location of obstacles and nature of cavities around window and door areas.

✓ All wall cavities around windows and doors should be filled with insulation.

Open-cavity wall insulation

Fiberglass batts are the most common open-cavity wall insulation. They achieve their rated R-value only when installed 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.

✓ Prefer batts marked R13 to batts marked R11.

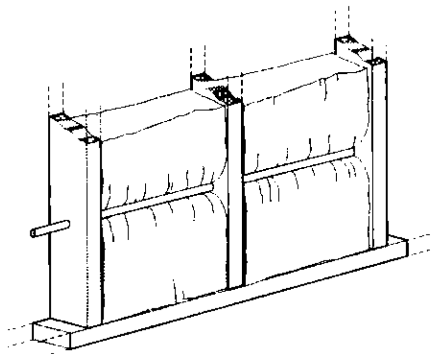
✓ Staple faced insulation to outside face of studs—avoid inset stapling.

✓ 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.

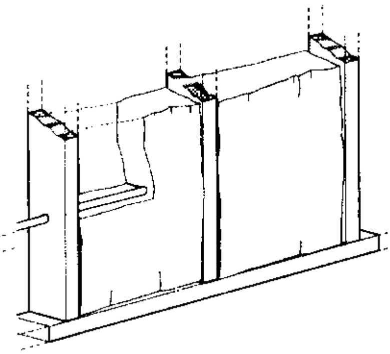
✓ Split batt around wiring rather than letting the wiring bunch the batt to one side of the cavity.

✓ Insulate behind and around obstacles with scrap pieces of batt before installing batt.

✓ Installed fiberglass insulation exposed to the interior living space must be covered with minimum $^1/_2$-inch drywall or other material that has an ASTM flame spread rating of 25 or less.



Fiberglass batts, compressed by a cable: *This reduces the wall's 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.*

3.2.6 Floor insulation and foundation insulation

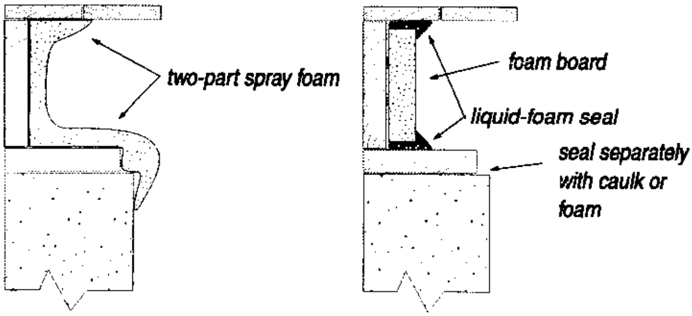
Floor insulation with floor air-sealing completes the thermal boundary at the base of the building, a region which seldom has a complete thermal boundary. Attic and wall insulation are higher priorities for homes in the Southeastern states. Floor insulation may or may not be cost-effective or practical, considering the home's weatherization budget and the other weatherization priorities.

Rim insulation and air-sealing

The area where floor joists meet the rim joist on two sides of the floor and the perimeter longitudinal box cavities on the floor's other two sides constitute a major weak point in the air barrier and insulation. Insulating and air-sealing both the rim joist and longitudinal box joist are appropriate as a individual procedures or as part of floor or foundation insulation.

Air-seal stud cavities in balloon framed-homes as a part of insulating the rim joist. Air-seal other penetrations through rim before insulating. Two-part spray foam is the most versatile air-sealing and insulation system for the rim-joist because spray foam air-seals and insulates in one step. Polystyrene or polyurethane rigid-board insulation is also good practice for insulating and air-sealing the rim-joist area and is somewhat cheaper per square foot. Longitudinal box sill cavities enclosed by a floor joist may be sealed and blown with wall insulation product unless moisture is present.

Fiberglass insulation is less effective for insulating rim joists because air sealing must be done separately and air can circulate around the fiberglass and cause condensation on the cold rim joist during winter. All joints in the rim-joist area should be sealed with caulk or foam before insulating with fiberglass batts.



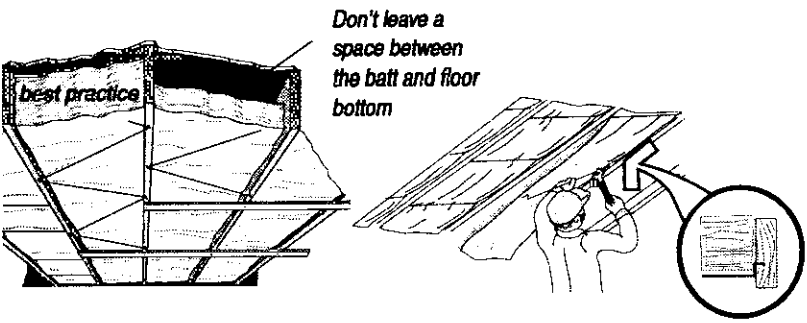
Foam-insulated rim joists: *Installing foam insulation is the best way to insulate and air-seal the rim joist.*

Floor insulation

All appropriate measures should be taken to establish an effective air barrier at the floor, prior to insulating the floor, to prevent air from passing through or around the insulation. The best way to insulate a floor cavity is to blow fibrous insulation between the floor and a breathable bottom barrier like Tyvek®, attached to joists with large-headed nails or stables and wood strips.

Another effective procedure is to completely fill the joist cavity with unfaced fiberglass insulation. Partially filling the cavity with fiberglass is less satisfactory because securing the batts up against the subfloor can be difficult. Consider the following specifications.

- ✓ Install minimum R19 to R38 insulation between floor joists.
- ✓ Insulation should be installed without voids, edge gaps, or end gaps.
- ✓ Insulation should fit snugly 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, plastic mesh, or other supporting material. Insulation should contact subfloor to prevent convecting air above the insulation from reducing its R-value.
- ✓ Faced insulation should be installed with the foil or kraft facing placed up towards the floor sheathing.
- ✓ Floor insulation should fit tightly against the rim joist.
- ✓ If balloon framed, air seal stud cavities prior to installing floor insulation.
- ✓ Insulation must not be installed over knob-and-tube wiring.
- ✓ If water pipes protrude below floor joist area, they should be insulated.
- ✓ Ducts remaining in the crawl space or unoccupied basement should be sealed and insulated.
- ✓ In crawl spaces, install a ground air-moisture barrier that runs up the foundation walls at least 6 inches.

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. 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, installed without voids or gaps. Extend air-moisture barrier up foundation wall a minimum of 6 inches. Overlap air-moisture barrier at least 6 inches.

Best practice involves sealing the seams in the ground moisture barrier with construction tape or acoustical sealant, making it a air-moisture barrier. If the crawl-space access is difficult or if the air barrier is at the floor, the polyethylene need not be sealed.

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.

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 three primary ways: increasing thermal resistance, decreasing solar heat gain, reducing air leakage. Shading is probably the most practical window improvement for the Southeast. The limiting factors to the application of other window and door measures are the high cost and low energy savings. For more information on weatherization priorities, see °*"Understanding energy usage" on page 2-2*.

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 1-14*.

3.3.1 Window shading

Much of the solar energy that strikes a home's windows will pass through the glass and enter the living space. This solar gain accounts for up to 40% of the summer overheating in many homes. It works far better to block this solar energy before it enters the home than to cool the home after it overheats.

Window shading increases comfort and reduces the cost of cooling, and is one of the most cost-effective weatherization measures in hot climates. Not all windows cause overheating, so you should direct your efforts towards windows where the most heat enters:

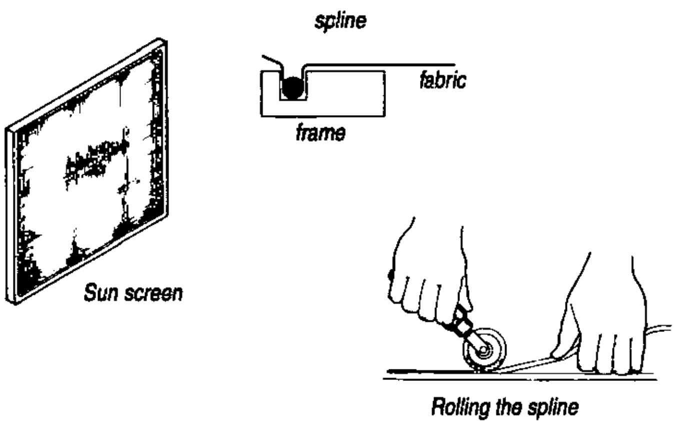
Windows with no shade from landscaping or roof overhangs.

- Windows that face east or west, followed by windows on the south side.
- Large windows.

Exterior window treatments

Sunscreens are one of the most effective window-shading options. Sun screens absorb or reflect a large portion of the solar energy that strikes them, while allowing a diminished but acceptable view out of the window.

Sunscreens are made of sun-resistant mesh fabric that is stretched over an aluminum frame. They are installed on the outside of the window, and work well on fixed, double-hung, or sliding windows. They aren't suitable for jalousie, casement, awning, or other out-swinging windows.



Sun screens: *Installed on the window's exterior, sun screens absorb solar heat before it enters the home. This strategy is superior to interior window treatments, which reflect heat back after it has entered.*

Sun screens are easily made in the shop. Cut the frames to size from bulk frame stock using a metal cutting saw. Screw the frames together through reinforced corner pieces. Cut the fabric cut to size, and fasten it to the frame using plastic splines that fit into the frame.

Install sunscreens on the exterior sash or window trim. Drill pilot holes for screws that pass through the aluminum frame, or use clips that are screwed to the window outside the sun screen.

Other exterior window shades such as awnings, shutters, or rolling shades can provide good shade for sunny windows, but are generally too expensive for weatherization programs.

Interior window treatments

Interior window shades with bright white or metallic surfaces can also slow solar heat gain. The reflective surface should face outdoors, though the interior surface can be any color. Interior shades are not as effective as exterior shades because they block solar energy after it enters the home, releasing some of this heat into the home.

Opaque or room-darkening roller shades are the most effective interior shading choice. Avoid translucent or light-admitting shades because they allow more heat to enter the home. Purchase window shades in the standard sizes that fit most windows. Custom-sized shades are considerably more expensive and aren't practical for weatherization programs.

Venetian blinds, mini-blinds, or cellular pleated shades are less cost-effective than roller shades, though they may have better acceptance among occupants. Traditional fabric curtains are the least effective solar shade. They are also more expensive, and often create a decorating conflict with the home's occupants.

Any interior shades must be closed during the day to be effective. Instruct the occupants to close window shades in the morning before their home begins to heat up, and to open them in the evening to help cool the home. They should also be opened during cool weather to allow solar heat to enter the home.

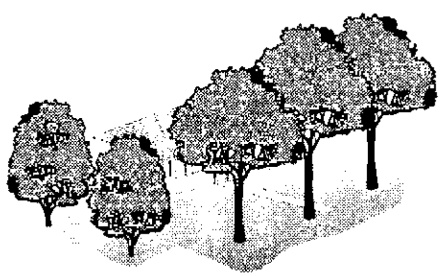
Interior reflective window films (like those used on automobiles) provide some shading while maintaining a view. They must be very dark, however, to provide much cooling benefit, and they tend to overheat windows, possibly voiding the window manufacturer's warranty.

Landscaping for Shade

Trees and bushes slow solar heat gain through windows, walls, and roofs. They also cool the air around the home when moisture evaporates from their foliage. Well-planned landscaping can reduce an un-shaded home's air conditioning costs by up to 50% while adding value to the home and neighborhood.

The best plan for cool landscaping includes tall trees on the south side of the home to block high mid-day sun. Shorter trees or bushes on the east and west block sun when it's lower in the sky.

Plant deciduous trees that loose their leaves in the autumn to admit winter sun. Choose types that are quick growing and easy to care for in your region. Check with a local nurseryman to determine the best type of trees, time to plant, and method of planting.



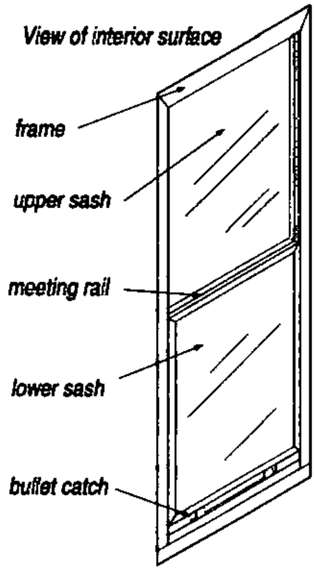
Trees for shade: *Landscaping is a good long-term investment for residences. Tall deciduous trees on the south block high summer sun while allowing lower winter sun to reach the home. Shorter trees or bushes provide protection from low-angle sun on the east and west.*

3.3.2 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 should be caulked around the frame at time of installation, except for weep holes that should not be sealed. If weep holes are not manufactured into new storm window, weep holes should 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.



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

- Fixed storm windows must not restrict the existing capacity and access required for emergency exits.

3.3.3 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 1-14.*

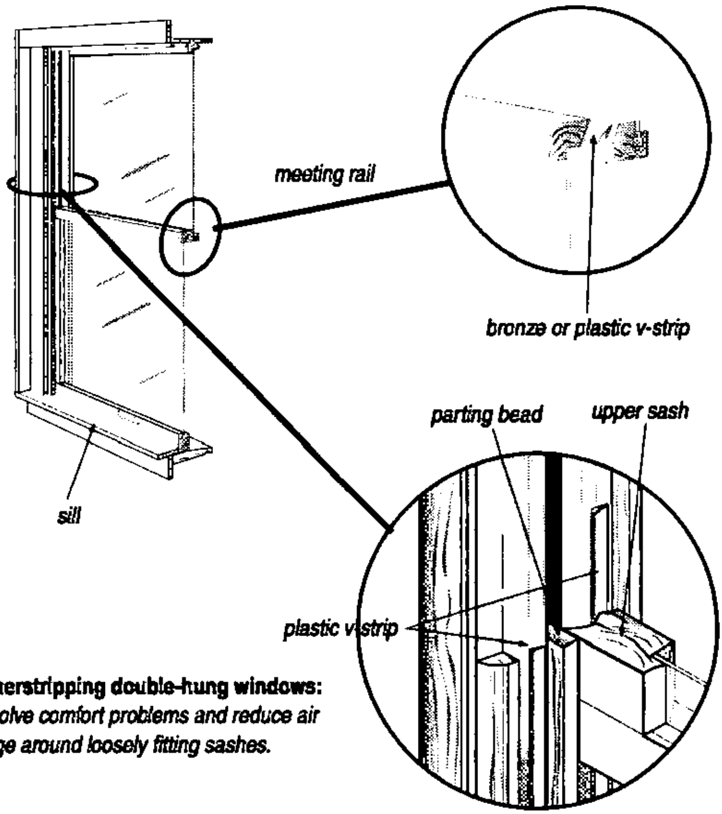
Repair measures may include the following measures:

- 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 1-14.*

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.

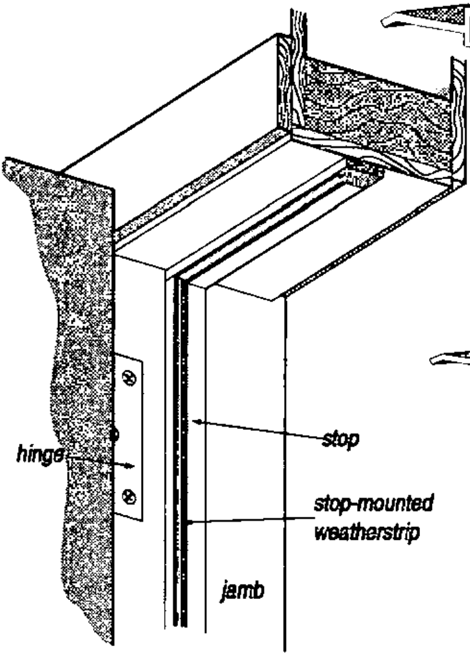
3.3.4 Door measures

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.

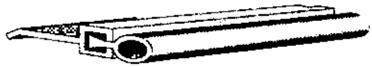
Door weatherstrip, thresholds and sweeps

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.



Vinyl flap weatherstrip is particularly flexible, allowing the door to remained sealed with seasonal movements of the door



Silicone bulb weatherstrip is much more flexible than vinyl bulb and therefore seals better.

Bronze v-strip mounts on the door jamb and is very durable.

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 1-14.*

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.

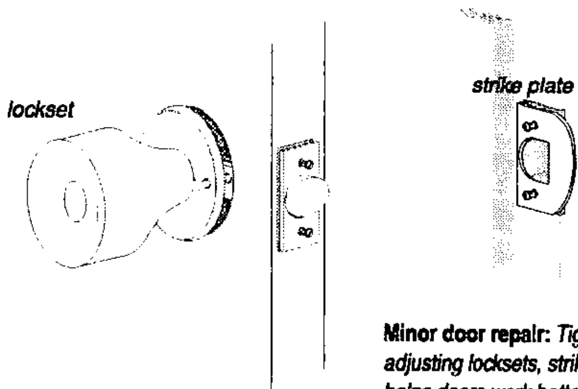
- All replacement doors must have a solid wood core or an exterior-grade foam core. Replace the door using a solid-core or insulated door-blank or a pre-hung steel insulated door. Replacing an exterior panel door with another panel door is not allowed. All replacement doors must have three hinges.
- Replacement door should not have glass panes. If home-owner 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.



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

✓ 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.

Storm doors

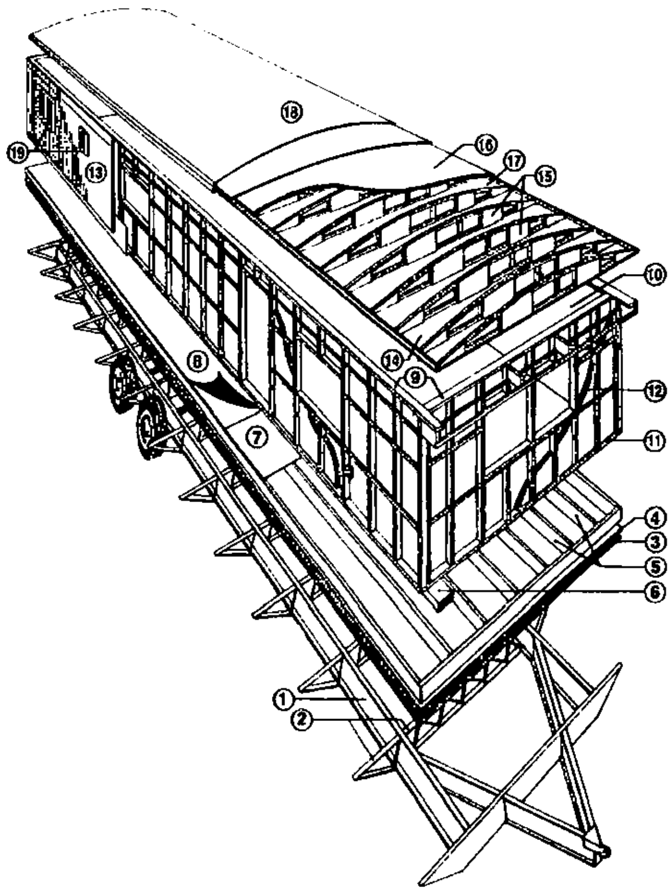
Storm doors are expensive per square foot of area and most weatherization programs don't install them because all of the common measures described here are considerably more cost-effective. Storm doors can damage steel insulated doors by causing them to overheat.

4.0 Mobile Home Standards

Mobile homes typically use more energy per square foot than conventional homes. Mobile homes are also 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. Mobile home heating retrofit and replacement are often cost-effective when energy usage is high.

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

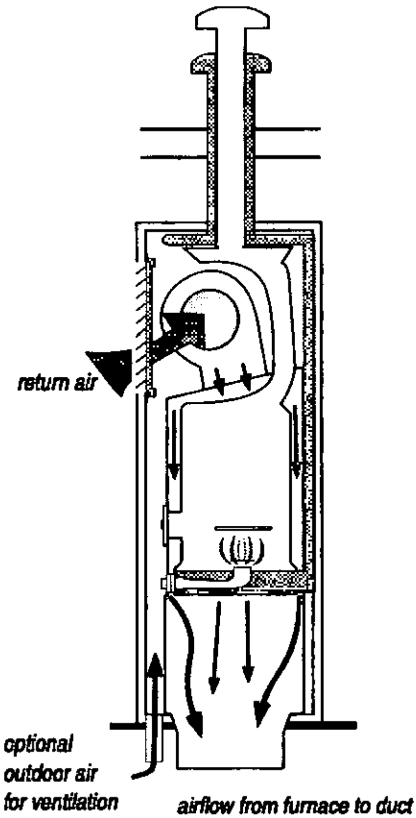
Mobile home furnaces are similar to furnaces for site-built homes in some ways and different in other ways. Mobile home combustion furnaces have been sealed-combustion since the early 1970s. Gas furnaces are either the old atmospheric sealed-combustion type or the newer fan-assisted mid-efficiency furnaces. Some older less-efficient sealed-combustion 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 directly 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.*

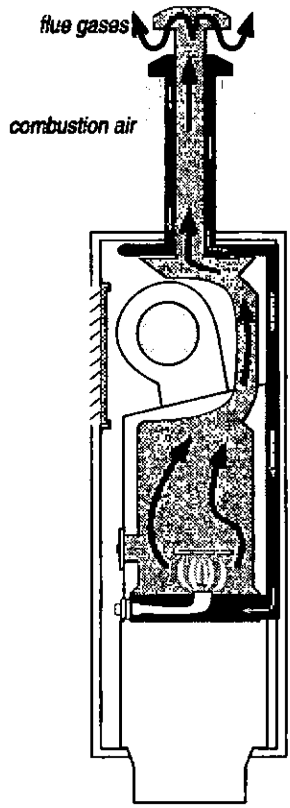
Mobile-home furnaces are different from conventional furnaces in the following ways.

- 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. 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.

Consider replacing the existing furnace with a sealed-combustion, downflow, condensing furnace. The only condensing furnaces, known to the author and approved for mobile homes, are made by the Coleman-Evcon Division of York.

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.

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

✓ Attach the furnace base firmly to the duct and seal all seams between the base and duct with mastic and fabric tape. Support the duct with additional strapping if necessary.

✓ 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 chimney that is manufactured specifically for the new furnace.

✓ If the old chimney opening doesn't exactly line up with the new furnace's flue, cut the opening larger so that the new chimney can be installed absolutely plumb. Also make sure the chimney cap is installed absolutely straight.

Mobile home furnaces have short chimneys, and their combustion process depends on a delicate balance between combustion air entering and combustion gases leaving. The furnace demands a plumb, leak-free chimney, and a properly installed chimney cap. Follow manufacturer's installation instructions exactly. See *"Mobile-home furnace venting" on page 5-15*.

4.2 Mobile Home Air Sealing

The locations and relative importance of air-leakage sites was a mystery before blower doors. Some mobile homes are fairly air-tight 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*

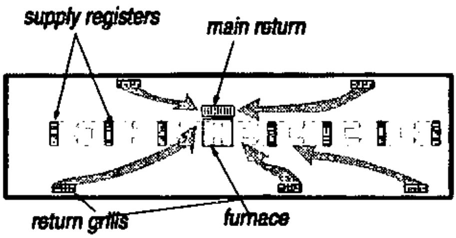
Air Sealing Procedure	Typical CFM_{50} Reduction
Caulking and weatherstripping	50–150
Installing tight interior storm windows	100–250
Sealing leaky supply ducts	100–500
Sealing leaky water-heater closet	200–600
Sealing floor as return-air plenum	300–900
Patching large air leaks in the floor, walls and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

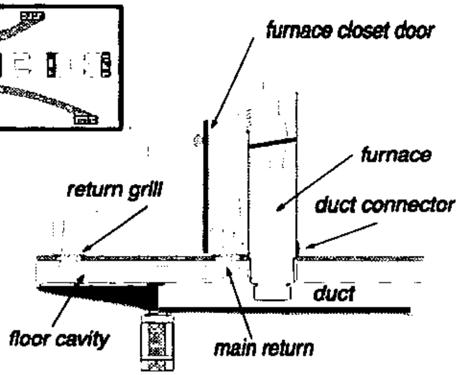
- Gaps around the electrical service panel box, light fixtures, fans, and flue pipes.
- Joints between the halves of double-wide mobile homes and between the main dwelling and additions.

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.



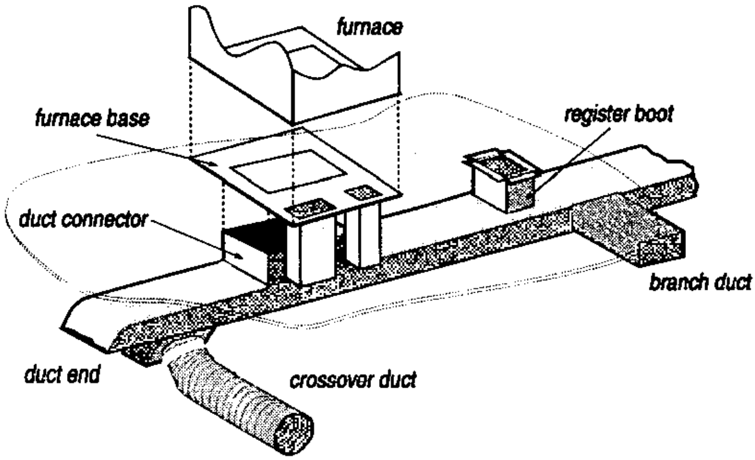


Floor return air: *Return air registers at the home's perimeter bring air back to the furnace. The floor cavity serves as one big leaky return duct. When leakage is serious, the floor return system should be eliminated.*

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 a 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.



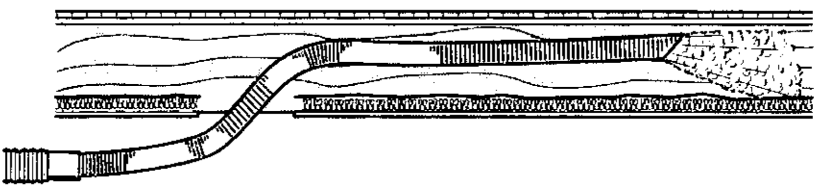
Mobile home ducts: *Mobile home ducts leak at their ends and wherever a joint occurs—especially at the joints beneath the furnace. The furnace base marries the furnace to the duct connector. Leaks occur where the duct connector meets the main duct and where it meets the furnace. Branch ducts are rare 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. The most important moisture-control measure is installing a ground-moisture barrier. See *"Moisture problems" on page 1-8.*

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, which greatly reduce the R-value.



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

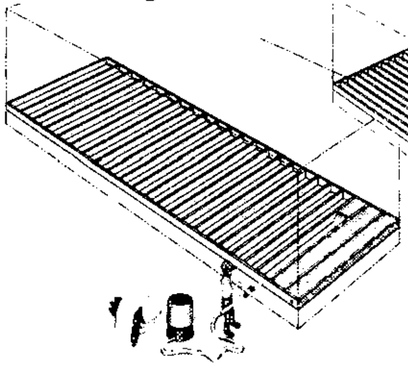
Preparing for mobile home floor insulation

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

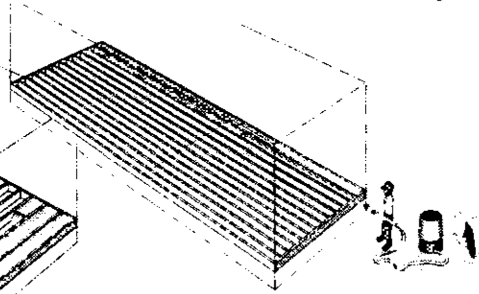
1. Tightly seal all holes in the floor.
2. Inspect the ducts and seal all significant holes in the ducts.
3. Install a ground moisture barrier in the crawl space.

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.*

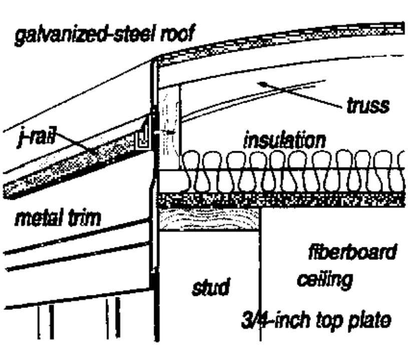


Blowing lengthwise cavities: *Floors with lengthwise joists can rarely be filled completely from the ends because of the long tubing needed. The middle can be filled from underneath.*

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 3-26.*

When blowing through holes from underneath the home, consider blowing through damaged areas before patching them.

4.3.2 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

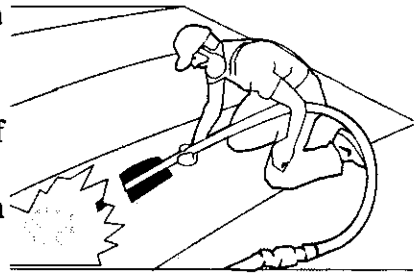
- ✓ Inspect the ceiling and seal all penetrations.
- ✓ Reinforce weak areas in the ceiling.
- ✓ Take steps to maintain safe clearances between insulation and recessed light fixtures and ceiling fans.
- ✓ Assemble patching materials such as metal patches, roof cement, sheet-metal screws, putty tape, and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

Blowing through the top

This procedure involves cutting large square holes. Each square hole provides access to two 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 permits 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 roof 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.



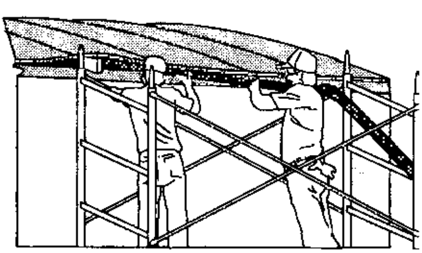
Roof-top insulation: *Blowing fiberglass insulation through the roof top is effective at achieving good coverage and density on almost any metal roof.*

6. Cover the first patch with a second patch, consisting of an 18-inch-square piece of foil-faced butyl rubber.

The advantages of this option are the excellent job it does at filling the critical edge area with insulation. The patches are easy to install if you have the right materials. Weather can be a bigger problem than with blowing through the edge.

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. (Two common choices include steel muffler pipe and aluminum irrigation pipe.)
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. The ideal way to refasten the metal roof edge is with air-driven staples, which is the way most roof edges were attached originally.

Note that this re-installation of the roof edge is the most important part of this procedure. Putty tape must be replaced and installed as it was originally. This usually involves installing one layer of putty tape under the metal roof and another between the metal roof edge and the j-rail. The advantages on this procedure is that if you have the right tools, including a powered stapler, this method can be very fast and doesn't require cutting into the roof. The disadvantages of this procedure are that you need scaffolding and you can't do it if the roof has a strongback.

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.

4.3.3 Cool roofs for mobile homes

Cool roof coatings reduce summer cooling costs and improve comfort by reflecting solar energy away from the home's roof and slowing the flow of heat into the home. They are shown to reduce overall cooling costs by 10-70%, and are a good choice for mobile homes or site-built homes with low-slope or flat roofs. Cool roof coatings are usually bright white, and must have a reflectivity of at least 60% to meet the Energy Star (small caps) requirement for cool roof coatings.

Cool roof coatings are usually water-based acrylic elastomers, and are applied with a roller or airless sprayer. They can be applied over most low-slope roofing materials such as metal, built-up asphalt, bitumen, or single ply membranes. Some underlying materials require a primer to get proper adhesion—check the manufacturer's recommendation for the material you'll use. Coatings are not recommended over shingle roofs.

Surface preparation is critical when applying any coating. The underlying roofing material must be clean so the coating will stick, and repairs should be performed if the existing roofing is cracked or blistered. Roof coatings will not stick to dirty or greasy surfaces, and they cannot be used to repair roofs in very poor condition. Observe the following specifications when installing cool roof coatings.

- ✓ Clean the roof of debris such as dirt, leaves, and toys. Wash the roof with water and a scrub brush, or better yet use a pressure washer.
- ✓ Reinforce any open joints around skylights, pipe flashings, roof drains, wall transitions, or HVAC equipment. For built-up asphalt or bitumen roofs, repair any cracks, blisters, or de-laminations. Use polyester fabric and roof coating for these reinforcements and repairs by dipping fabric patches in the roof coating and spreading them over the

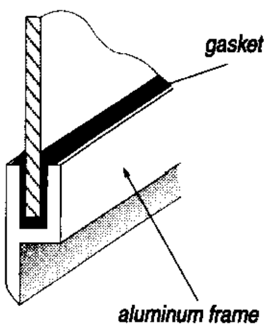
existing roofing, or by laying dry fabric into a layer of wet coating. Smooth the patch down with a broad-knife or squeegee to remove bubbles or wrinkles. Allow any repairs to cure for 1 to 2 days before applying the top coat.

- ✓ For metal roofs, sand any rusted areas down to sound metal. Install metal patches over any areas that are rusted through, followed by polyester patches as described above.
- ✓ Install the coating when dry weather is predicted. Rain, heavy dew, or freezing weather, if it happens within 24 hours of installation, will weaken the coating's bond to the underlying roofing.
- ✓ Protect any nearby windows, siding, or automobiles from over-spray or splatters. For roller application, use a large brush for the edges, and a shaggy 1 to 1 $^1/_2$ inch roller on a 5- or 6- foot pole for the field. For airless sprayer application, experiment with different nozzles to find the one that delivers enough material without dripping. By either method, run the coating up roof jacks, skylight curbs, and other penetrations to help seal these areas. Install at least two coats, with the second coat applied in the opposite direction to the first to get more complete coverage. Allow a day for drying between coats.

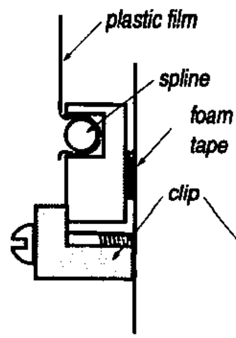
4.4 Mobile Home Windows and Doors

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

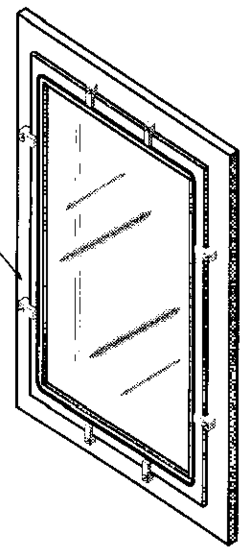
4.4.1 Mobile home storm windows



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



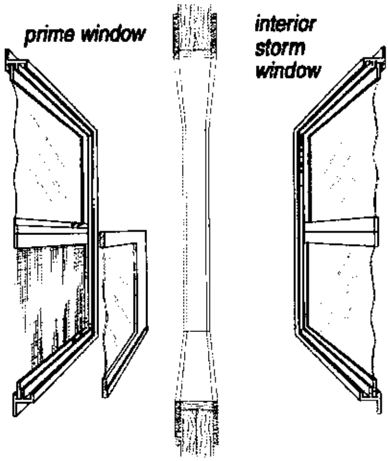
Plastic storms: *Some newer storm-window designs use a lightweight aluminum frame and flexible or rigid plastic glazing.*



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

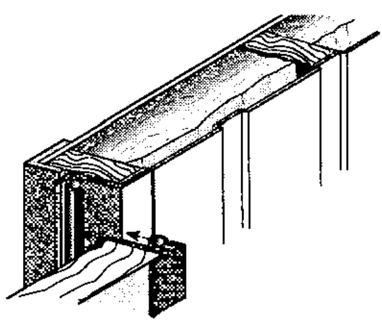
Inspect condition of rough opening members before replacing windows. Replace deteriorated, weak or waterlogged framing members.

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 Mechanical System Specifications

Combustion heating systems heat most homes and their operation generates a host of important topics. Chimneys, venting, and combustion air lead off this chapter because they are universal to combustion heating. Combustion safety and efficiency is the topic of the middle part of this chapter. Distribution systems, furnaces and boilers, and installation issues follow the sections on combustion. The chapter closes by addressing water heating, refrigerators, and lighting.

Gas and oil combustion efficiency and safety are discussed in separate sections. Natural gas and propane systems are most common and they are 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.

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.

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 their combustion gases makes them operate more safely.

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

5.1 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 5-1: 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

5.1.1 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.

5.1.2 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.

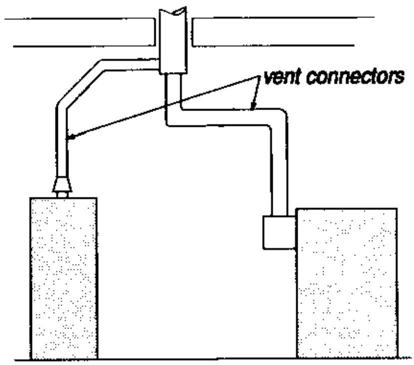
- A vent connector is almost always the same size as the vent collar on the appliance it vents.
- Vent-pipe sections should be fastened together with screws or rivets.
- The vent connector should be sealed where it enters the chimney.
- Vent connectors should be free of rust, corrosion and holes.
- The 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 5-2.*

Table 5-2: *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

- 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.



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.*

- Vent connectors must slope upward toward their outlet or to their connection with the chimney at a 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.

Table 5-3: *Vent Connector Diameter (in.) and Maximum Horizontal Length (ft.)*

3"	4"	5"	6"	7"	8"	9"	10"	12"	14"
4.5'	6'	7.5'	9'	10.5'	12'	13.5'	15'	18'	21'

From *International Fuel Gas Code 2000*

- 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

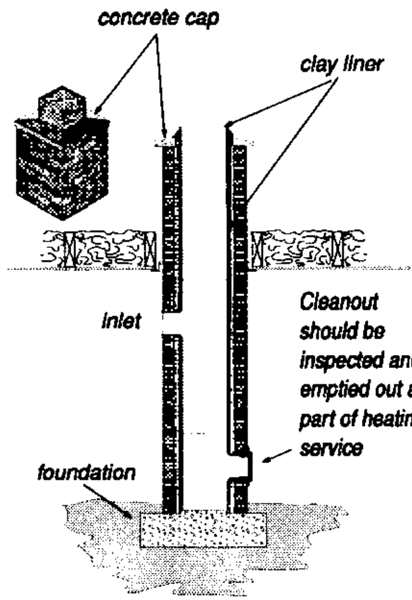
Table 5-4: *Clearances to Combustibles for Common Vent Connectors*

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

with a minimum clearance to combustibles and with a reference to a testing and listing agency, like Underwriters Laboratory.

5.1.3 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 a very 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.

- Existing masonry chimneys should be lined with a fireclay flue liner. There should be a ½-inch to 1-inch air gap between the clay liner and the chimney's masonry 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.
- The chimney's penetrations through floors and ceilings should be sealed with metal as a firestop and air barrier.
- Deteriorated or unlined masonry chimneys may be rebuilt as specified above or relined as part of heating-system replacement or venting-safety upgrade. As an alternative, the vertical chimney may be replaced by a sidewall vent, equipped with a power venter mounted on the exterior wall.

Table 5-5: 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. Parts include: metal pipe, weight-supporting hardware, insulation shields, roof jacks, and chimney caps. One manufacturer's chimney may not be compatible with another's connecting fittings.

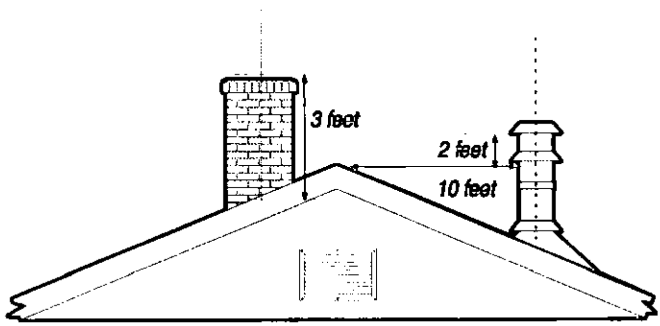
All-fuel metal chimneys come in two types: insulated double wall metal pipe and triple-wall metal pipe. Install them strictly observing the manufacturer's specifications.

All-fuel metal chimney: *These chimney systems include transition fittings, support brackets, roof jacks, and chimney caps. The pipe is double-wall insulated or triple wall.*

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 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.*

Table 5-6: Roof Slope and B-Vent Chimney Height (feet) Above Roof

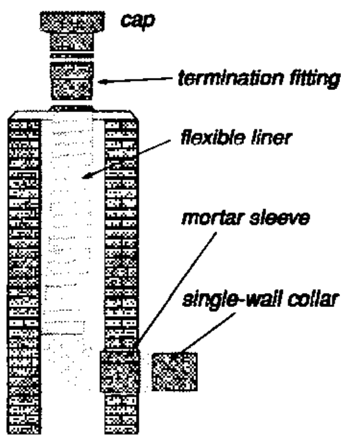
flat-6/12	6/12-7/12	7/12-8/12	8/12-9/12	9/12-10/12	10/12-11/12	11/12-12/12	12/12-14/12	14/12-16/12	16/12-18/12
1'	1' 3"	1' 6"	2'	2' 6"	3' 3"	4'	5'	6'	7'

From *International Fuel Gas Code 2000*

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 5-13*.

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 such 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 to reduce condensation.

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%.

5.1.4 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 are Category I, which have negative pressure in vertical chimneys 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 both the appliance and vent.

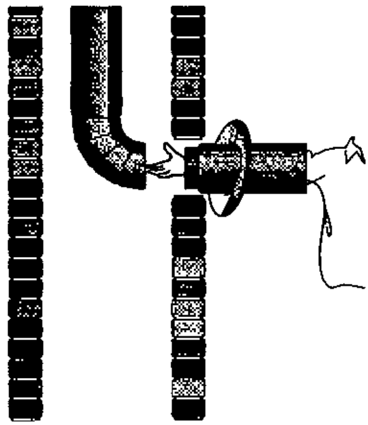
Venting fan-assisted furnaces and boilers

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 Category I 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.
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



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.*

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 venting choice of whether to install a fan-assisted furnace or boiler 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 draft. B-vent must be sealed with high-tempera-

Table 5-7: Characteristics of Gas Furnaces and Boilers

AFUE	Operating characteristics
70+	Category I, draft diverter, no draft fan, standing pilot, non-condensing, indoor combustion and dilution air
80+	Category I, no draft diverter, draft fan, electronic ignition, indoor combustion air
90+	Category IV, no draft diverter, draft fan, low-temperature plastic venting, positive draft, electronic ignition, condensing heat exchanger, outdoor combustion air is strongly recommended

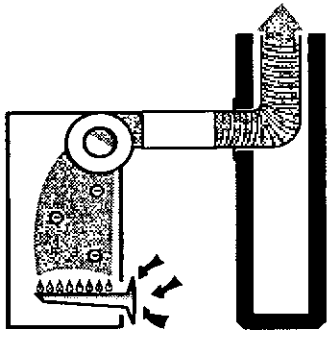
ture silicone caulking or other approved means to air-seal its joints.

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 airtight stainless-steel vent piping or B-vent. B-vent must be used in concealed or ventilated areas like crawl spaces or attics.

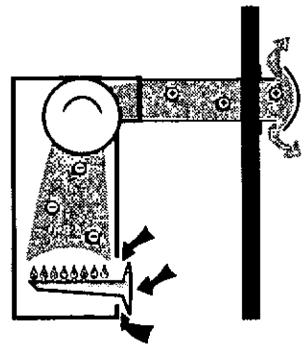
Existing fan-assisted appliances may have problems with weak draft and condensation when vented horizontally. Horizontally vented, fan-assisted furnaces and boilers may require a retrofit power venter to create adequate draft.

Condensing-furnace venting

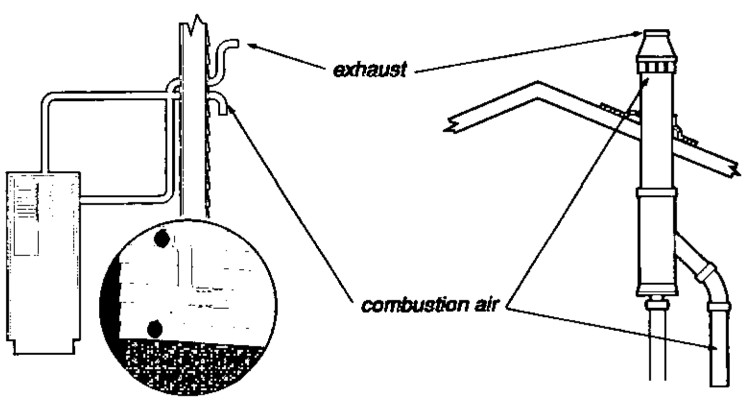
Condensing furnaces with 90+ AFUE are vented horizontally or vertically through PVC Schedule 40 pipe. The vent is pressurized, making it Category IV. Vent piping should be sloped back toward the appliance, so that its system of condensate disposal and treatment can function.



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.*



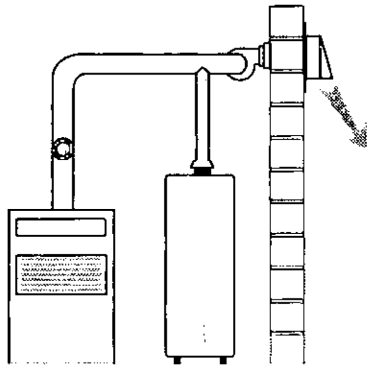
Condensing furnace venting: *The two common types of termination for plastic condensing vents are separate pipes and a combined fitting. Vents going through the roof are preferred for their being more tamper and damage resistant.*

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.

5.1.5 *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.

Many power venters allow precise control of draft through air controls on the their fans. 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/or barometric damper, minimizes excess combustion and dilution air. Flue gas temperatures for power venters can be cooler than temperatures needed to power vertical atmospheric chimneys. Less excess air and cooler flue gases can improve combustion efficiency in many cases, compared to the non-adjustable draft of a vertical chimney, however the power venter must be installed by a technician familiar with adjusting the draft to each appliance.



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. Types B or L vent are good choices for horizontal vent piping, depending on whether the fuel is gas or oil.

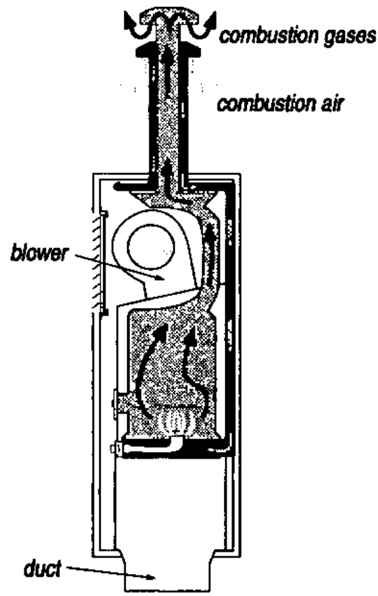
Power venters should be considered as a venting option when:

- 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 with its 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 new furnace or boiler is vented through a plastic venting system.
- High draft in the existing vertical chimney is creating unstable combustion or low steady-state efficiency in the appliances connected to it.

5.1.6 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 chimneys and chimney caps must be installed perfectly vertical and the cap must be securely attached to avoid venting problems and tripping of the pressure switch.*

When replacing standard 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. The roof jack may need replaced and the hole for the chimney moved. It is essential that the chimney be vertical and that the chimney cap not be tipped. Many callbacks are caused by chimney and chimney-cap alignment. See *"Furnace replacement" on page 4-5.*

The Coleman Evcon Corporation makes downflow condensing furnaces approved for use in mobile homes. These positive-draft furnaces may eliminate venting and combustion-air problems, common to mobile home furnaces, because of their robust positive draft and negatively pressurized combustion-air vent.

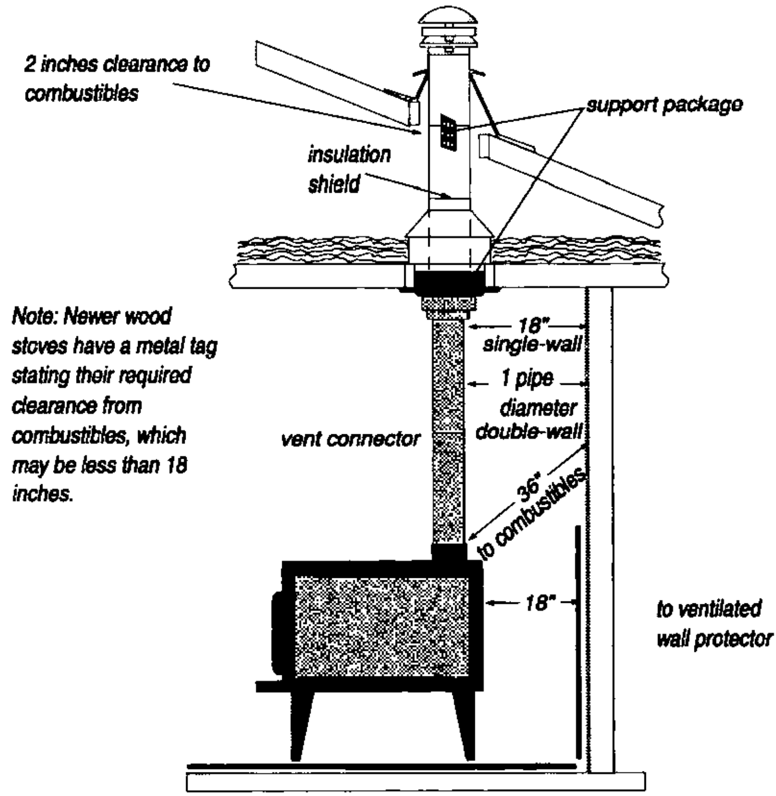
5.1.7 Wood-heating venting and safety

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.

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 allow the listed clearance to be reduced by half. See *"Venting combustion gases" on page 5-2*.

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 appropriate. 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.



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.*

- ✓ 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.

5.2 Combustion Air

Combustion appliances need a source of combustion air while they are operating. The exception to this rule is sealed-combustion or direct-vent appliances, which bring in their own outdoor air through a dedicated pipe. Common problems relating to combustion air and venting along with the complexity of codes and recommendations on combustion air argue strongly in favor of installing direct-vent appliances.

A combustion-air source must deliver between 15 cfm and 500 cfm. 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 5-8: CFM Air Requirements for Combustion Furnaces or Boilers

Appliance	Combustion Air (cfm)	Dilution Air (cfm)
Conventional Oil	38	195
Flame-Retention Oil	25	195
High-Efficiency Oil	22	–
Conventional Atmospheric Gas	30	143
Fan-Assisted Gas	26	–
Condensing Gas	17	–
Fireplace (no doors)	100–600	–
Airtight Wood Stove	10–50	–

A.C.S. Hayden, Residential Combustion Appliances: Venting and Indoor Air Quality Solid Fuels Encyclopedia

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.

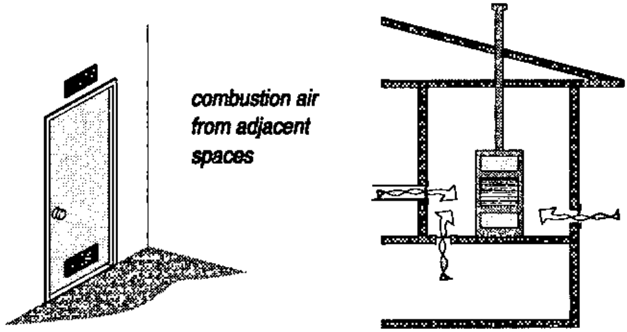
A combustion zone is an area containing one or more combustion appliances. Combustion zones are classified as either un-confined spaces or confined spaces. Un-confined spaces are open or connected to enough building volume and air leakage to provide combustion air. For un-confined spaces, combustion air comes from leaks within the combustion zone. Confined spaces are combustion zones with a closed door and sheeted walls and ceiling that create an air barrier between the appliance and other indoor spaces. For confined spaces, combustion air must come from outside the combustion zone. 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 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 or direct-vent appliances.

5.2.1 Un-confined-space combustion air

Combustion appliances located in most basements, attics, and crawl spaces get adequate combustion air from leaks intentional openings in the building shell. Even when a combustion appliance is located within the home's living space, it usually gets adequate combustion air from air leaks unless the house is airtight or the combustion zone is depressurized. See *"Worst-case draft and pressure test" on page 5-27.*



Passive combustion-air options: *Combustion air can be supplied from adjacent indoor spaces or from outdoors. Two openings into the combustion zone are preferred*

5.2.2 Confined-space combustion air

A combustion appliance located in a confined space, surrounded by materials that are relatively effective air barriers, may need a vent connecting it to an adjacent indoor area, the crawl space, or outdoors. 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.

However if the mechanical room is connected to adjacent spaces through large air passages like floor-joist spaces, the combustion zone is not actually a confined space even though it has a door separating it from other indoor spaces. This connection between the combustion zone and other spaces could be confirmed by pressure testing. See *"Very simple pressure tests" on page 2-17*. On the other hand, if the home is fairly airtight, the combustion zone may be unable to provide adequate combustion air, even when the combustion zone is much larger than the minimum room volume for a confined space. See *"Building Components Compared by Air Permeance at 50 Pascals" on page 2-16*.

Combustion air from adjacent indoor spaces is often preferred over outdoor combustion air because of the possibility of wind depressurizing the combustion zone. However, if there is a sheltered outdoor space from which to draw combustion air, this is a superior choice. Outdoor air is generally cleaner and dryer than indoor air, and a connection to the outdoors makes the confined space less affected by indoor pressure fluctuations.

For every 1,000 Btu/hour input, combustion-air vent to another indoor space should have a total of 2 square inches (in^2) of net free area. Net free area is smaller than actual vent area and takes the blocking effect of louvers into account. Metal grills and louvers provide 60% to 75% of their area as net free area while wood louvers provide only 20% to 25%.

Here is an example of sizing combustion air to another indoor area, the furnace and water heater are located in a small mechanical room sheeted on the walls and ceiling with drywall. The furnace has an input rating of 100,000 Btu/hour. The water heater has an input rating of 40,000 Btu/hour. Therefore, there should be 280 in^2 of net free area of vent between the mechanical room and other rooms in the home. ($[100,000 + 40,000]/1,000 = 140 \times 2\ in^2 = 280\ in^2$).

In confined spaces or airtight homes where outdoor combustion air is needed, prefer low vents to high ones. A combustion-air vent into an attic may depressurize the combustion zone in some cases because the attic tends to be an depressurized zone where air is being exhausted. The preferred installation is to connect the combustion zone to a ventilated crawl space or directly to outdoors. The vent opening should have one square inch (1 in^2) of net free area for each 3000 Btu/hour of appliance input.

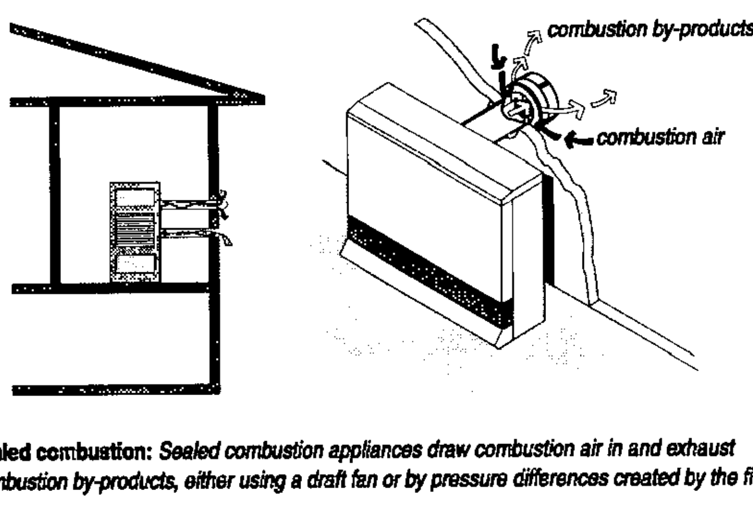
Choose an outdoor location that is sheltered, where the wall containing the vent isn't parallel to prevailing winds. Wind blowing parallel to an exterior wall and at a right angle to the vent opening tends to de-pressurize both the combustion-air opening and the combustion zone connected to it. Indoors,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

5.2.3 Proprietary combustion-air systems

Any passive combustion-air inlet can potentially depressurize the combustion zone because pressure from wind or stack effect can extract 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 draft problems, 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

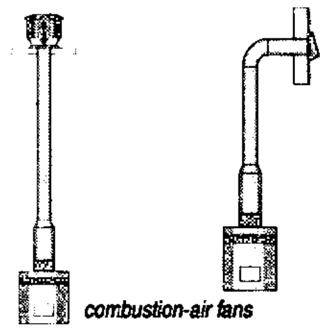


Sealed combustion: *Sealed combustion appliances draw combustion air in and exhaust combustion by-products, either using a draft fan or by pressure differences created by the fire.*

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

Fan-powered combustion air

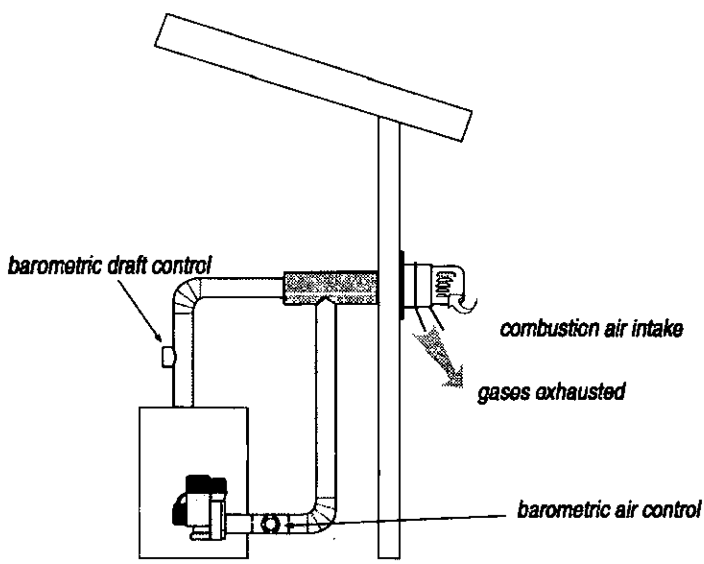
Field Controls Inc. manufactures a proprietary combustion-air system that introduces outdoor air through a fan that sits on the floor and attaches to a combustion-air duct to outdoors.



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.



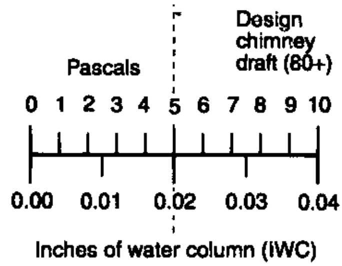
Sealed-combustion, oil-heating retrofit: *Direct supply of combustion air to gun-type oil burners is a good option for shielding the oil burner from house pressures.*

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.

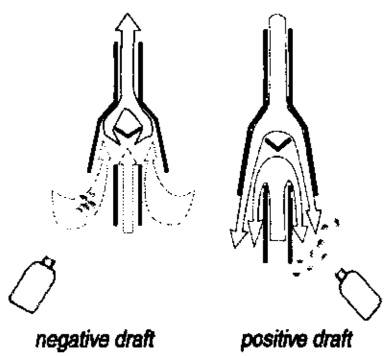
5.3 MEASURING DRAFT AND HOUSE PRESSURES

The main purpose of measuring draft is to insure that the combustion gases are being vented from a dwelling. Draft is measured in inches of water column (IWC) or Pascals.



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

5.3.1 Draft characteristics in combustion appliances



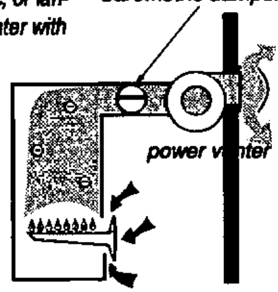
Negative versus positive draft: *With positive draft air flows down the chimney and out the draft diverter. A smoke bottle helps distinguish between positive and negative draft.*

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.

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.

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.



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.*

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. These appliances have draft in the range of +0.05 to +0.35 IWC or 12 to 85 pascals and are much less influenced by indoor and outdoor pressures.

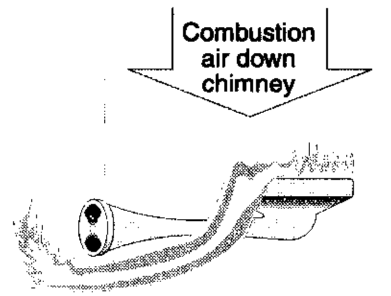
Power venters with sidewall vents are a good alternative, when a vertical chimney is inadequate or non-existant. Yet another venting option is a draft inducer, a fan installed inside a vertical chimney, used to increase draft.

5.3.2 Worst-case draft and pressure 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 chimneys should vent their combustion gases even under these extreme conditions.

Draft is measured downstream of the draft diverter or barometric draft control in older furnaces, boilers, and water heaters. Downstream generally means above the draft diverter or between the draft diverter and chimney.

Draft is the pressure difference between the chimney and combustion zone. Atmospheric-draft appliances are draft-tested during the worst-case conditions. This worst-case draft test will discover whether or not the venting system will exhaust the combustion gases when the combustion-zone pressure is as negative as you can make it.

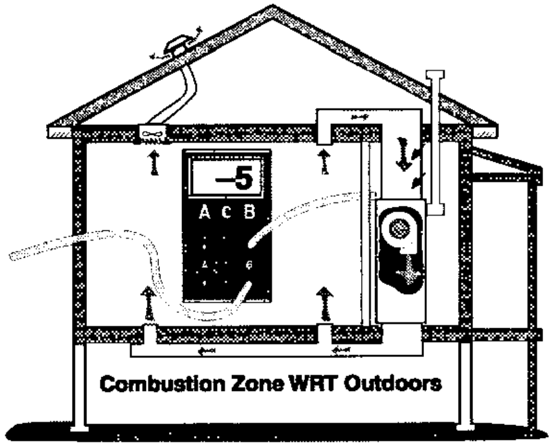


Flame roll-out: *Flame roll-out can occur when the combustion zone is depressurized beyond 8 pascals or during very cold weather.*

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 the pressure difference between combustion zone and outdoors, and record the current natural pressure difference.
2. Turn on the exhaust fans, clothes dryer, and air handler; then measure the combustion zone-to-outdoors pressure difference again.
3. While air handler and exhaust fans are running, open and close interior doors until the negative pressure difference

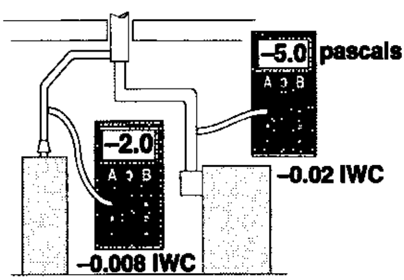
A reading more negative than –5 pascals indicates a significant possibility of backdrafting.



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

between the combustion zone and outdoors is at its maximum. Record this maximum or worst-case depressurization value. A combustion zone-to-outdoors pressure difference of more than –5 pascals during this test indicates a danger of backdrafting naturally drafted gas and oil appliances. A combustion zone-to-outdoors pressure difference of –8 pascals or more indicates a danger of flame roll-out. See *"Minimum Worst-Case Draft" on page 5-29.*

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



Worst-case draft testing: *Measure draft for atmospheric gas appliances at worst-case conditions to ensure proper venting. Draft is measured on the chimney side of the draft diverter.*

5. Take all necessary steps to identify and remove excessive negative house

pressures. See also *"Measuring duct-induced room pressures" on page 2-24*. Also, take appropriate measures to increase draft by undertaking chimney improvements, combustion air, or other measures to encourage the venting of combustion gases. For more information, see *"Venting combustion gases" on page 5-2* and *"Combustion air" on page 5-18*.

Table 5-9: *Minimum Worst-Case Draft*

Appliance	<20	21-40	41-60	61-80	>80
Gas-fired furnace, boiler, or water heater with atmospheric chimney	–5 Pa. –0.02 IWC	– 4 Pa. –0.016 IWC	–3 Pa. –0.012 IWC	–2 Pa. –0.008 IWC	–1 Pa. –0.004 IWC
Oil-fired furnace, boiler, or water heater with atmospheric chimney	–15 Pa. –0.06 IWC	– 13 Pa. –0.053 IWC	–11 Pa. –0.045 IWC	–9 Pa. –0.038 IWC	–7 Pa. –0.030 IWC

Ambient CO levels should be monitored in the combustion zone during draft testing, especially if depressurization of the combustion zone exceeds –5 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 –15 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 2-24*.

5.3.3 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 could be blocked or excessively leaky.

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 5-8.*

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 5-60.*

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 5-18.*

5.4 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.

Oxygen from the air

Carbon dioxide and water are the products of complete combustion.

Carbon monoxide is the product of incomplete combustion

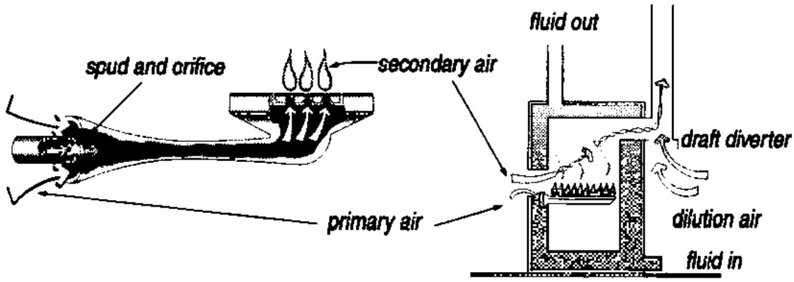
$$CH_4 + O_2 \longrightarrow CO_2 + H_2O + CO + O_2$$

Natural gas or another hydrocarbon

Some oxygen goes through combustion without reacting. This excess oxygen informs us about the fuel-air mixture.

5.4.1 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

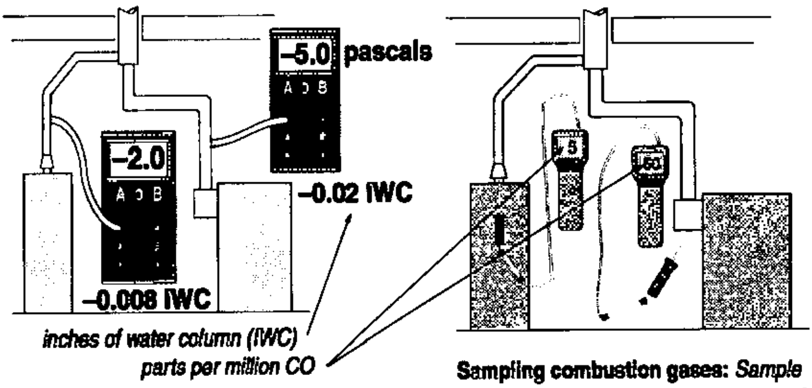
Perform the following inspection procedures and maintenance practices on all gas-fired furnaces, boilers, water heaters, and space heaters. The goal of these measures is to reduce CO, stabilize flame, and test safety controls. For information on the effects of CO, see *"Carbon monoxide" on page 1-6.*

- ✓ 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 5-54.*
- ✓ Furnaces and boilers should have dedicated circuits. 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 set-

ting 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 during operation.



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.

Table 5-10: Combustion Standards for 80+ and 90+ Gas Furnaces

Performance Indicator	80+	90+
Maximum depressurization (Pa)	–5 Pa.	–10 Pa.
Carbon monoxide (CO) (ppm)	≤ 100 ppm	≤ 100 ppm
Stack temperature (°F)	325°–450°	≤ 120°
Heat rise (°F)	40–70°*	30–70°*
Oxygen (%O2)	4–9%	4–9%
Gas pressure Inches (IWC)	3.2–3.9 IWC*	3.2–3.9 IWC*
Steady-state efficiency (SSE) (%)	80–82%	92–97%
Draft (IWC)	–0.02 IWC	0.1–0.4 IWC*

* pmi = per manufacturer's specifications

- 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 over-firing, closed primary air intake, and flame impingement.

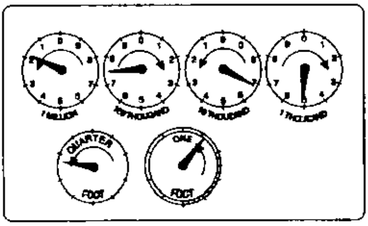
✓ Take action to improve draft, if inadequate because of improper venting, obstructed chimney, etc.

✓ Seal leaks in vent connectors and chimneys.

✓ Adjust gas input if combustion testing indicates overfiring or underfiring.

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.
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 5-11 on page 37* 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 that you must multiply the number in the table by 1000.

Note: *Table 5-11 on page 37* 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 or down within a range of 3.2 to 3.9 IWC. If the measured value is still out of range, replace the existing orifices with orifices sized to give the correct input.

Table 5-11: 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

5.4.2 Leak-testing gas piping

Natural gas and propane piping systems may leak 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.

5.4.3 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 maintenance. 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.

✓ Each oil furnace or boiler should have a dedicated electrical circuit. 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.

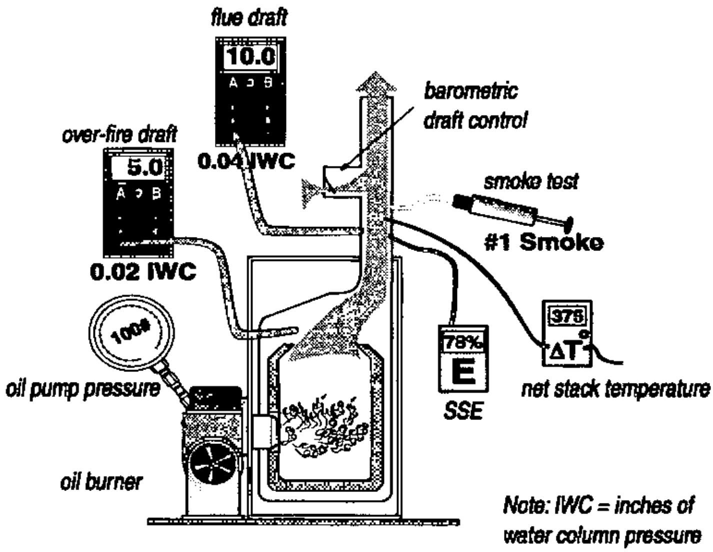
✓ Sample undiluted flue gases with a smoke tester, following the smoke-tester instructions. Compare the smoke smudge left by the gases on the filter paper with the manufacturer's smoke-spot scale to determine smoke number.

✓ Analyze the flue gas for O_2 or CO_2, temperature, CO, and steady-state efficiency (SSE). Sample undiluted flue gases between the barometric draft control and the appliance.

Table 5-12: *Minimum Combustion Standards for Oil-Burning Appliances*

Oil Combustion Performance Indicator	Non-Flame Retention	Flame Retention
Oxygen (% O_2)	4–9%	4–7%
Stack temperature (°F)	325°–600°	300°–500°
Carbon monoxide (CO) parts per million (ppm)	≤ 100 ppm	≤ 100 ppm
Steady-state efficiency (SSE) (%)	≥ 75%	≥ 80%
Smoke number (1–9)	≤ 2	≤ 1
Excess air (%)	≤ 100%	≤ 25%
Oil pressure pounds per square inch (psi)	≥ 100 psi	≥ 100-150 psi (pmi)*
Over-fire draft (IWC negative)	.02 IWC	.02 IWC
Flue draft (IWC negative)	0.04–0.1IWC	0.04–0.1 IWC

- ✓ Measure chimney draft downstream from the barometric draft control and over-fire draft upstream.
- ✓ 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.
- ✓ 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 the burner will shut off, within 45 seconds, when the cad cell is blocked from seeing the flame.

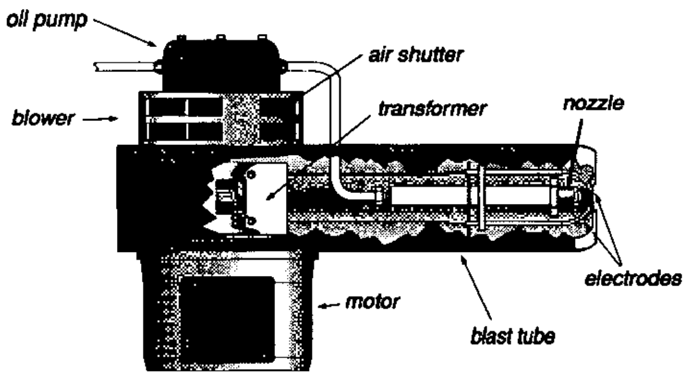


Measuring oil-burner performance: *To measure oil-burning performance indicators, a manometer, flue-gas analyzer, and pressure gauge are necessary.*

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).



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

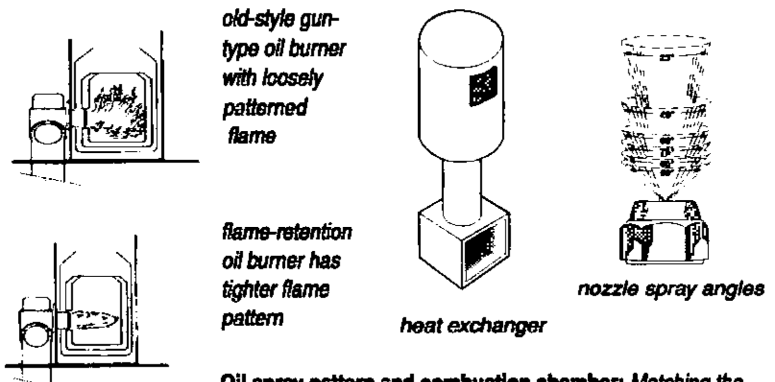
- ✓ Clean or replace air filter.
- ✓ Remove soot and sludge from combustion chamber.
- ✓ Remove soot from heat exchange surfaces.
- ✓ Clean dust, dirt, and grease from the entire burner assembly.
- ✓ Set oil pump to correct pressure.
- ✓ Adjust air shutter to achieve specified oxygen and smoke.
- ✓ Adjust 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 previously 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, which have been available for more than 20 years, waste less heat and have steady-state efficiency (SSE) of 80% or slightly more. Replacing an old-style 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 flame-retention burners and their older cousins.



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.

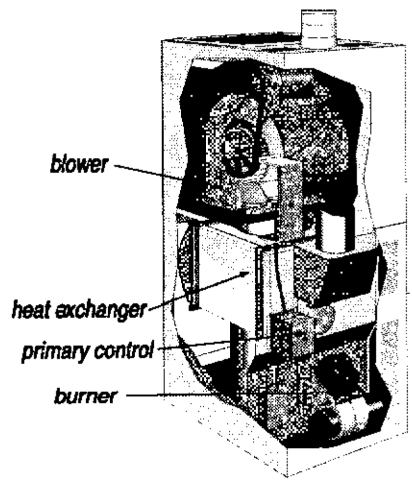
- Size the burner and nozzle to match the building's heat load, making adjustments for new insulation and air sealing done during weatherization. (With steam heating size the burner to existing radiation surface area.)
- Install new combustion chamber, choosing one that fits the size and shape of the 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.

5.5 HEATING-SYSTEM REPLACEMENT SPECIFICATIONS

Don't assume that older furnaces and boilers are inefficient until testing them. During testing, make appropriate efforts to repair and adjust the existing furnace or boiler, before deciding to replace it. Replacement parts like gas valves and controls for older heating units are commonly available.

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 deciding between retrofit and replacement.

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.



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

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%. However gas furnaces and boilers with AFUEs of 90% should be given special consideration. These high-efficiency furnaces are direct-vent, sealed-combustion units with health and safety benefits in addition to their superior efficiency and significantly lower fuel usage.

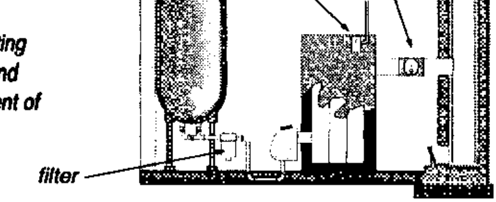
Heat load calculations, used to size the new heater, should consider reduced heating loads, resulting from insulation and air-sealing work. Heat load calculations should follow Manual J procedures.

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

5.5.1 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 original system should be diagnosed 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 5-5.*

- ✓ 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 match 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.

5.5.2 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 existing 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 original system should be diagnosed and corrected during the heating-system replacement.

The new furnace should have an Annual Fuel Utilization Efficiency (AFUE) 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 strongly recommended.

- ✓ 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 5-36.*
- ✓ If necessary, measure gas pressure, and increase or decrease gas pressure to obtain proper gas input.

✓ Test gas water heater to insure that it vents properly after installation of a sealed-combustion, 90+ AFUE furnace. Install a chimney liner if necessary.

✓ 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 5-2* for more information about National Fire Protection Association (NFPA) Standards.

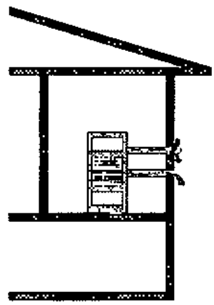
✓ Ensure proper sediment trap on gas line.

***Table 5-13:** Minimum Combustion Standards for Gas-Burning Furnaces*

Gas Combustion Performance Indicator	80+ Furnace	90+ Furnace
Oxygen (% O_2)	4–9%	4–9%
Stack temperature (°F)	325°–450°	90°–120°
Carbon monoxide (CO) parts per million (ppm)	≤ 100 ppm	≤ 100 ppm
Steady-state efficiency (SSE) (%)	80–82%	92–97%
Gas pressure (inches water column or IWC)	3.2–3.9 IWC	3.2–3.9 IWC
Supply temperature (°F)	120–140°	95–140°

5.5.3 Furnace replacement

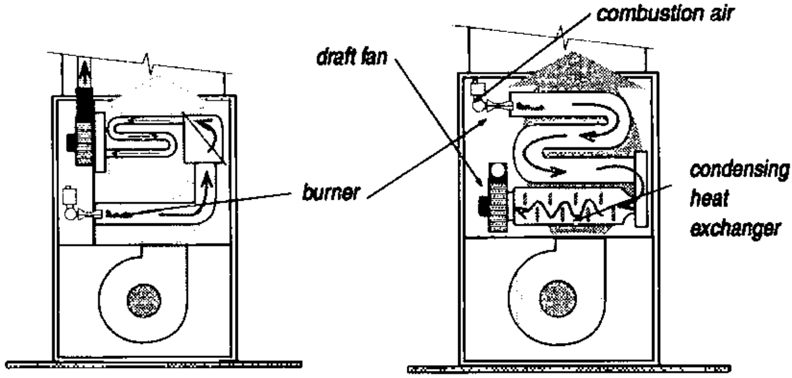
The overall goal of furnace replacement is to provide a forced-air heating system in virtually new condition, even though existing supply and return ducts may remain. Any design flaws in the ducts and registers should be diagnosed and corrected during the furnace replacement.



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

Observe the following standards in furnace installation.

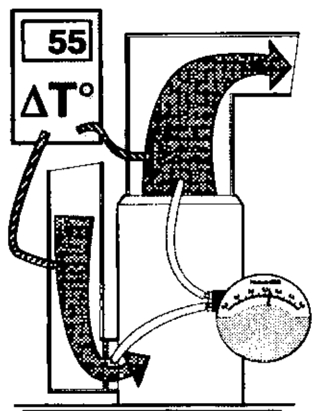
- ✓ Furnace should be sized to the approximate heating load of the home, accounting for post-weatherization heat-loss reductions.
- ✓ Installer should add return ducts or supply ducts as part of furnace replacement to improve air distribution, to eliminate duct-induced house pressures, and to establish acceptable values for static pressure and heat rise.
- ✓ 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 this important joint.
- ✓ All ducts should be sealed as described in *"Duct air-tightness standards" on page 5-57.*
- ✓ 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.



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

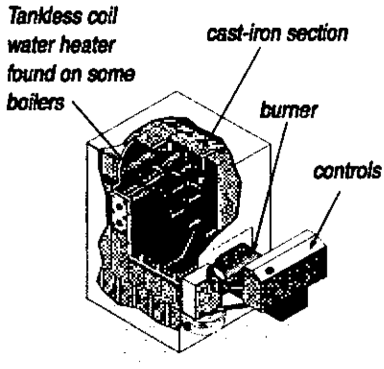
90+ gas furnace: *A 90+ furnace has a condensing heat exchanger and a stronger draft fan for pulling combustion gases through its more restrictive heat exchange system and establishing a strong positive draft.*

- ✓ 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 should not be set to operate continuously.
- ✓ Seal holes through the jacket of the air handler with mastic or foil tape.
- ✓ Filters should be held firmly in place and provide complete coverage of blower intake or return register. Filters should 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.*

5.5.4 Boiler replacement



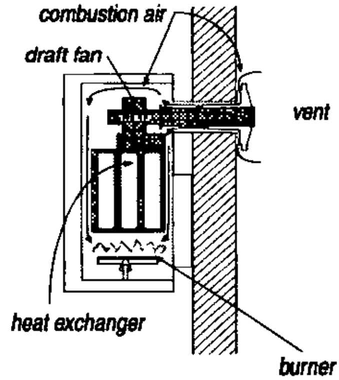
Cast-iron sectional boilers: *Are the most common boilers for residential applications.*

Don't assume that a boiler replacement will save much energy unless the boiler's steady-state efficiency can't be raised to around 80%. 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 venting, piping, and controls should be diagnosed and corrected during the boiler replacement.

Boiler piping and controls present many options for zoning, boiler staging, and energy-saving controls. Dividing homes or multifamily buildings into zones, with separate thermostats, can significantly improve energy efficiency over operating a single zone. Modern hydronic controls can provide different water temperatures to different zones with 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 or power-draft fan. It should not have a draft diverter.

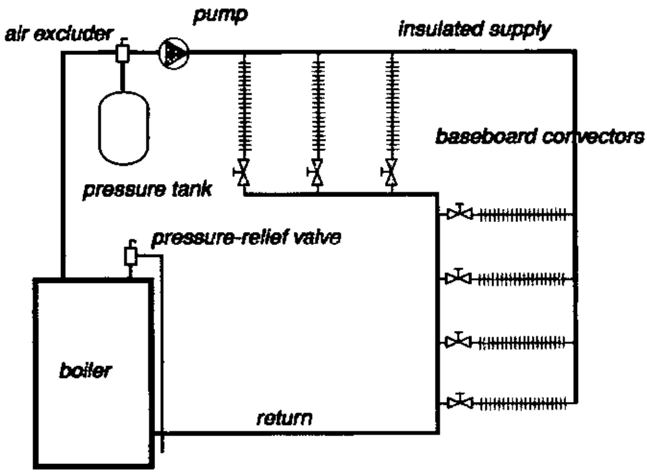
Boiler seasonal efficiency is more sensitive to proper sizing than is furnace efficiency. A boiler should not be oversized by more than 15%. Consider the following specifications when replacing boilers.



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

- ✓ Inspect chimney for proper sizing and deterioration. Repair and re-line the chimney as necessary.
- ✓ 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 should be replaced, unless it is verified to be the proper size for the new system and 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, unless the boiler is designed for condensing. Install piping bypasses, mixing valves, primary-secondary piping, or other strategies, as necessary, to prevent condensation within a non-condensing boiler.
- ✓ Recognize the boiler installation's potential for causing condensation in the vent connector and chimney. If the boiler's steady-state efficiency is expected to be more than 83%, condensation-resistant venting and condensation drains should be designed into the venting system. These custom venting systems are provided or specified by the manufacturer.

✓ A pressure-relief valve must be installed with the new boiler and connected to a drain pipe, draining into a floor drain.



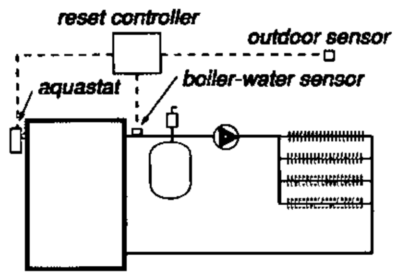
Simple reverse-return hot-water system: *The reverse-return method of piping is the simplest way of balancing flow among heat emitters.*

✓ 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 controllers to adjust supply 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.

5.5.5 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 5-57* and *"Improving duct-system airflow" on page 5-60.*

✓ Verify that safety limits, heat rise, and static pressure conform to manufacturer's specifications.

5.6 FORCED-AIR SYSTEM STANDARDS

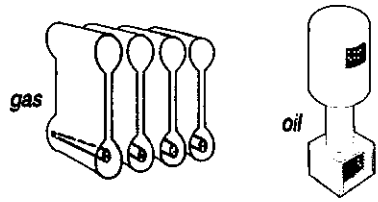
The overall system efficiency of an oil or gas forced-air heating system is affected by blower operation, duct leakage, balance between supply and return air, and duct insulation levels. Retrofits to the forced-air system generally are more cost-effective than retrofits to the heating unit itself.

5.6.1 Inspecting furnace heat exchangers

Leaks in heat exchangers are 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 5-32*. Consider using one or more of the following 7 general options for evaluating heat exchangers.

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

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.

5.6.2 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 supply air and collect return air only within the intentionally heated portion of the house. Taking return air from an un-heated area of the house such as an unoccupied basement is not acceptable.
- The fan-off temperature should be between 95° and 105° F, with the lower end of the scale being preferable for maximum efficiency.
- The fan-on temperature should be less than 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

Table 5-14: Furnace Operating Parameters

Heat Rise = Supply Temperature – Return Temperature

20°–45°	45°–70°	70°–95°
Inadequate heat rise: condensation and corrosion possible.	Heat rise OK for both efficiency and avoidance of condensation.	Heat rise excessive: Check fan speed, heat exchanger and ducts.

Fan-off Temperature

85°–100°	100°–115°	115°–130°
Excellent fan-off temperature if comfort is acceptable.	Borderline acceptable: Consider replacing fan control.	Unacceptable range: Significant savings possible by replacing fan control.

Fan-on Temperature

100°–120°	120°–140°	140°–160°
Excellent fan-on temperature range: No change needed.	Fair: Consider fan-control replacement if fan-off temperature is also borderline.	Poor: Replace fan control.

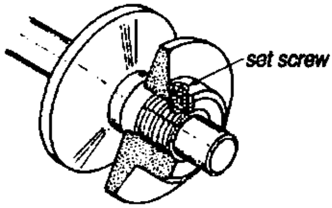
switched off within 2.5 minutes of the end of the combustion cycle.

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

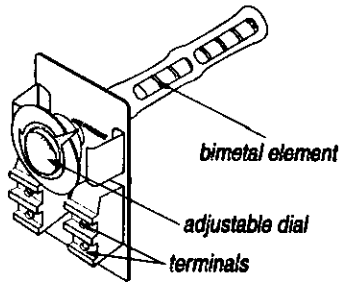
✓ Reduce heat rise by cleaning or changing dirty filters, cleaning the blower, increasing fan speed, and improving ducted air circulation. See *"Improving duct-system airflow" on page 5-60.*

✓ 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.

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



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.*

5.6.3 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 2-22.*

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.

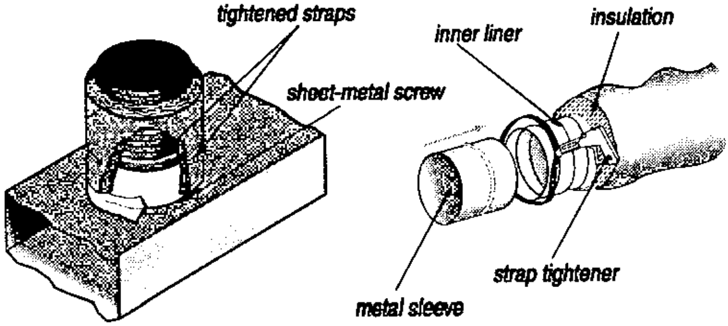
✓ Plenum joint at air handler: These joints may have been difficult to fasten and seal because of tight access. Go the extra mile to seal them airtight with mastic and fabric mesh tape even if it requires cutting an access hole in the plenum.

✓ 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 usually leaky.

✓ Tabbed sleeves: Attach the sleeve to the main duct with 3-to-5 screws and apply mastic plentifully.

✓ Flexduct-to-metal joints: Apply mastic to the metal sleeve. Clamp the flexduct's inner liner over this strip of mastic with a plastic strap using a strap tensioner. 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.*

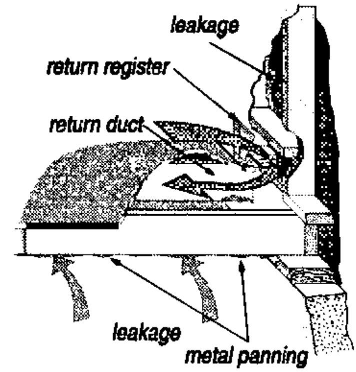
✓ Support ducts and duct joints with duct hangers where needed.

✓ 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.

✓ Consider sealing off supply and return registers in unoccupied basements.

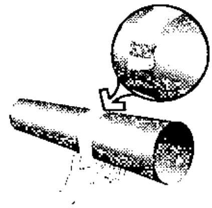
✓ Seal penetrations made by wires or pipes traveling through ducts. Even better: move the pipes and wires and patch the holes.



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

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.



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.

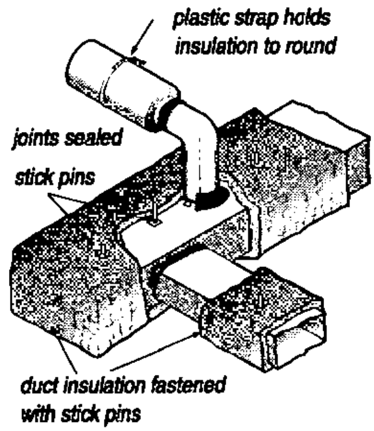
Duct mastic: *Mastic, reinforced with fabric webbing, is the best choice for sealing ducts.*

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

5.6.4 Duct insulation

Insulate supply ducts that run through unconditioned areas outside the thermal boundary such as crawl spaces, attics, and attached garages 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.*

5.6.5 Improving duct-system airflow

Inadequate airflow is a common cause of comfort complaints. 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 capacity. See *"Furnace replacement" on page 5-48* for more information about airflow indicators.

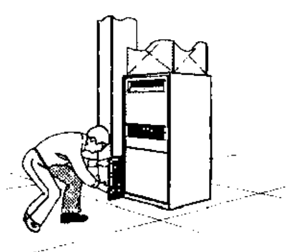
When the air handler is on there should be a strong flow of air out of each supply register, providing its balancing damper is open. Low airflow may mean that a branch is blocked or separated, or that return air is not sufficient. When low airflow is a problem, consider the following obvious improvements.

- ✓ Clean or change filter.
- ✓ Clean furnace blower.
- ✓ Clean air-conditioning or heat pump coil. (If the blower is dirty, the coil is probably also dirty.)
- ✓ Increase blower speed.
- ✓ Lubricate blower motor and check tension on drive belt.
- ✓ Repair or replace bent, damaged, or restricted registers.

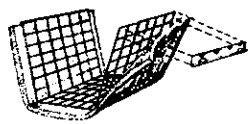
Filter and blower maintenance

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.

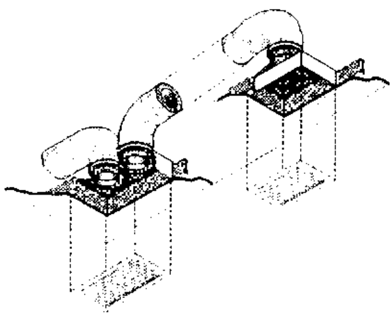
Duct improvements to increase airflow and improve comfort

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 2-24*.

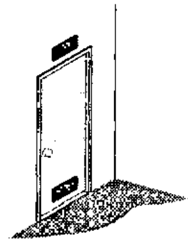
- Remove obstructions to registers and ducts such as rugs, furniture, and objects placed in ducts, like children's toys and water pans for humidification.
- Remove kinks from flex duct, and replace collapsed flex duct and fiberglass duct board.
- Install additional supply ducts and return ducts as needed to provide heated air throughout the building, especially into additions to the building.
- Install a transfer grille between the bedroom and main body of house to improve airflow. Undercut bedroom doors, especially in homes with single return registers.
- 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.

New ducts

New ducts should not be installed in unconditioned spaces unless absolutely necessary. If ducts are located in uncondi-



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 system airflow. Installing an additional return duct directly into the air handler is a preferred strategy.*

tioned spaces, joints should be sealed and the ducts insulated as described previously. See *"Duct air-tightness standards" on page 5-57* and *"Duct insulation" on page 5-59.*

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.

5.6.6 Room heat pumps

Room heat pumps can provide all or part of the heating and cooling needs for small homes. These one-piece room systems (also known as terminal systems) look like a room air conditioner, but provide heating as well as cooling. They can also provide ventilation air when neither heating nor cooling are required. They mount in a window or through a framed opening in a wall.

Room heat pumps can be a good choice for replacing existing un-vented gas space heaters or obsolete central heating systems. Their fuel costs may be somewhat higher than oil or gas furnaces, though they are safer and require less maintenance than combustion appliances. Room heat pumps also gain some overall efficiency because heat a single zone and don't have the delivery losses associated with central furnaces and ductwork.

If they replace electric resistance heat, they consume only one-half to one-third the electricity to produce the same amount of heat.

Room heat pumps have a cooling efficiency comparable to the best new window air conditioners. They operate at up to twice the efficiency of older air conditioners.

Room heat pumps draw a substantial electrical load, and may require 240-volt wiring. Provide a dedicated circuit that can support the equipment's rated electrical input. Insufficient wiring capacity can result in dangerous overheating, tripped circuit breakers, blown fuses, or motor-damaging voltage drops. In most cases a licensed electrician should confirm that the house wiring is sufficient. Don't run portable heat pumps or any other appliance with extension cords or plug adapters.

Observe the following specifications when installing room heat pumps.

- ✓ Install the unit in a central part of the home where air can circulate to other rooms. Choose a location near an electrical outlet, or where a new outlet can be installed if it's needed.
- ✓ Don't install the unit where bushes will cover it. Heat pumps need lots of outdoor air circulation to operate at maximum efficiency.
- ✓ If you install the unit in a window, choose a double-hung or sliding window that stores out of the way. Portable units don't work well in out-swinging casement windows or up-swinging awning windows.
- ✓ If you install the unit in a framed opening in the wall, use the same guidelines you would to frame a new window or door. Provide headers, beams, or other structural supports where studs are cut, or install it in an opening under an existing window where structural support is already provided by the window framing.
- ✓ Provide solid supports underneath the unit. These can be manufactured brackets, wood-framed brackets, or brackets

fabricated from metal. Fasten the unit with screws to the window jamb and/or sash.

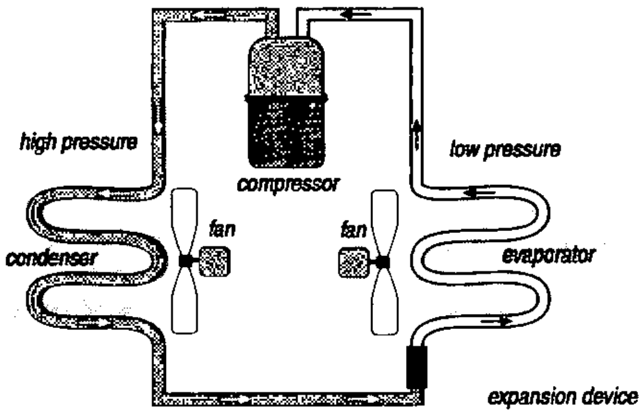
✓ Seal around the exterior siding and trim to keep rain out of the wall cavity. Seal the unit to the opening with the shields provided by manufacturer or with plywood, caulking, or sheet metal.

Table 5-15: Installing Room Heat Pumps of Air Conditioners

Issue	Window installation	Wall installation
Difficulty of installation	Easiest.	Wall framing required.
Access issues	Window will be inoperable, with no access for fire egress or ventilation.	None.
Air sealing	Care required to properly seal unit to window jambs.	Easy to seal permanently.
Future adaptability	Easy to remove if homeowner switches fuel or type of system.	Poor. Homeowner is left with a hole in the wall if they switch fuel or type of system.

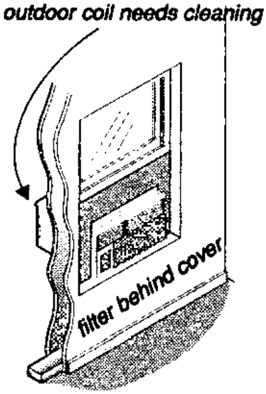
5.7 MAINTAINING AIR-CONDITIONING SYSTEMS

Many low-income clients in the Southeast have room air conditioners and a smaller percentage have central air conditioning systems. Maintaining clean filters and coils is essential to keeping air conditioners running at an acceptable efficiency. Other air-conditioning adjustments require more training and skill in diagnosing specific problems.

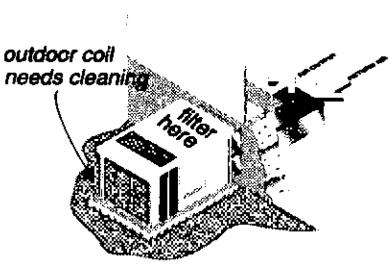


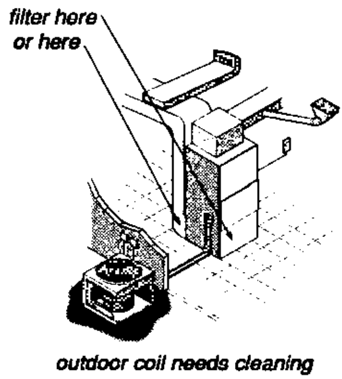
Refrigeration and air-conditioning cycle: *Refrigerant evaporates in the evaporator, absorbing heat from the metal coil and passing air. The compressor compresses the refrigerant, preparing it to condense within the condenser. The condensing refrigerant heats the condenser coil to a significantly higher temperature than the outdoor air and so the outdoor circulating through the condenser is heated and takes away the heat collected by the evaporator indoors.*

Air conditioners come in two basic types, packaged systems and split systems. Packaged air conditioners include room air conditioners and room heat pumps, along with packaged central air conditioners mounted on roofs and on concrete slabs outdoors. Split-systems have a condenser outdoors and an air-conditioning coil, located indoors inside a furnace, heat pump, or adjoining main supply duct.



Air conditioner types: *Room air conditioners are most common type for low-income homes. All types of air conditioners need clean filters and coils to achieve acceptable efficiency.*



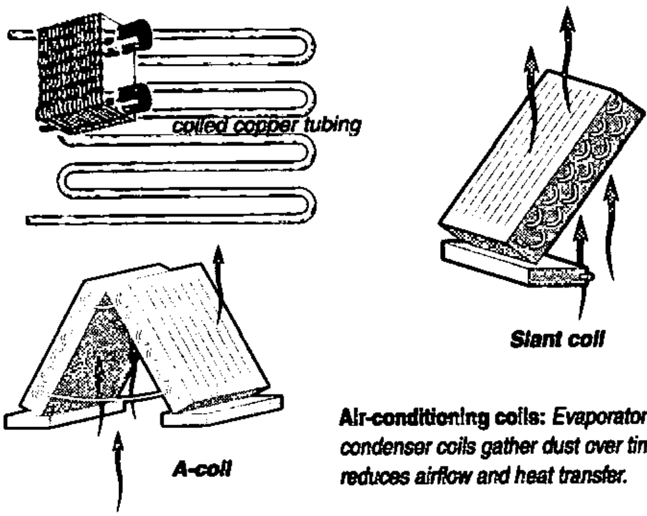


5.7.1 Cleaning air-conditioning coils

Clean filters and air-conditioning coils are a minimum requirement for efficient operation. For more information on filters and their location, see *"Furnace filter location" on page 5-61.*

Keeping filters clean is the best way to keep coils clean. Cleaning a coil is much more difficult than changing or cleaning a filter. When a filter is dirty or absent, dirt collects on the coil, fan blades, and other objects in the air stream. The dirt deposits reduce airflow and will eventually cause the air-conditioning system to fail.

Dirt builds up on a coil from the side where the air enters. The heaviest deposits of lint, hair, and grease will coat that side of the indoor coil. The best strategy is to dampen this surface layer and brush the heavy dirt off before trying to wash the finer dirt out with cleanser and water.

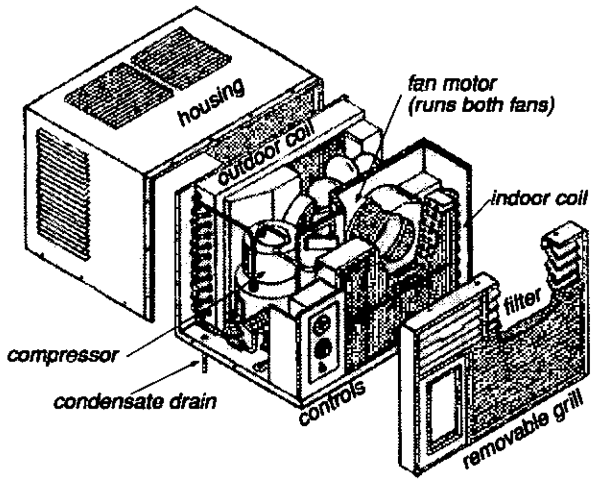


Air-conditioning coils: *Evaporator and condenser coils gather dust over time, which reduces airflow and heat transfer.*

The outdoor coils of air conditioning systems aren't protected by filters. They get dirty depending on how much dust is in the outdoor air. If there is little dust and pollen in an area, the outdoor coil may only need cleaning every three years or so. However, if there is a lot of pollen and dust, annual cleaning would be a good practice. It would be a safe assumption that all outdoor coils need cleaning.

Cleaning room air conditioner coils

Room air conditioners have flimsy foam or fiberglass filters that lie up against the inside coil (evaporator coil). It's good practice to carry a roll of filter material to replace worn-out or non-existent filters. Cleaning the indoor coil is easy since the heaviest dirt collects on the surface of the coil facing the inside of the home. Cleaning the outdoor coil (condenser coil) is more difficult. Usually cleaning the outdoor coil involves removing the room air conditioner from the window and taking it to an outdoor location where you can use a hose. The housing of the air conditioner must be removed to clean the outdoor coil.



Cleaning room air conditioners: *Room-air-conditioner performance deteriorates as it accumulates dirt. The unit will eventually fail to cool the room or break down unless cleaned.*

Observe the following steps when cleaning the indoor and outdoor coils of a room air conditioner.

1. Remove the grill and filter on the interior side of the unit.
2. Unplug and remove the air conditioner temporarily from the window or wall. With some units, the mechanical parts slide out of the housing, and with others you must remove the whole unit, housing and all.
3. Take the unit to an clean outdoor area that drains well, like a driveway or patio.
4. Cover the compressor, fan motor, and electrical components with plastic bags, held in place with rubber bands.
5. Dampen each of the coils with a light spray of water, then rake as much dirt off the coils as you can with an old hairbrush.
6. Spray some heavy-duty household cleaner into both coils, and let the cleaner set for a minute or two.

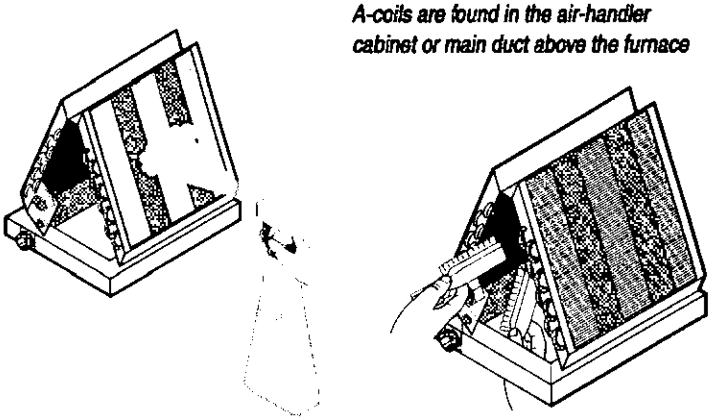
7. Rinse the cleaner and dirt out of the coils with a gentle spray from a hose.
8. Repeat the process until the water draining from the coils is clean.

Cleaning blowers and indoor evaporator coils

Every indoor evaporator coil should be protected by an air filter that fills the entire cross-sectional area of return duct leading to the blower and indoor coil. Filters are easier to change or clean compared to cleaning a blower or coil. If equipped with clean well-fitting filters, the blower and coil will remain clean for many years. However, many coils haven't had the benefit of such filters and are packed with dirt.

1. Shut off the main switch to the air handler.
2. Open the blower compartment and look into the blades of the blower, using a flashlight. Reach in and slide your finger along a fan blade. Have you collected a mound of dust?
3. If the blower is dirty, remove it and clean it. If you remove the motor, you can use hot water or cleaner and water to remove the dirt.
4. If the blower was dirty, the indoor coil is probably also dirty. Inspect the coil visually if you have access.

5. If the coil is dirty, clean it using a brush, cleaner and water as described previously in *"Cleaning room air conditioner coils" on page 5-68.*



Cleaning an A-coil: *A-coils are found in upflow and downflow air handlers. In downflow models the dirt collects on top and on upflow units dirt collects on the bottom.*

A–1 Tools for air sealing and insulating

Insulation blower	Hammers and wrecking bars
Blower hoses 4, 3, & 2.5 inch	Caulking guns
Extension ladders, leveler, & hooks	Squares: framing, combo, dry-wall
Fill tubes and hose fittings	Coveralls and gloves
Step van or utility trailer	Broom and dust pan
Drills, drivers, and bits	Cleaning fluid and rags
Step ladders: 4, 6, & 8 foot	Steel tape measures
Scratch awl and pin punches	Hack saw and blades
Scaffold, planks, and handrail	Hand saws
Metal-siding zip tool	Tin snips: hand and electric
First-aid kit	Chisels: cold and wood
Portable lights	Screw- and nut-driver bits
Hand staplers	Drill index with bits
Circular saw with blades	Cat's paw
Reciprocating saw with blades	End nippers
Extension cords	Pliers: electrical & slip-joint
Compressor and power stapler	Screw drivers and nut drivers
Respirators and filters	Putty warmer
Tool boxes	Putty knives and scrapers
Shop vacuum, hoses, attachments	HEPA vacuum with attachments

A–2 Tools for auditing and mechanical

Blower door	Hand truck
Digital manometer with hoses	Cordless drill-driver
Pressure pan	Inspection mirror
Calculator	Coveralls and gloves
Laptop computer	Panduit strap tightener
Auditing software	Screw and nut drivers
Hack saw and blades	Sockets and ratchet
Cargo van or pickup with utility boxes	Clipboard box, writing supplies, pencils
Digital combustion analyzer	Wire and bristle brushes
Digital CO detector	Tin snips
Digital thermometer with ΔT	Chisels: cold and wood
Moisture meter	Screw and nut driver bits
Remote viewer	Drill index with bits
Non-contact voltage detector	Adjustable wrenches
Volt-ohmmeter	Tool boxes
Digital wattmeter	Pliers: electrical & slip-joint
Plug-in circuit tester	Screw drivers and nut drivers
Heat-exchanger test kit	Pipe wrenches
Steel tape measures	Wire strippers
Flash lights and portable lights	Sheet-metal crimper
Portable tape recorder	Pop riveter

A–3 Weatherization materials and inventory

Fiberglass batts	Assorted staples
Cellulose blowing wool	1/4-inch plywood or hardboard
Fiberglass blowing wool	Plastic sheeting
Sheet foam insulation	Plastic garbage bags
Two-part spray foam	Construction adhesive
One-part squirt foam	Programmable thermostats
Fiberglass duct wrap	Replacement furnaces
Water heater insulation	Replacement water heaters
Foam pipe sleeves	Replacement refrigerators
Foam backer rod	Compact fluorescent lamps
Closed-cell foam tape	Energy-saving shower heads
Bronze v-seal weatherstrip	Replacement fan controls
Jamb-up weatherstrip	Assorted furnace filters
Putty tape	Furnace filter material
Acrylic latex w/ silicone caulk	Duct mastic and web tape
Acoustical sealant	Duct tape and electrical tape
Disposable coveralls, boot covers, and gloves	Assorted wire nuts and electrical connectors
Silicon or urethane caulk	Disposable paint brushes
Sheet metal	Proper vents
Assorted lumber	Client-education booklets
Assorted screws and nails	Assorted chimney pipe

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