Adopted by the Clark County, Nevada
Neighborhood Stabilization Program
June 2009

Note: These specifications are adopted as an integral part of the rehabilitation specifications & codes enforced within the jurisdiction of Clark County, Nevada, for purposes of quantifying performance of energy systems installed in residential buildings pursuant to these program requirements.

Home Performance Specifications For Warm Climates

Produced in support of the
Home Performance with ENERGY STAR© Program
Sponsored by
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and the U.S. Department of Energy

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Summary of Numerical Standards Presented Here

Home Performance Measure	Numerical Standard	Page
Cool Roofs, Insulation, and Windows		
Cool roofing materials	SRI≥80	*18.*
Radiant barrier film	e ≤ 0.08	*18.*
Radiant barrier paint	e ≤ 0.23	*19.*
Attic insulation	If ≤ R-19, install ≥ R-38	*19.*
Rooftop insulation	≥R-20 or highest achievable	*26.*
Open-cavity roof insulation	≥R-20 or highest achievable	*27.*
Wall insulation	Fill cavity to highest achievable R-value	*29.*
Kneewall/open-wall insulation	≥R-13 with vapor permeable sheathing	*24.*
Vertical access door	≥R-13	*25.*
Attic horizontal access door	≥R-15	*20.*
Wall insulation density	Cellulose: ≥3.5 pcf Fiberglass: ≥1.5 pcf	*31.*
Floor insulation	≥ R-21 or fill the floor cavity	
New window U-Factor	U ≤ 0.32	*44.*
New window SHGC	SHGC ≤ 0.35	*44.*
Retrofit window shading	SC ≤ 0.50	*40.*
Air Sealing and Ventilation		
CAZ depressurization limits	*Table 4-1 on page 56.*	
General house pressures	3 pascals between rooms 2 pascal house-to-outdoors	*55.*
Air sealing	If ≥ 1.5 CFM_{50}/ft^2, reduce 20% or more	*56.*
Minimum ventilation level (MVL)	1 (one) CFM_{50} per square foot of conditioned area	*62.*

Summary of Numerical Standards Presented Here

Home Performance Measure	Numerical Standard	Page
Home needs whole-house ventilation	≤0.80 CFM_{50} per square foot of conditioned area	*62.*
Whole house ventilation fan size	15 CFM per person or 0.35 ACHn	*61.*
Fan capacity, noise, efficacy	*Table 4-3 on page 64.*	
Air Conditioners, Heat Pumps, and Ducts		
Replacement HP and AC	*Table 5-1 on page 71.*	
System airflow	≥ 400 cfm per ton	*72.*
Total external static pressure	≤ 0.50 IWC or 125 pascals	*73.*
Duct leakage / sealing CFM_{25}	< 7% of floor area or 40% reduction	*78.*
Flex duct R-value	≥ R-8	*80.*
Metal-duct R-value	≥ R-8	
Refrigerant charge-checking	*See "Charge checking" on page 84.*	
Combustion Safety		
Carbon monoxide (CO) level (worker)	>35 ppm cease testing	*85.*
Gas Range CO	100-300 ppm: 2 steps required	*86.*
Gas Range CO	>300 ppm: 3 steps required	*86.*
CO, draft, and spillage	*Table 6-2 on page 92.*	
Tune-up combustion standards	*Table 6-3 on page 96.*	

CHAPTER 1: INTRODUCTION TO RESIDENTIAL SPECIFICATIONS

In 2005, the Regional Technical Forum decided to simplify the understanding of residential energy-program requirements by supplying a single source for technical specifications. These specifications present a whole-house approach required by the the Home Performance with ENERGY STAR© Program (HPwES) sponsored by EPA and DOE.

The current features of this whole-house approach include specifications for the following.

1. Installation of insulation and replacement windows.
2. Blower door testing with cost-effective shell air sealing.
3. Assessing the need for whole-house ventilation, including sizing the ventilation fan.
4. Duct testing with cost-effective duct sealing.
5. Combustion safety testing.
6. Evaluating the opportunity to employ solar electricity systems.

These specifications pertain to buildings with 1 to 4 residential units.

1.1 PURPOSE AND INTENT

The purpose of HPwES is to save energy, save money, reduce pollution, and enhance the healthiness, safety, and durability of homes. HPwES seeks to accomplish these goals in the most cost-effective way.

Every home-energy retrofit job has a limited budget. The wisest investment of customer dollars requires setting priorities based on cost-effectiveness and then accomplishing these priorities from the top down until the budget is spent. In this way, the

benefits to the home owners and occupants, the energy-distribution system, and society are maximized.

1.2 General Specifications

Administrators, managers, and installers must observe the following general specifications in the execution of residential energy programs governed by these specifications.

1. Weatherization measures must be installed in accordance with all applicable State codes, local codes, and Federal regulations.
2. The specifications in this document are minimum requirements but are intended to meet or exceed applicable existing codes and regulations.
3. Users of these specifications may apply more restrictive requirements than those given here. When more than one specification applies to work being done, the most stringent should apply.
4. Installers must work in a safe and beneficial way.
5. All materials, used under programs governed by these specifications, must be free from defects and damage. Materials must be resistant to corrosion, ultraviolet light, and chemical reaction with other materials.
6. Before installing weatherization measures, installers must ensure that building components are free from moisture problems and other significant damage.
7. Sealed, insulated-glass units must be warranted against seal failure for a minimum of 5 years by the manufacturer. The installer must provide a written warranty, with the installation date, to the customer. Manufacturers' written warranties may be used if they are dated.
8. Other weatherization materials, products, and labor must be warranted by the installer, against failure due to manufacturing and installation defects, for a period of at least 2 years from the installation date.
9. Home performance work must not damage adjacent building components, or if damage occurs, these building components must be repaired.

1.3 Sources for These Specifications

The specifications contained here are derived from the following documents.

1. Oregon Department of Energy Premium-Efficiency Duct-System Standards, October 2003
2. Building Performance Institute (BPI) 2005 Technical Standards for the following job designations.
   a. Building Analyst
   b. Shell Specialist
   c. Heating Specialist
   d. Air Conditioning and Heat Pump Specialist
3. Performance Tested Comfort Systems Air-Source Heat Pump Installation Standards
4. Quality HVAC Installation Draft Standards; Air Conditioning Contractors of America 2006
5. *Installation Masters Window Installation Manual* by American Architectural Manufacturers Association, 2005
6. Regional Technical Forum (RTF) Site-Built Housing Weatherization Standards October 2006

CHAPTER 2: INSULATION AND COOL ROOFS

The specifications presented here concern the safety and effectiveness of insulation installed in existing homes. Insulation for attics, roofs, walls, and floors is covered here. Specifications for cool roofs begins this chapter.

2.1 GENERAL SPECIFICATIONS

Observe and comply with these general specifications.

1. Observe all relevant provisions of the Building Performance Institute Standards, California Title 24 Standards, building codes, or other applicable local codes, as well as the interpretations of local building-code officials.
2. Insulation must be installed between the home's conditioned spaces and either the outdoors or unconditioned spaces, such as attics, crawl spaces, and attached garages.
3. Protect insulation from moisture. Take whatever steps are necessary to solve moisture problems in and around the building component to be insulated, or else don't insulate.
4. Seal all air leaks in the building assembly to be insulated before insulating work begins.
5. Insulate and seal access doors. Access doors in ceilings, walls, and floors must be insulated to the approximate R-value of the assembly they are a part of. Access doors must be substantially airtight.
6. Install insulation against the interior sheeting of the home. Don't allow an air gap in a building cavity between the home's interior and the insulation.
7. When foam-plastic insulation is installed, a code-approved ignition barrier must be present between the insulation and the interior of the building.

2.2 Cool Roofs

Cool roofs are roofs that employ reflective roofing, radiant barriers, and/or insulation to reduce roof solar gain during the cooling season. Cool roofs provide comfort and electricity-cost advantages over traditional roofs. White roofs aren't for everyone, but there are other ways of blocking the radiant-heat transfer through roofs.

2.2.1 Cool Roofing Materials

Cool roofing materials are defined here as having the following minimum standards.

1. Solar reflective index (SRI) of ≥ 80
2. Reflectance of ≥ 0.60.
3. Emittance of ≥ 0.80

The following common roofing materials meet these standards.

Table 2-1: Minimum Standards for Cool Roofing Materials

Roofing Material	Reflectance	Emittance	SRI*
White roof coatings	0.70–0.85	0.90	87–107
White tile	0.73	0.9	91
White membrane	0.70	0.87	84
White metal	0.60–0.70	0.85	82

Source: Lawrence Berkeley Laboratory
*SRI = Solar Reflective Index

2.2.2 Radiant Barriers

Radiant barriers are defined here as metal films or coatings that have the minimum standards listed here.

1. Aluminum-foil radiant barriers must be stapled to rafters with one staple every 3 inches.
   a. Emittance must be ≤0.08
   b. Reflectance must be ≥ 0.90
2. Spray metalized coatings, designed as low-emittance materials, to underside of roof deck.
   a. Coating emittance must be ≤0.23

2.2.3 Attic and Roof Insulation for Cool Roofs

Attic and roof insulation is important for slowing heat transmittance through attics and roof cavities. For the maximum performance of cool roofs, observe the following specifications.

1. Insulate attics and roof cavities to R-38 if they currently have less than R-19 insulation.
2. Seal all significant air leaks through the attic or roof before insulating.
3. Observe the specifications presented next for attic and roof insulation.

2.3 Attic and Roof Insulation

This section covers both attic insulation and roof insulation applied from the top or bottom of the roof assembly.

2.3.1 Blown Attic Insulation

Blown attic insulation is preferred to batts because of the seamless installation of blown insulation.

1. All major air leaks must be sealed before attic insulation is installed, including the following.
   a. Plumbing vents and electrical-wire penetrations
   b. Gaps around chimneys
   c. Balloon-framed interior and exterior wall cavities

d. Top plates of interior wall partitions

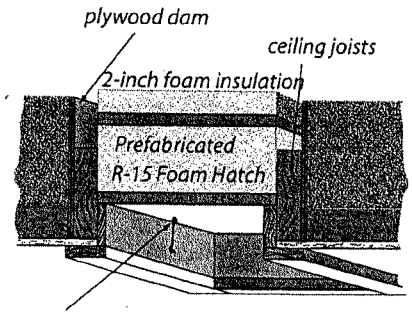
e. Interior kitchen or bathroom soffits

f. Housings of exhaust fans and recessed lights

g. Pocket doors

2. If the attic insulation has a thermal resistance of R-19 or less, add additional insulation to achieve R-38 or more.

3. Blown insulation should be installed at the highest achievable density, to reduce settling and convection within the insulation.



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

4. The area around the hatch should have the same high thermal resistance as the remainder of the attic. Provide an insulation dam around the attic access, to prevent loose-fill insulation from spilling into the living space when the hatch is opened. Dams may be wood sheeting or batt insulation.

5. Attic hatches must be insulated to a minimum of R-15.

6. Attic hatches must be weatherstripped.

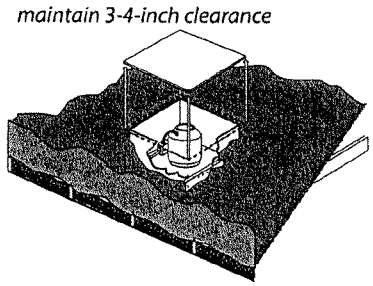
7. Use baffles to prevent blown insulation from blocking the eave/soffit vents. Baffles must be rigid material, such as moisture-treated cardboard to prevent windwashing through the insulation. The baffles should extend at least 4 inches above the final level of insulation.

Attic Insulation Safety

Installers must recognize potential hazards in attics and take action to avoid them.

1. Before an attic is insulated, all electrical connections must be enclosed in electrical boxes with cover plates.

2. Installer must protect heat-producing fixtures from attic insulation with solid non-combustible enclosures. Heat producing fixtures include the following.



Recessed light fixtures: Covering recessed light fixtures with fire-resistant drywall or sheet-metal enclosures reduces air leakage and allows installers to safely insulate around and over top of the box.

   a. Recessed light fixtures and fans

   b. Doorbell transformers

   c. Miscellaneous line voltage electrical devices

   d. All chimneys

3. The solid enclosures, surrounding heat-producing fixtures, must comply with the following specifications.

   a. Enclosures must be secured to surrounding framing or ceiling.

   b. Enclosures must keep insulation at least 3 inches but not more than 4 inches away from the sides and tops of heat-producing fixtures.

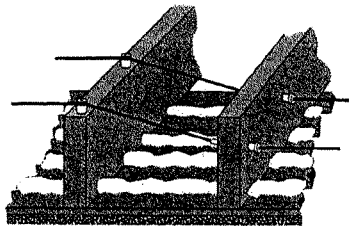
   c. Fiberglass insulation doesn't meet the criterion of a solid non-combustible enclosure.

4. Observe the following exceptions to the requirement for installing non-combustible enclosures around heat-producing fixtures.

a. UL listed Type IC (insulation contact) light and fan fixtures may be surrounded with loose-fill insulation and need not have a non-combustible enclosure. If in doubt about whether a fixture is IC, follow the specifications in #3 above.

b. Non-combustible fiberglass and rock wool insulation may be blown up against masonry chimneys, B-vent chimneys, and prefabricated all-fuel chimneys. Non-combustible insulation conforms to the standard test method ASTM E136.82. Single-wall chimneys aren't included in this exception and must have non-combustible enclosures.

5. Insulation must not surround live knob-and-tube wiring. Unfaced fiberglass batts may be laid under and/or tented over knob-and-tube wiring as long as the insulation remains at least 3 inches away from the wires.



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

6. In an attic, foam insulation must be protected from ignition by $1^1/_2$-inch thick mineral fiber insulation, plywood, particleboard, hardboard, gypsum wallboard, 26-gauge galvanized steel, proprietary ignition barrier, or other approved material. The ignition barrier must completely cover the foam insulation.

7. No electrical fixture or chimney may be surrounded by liquid foam insulation. This practice could cause overheating of the fixture or chimney or expose the insulation to higher temperatures than its manufacturer recommends.

8. New or retrofitted kitchen range exhaust fans, vented through the ceiling, must be connected to a duct made of 26-gauge galvanized steel. This duct must be substantially airtight and terminate directly to the outdoors, employing a code-approved water-tight metal vent cap. The termination fitting should be equipped with a backdraft damper if the fan has no backdraft damper.

Moisture Source-Reduction and Attic Ventilation

Moisture source-reduction is very important to preserving the thermal resistance and durability of insulation.

1. All roof leaks and other visible moisture problems must be investigated and mitigated before installing attic insulation.

2. Technicians must identify air leaks into the attic and seal them to prevent moist-air migration and save energy. Inspect of the following areas to locate attic air leaks.

   a. Attic floor underneath the insulation to locate thermal by-passes and cavities requiring air sealing.

   b. Water-damaged or moldy ceiling surfaces and roof sheathing.

   c. Attic insulation that has turned black as a result of air movement through the insulation.

3. Assess attic air leakage with a blower door when visual inspection isn't sufficient.

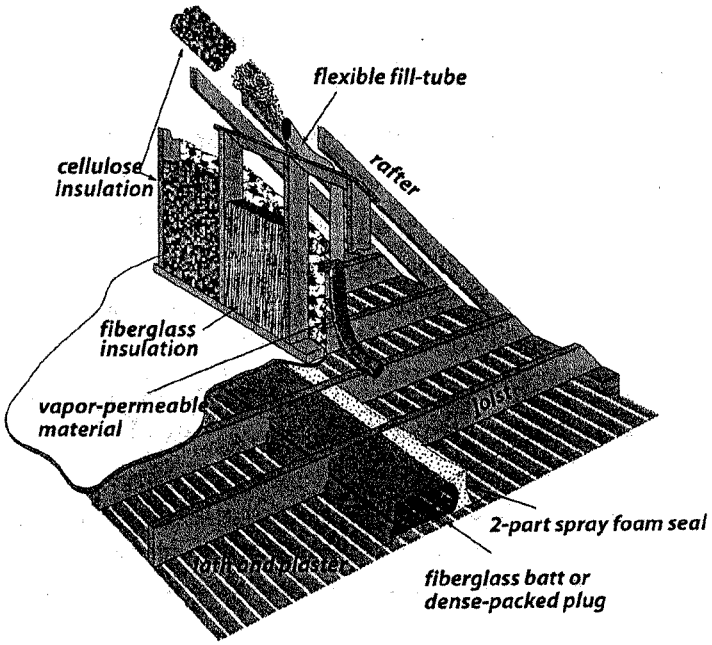
4. Install no additional attic ventilation without first sealing air leaks and verifying the presence of an effective air barrier at the ceiling.

5. When installing additional attic ventilation, strive for balanced areas of high and low attic vents. Position additional attic vents with the goal of maximizing cross ventilation to avoid stagnant areas.

2.3.2 KNEEWALL-ATTIC INSULATION

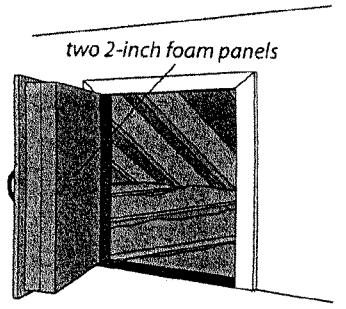
Second floors with kneewalls contain different cavities and surfaces, requiring insulation and air-sealing.

1. Installer must create a strong airtight seal between each floor joist underneath the kneewall. Plugging these spaces with loose-fill insulation is not acceptable without a rigidly adhered barrier like foam board or sprayed foam.
2. Seal all air leaks in kneewalls before insulating them.
3. Kneewalls must be either insulated with high-density blown insulation or high-density batts (≥R-13). In either case, the wall must be sheeted with a vapor-permeable air barrier: Tyvek®, OSB, expanded polystyrene sheets, or equivalent.



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

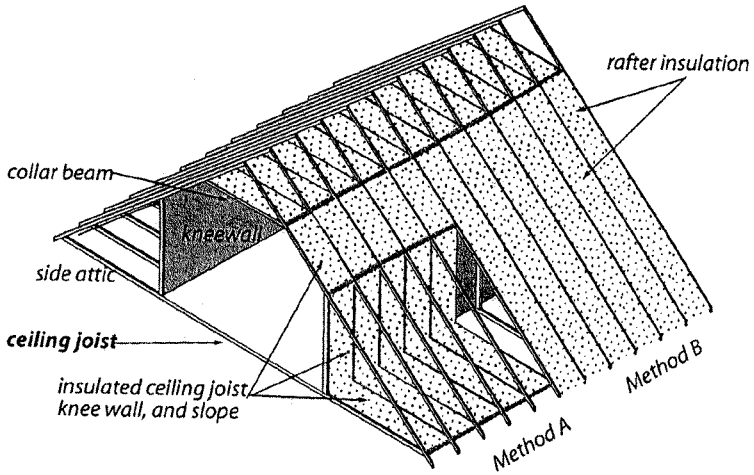
4. Insulate the access door through the kneewall to R-13. Weatherstrip the door and install a latch if necessary to ensure tight closure.
5. Sloped roof must be blown with high-density fiberglass, cellulose, or rock wool. Fiberglass batts, or other containment materials used at the lower and upper cavity openings, should allow for rapid drainage or vapor diffusion.



Insulated access door in kneewall: Attain the highest practical R-value and at least R-21

6. The outer floor joists of the kneewall attic should be blown with loose-fill insulation if the joist spaces are open or blown with dense-packed insulation if the joists are covered by floor boards.

7. The attic above the collar beam must be insulated as described in *"Attic and Roof Insulation" on page 19.*



Finished attic: This illustration depicts two approaches to insulating a finished attic. Either A) insulate the kneewall and side attic floor, or B) insulate the rafters. Method A reduces the size of the heating envelope. The use of the finished attic must be determined before treating the attic.

2.3.3 Roof-Cavity and Rooftop Insulation

This section covers insulating the roof deck from the top during re-roofing and insulating the underside of the roof deck.

Rooftop Insulation

Observe the following specifications for insulating roof cavities from outside the building.

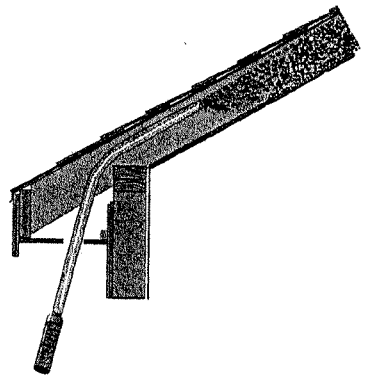
1. Roofs should be insulated to a minimum of R-20, or the highest thermal resistance achievable.
2. Drainage must be designed and built into a new rooftop insulation-and-roofing system for flat or nearly flat roofs to minimize ponding.

3. When plastic foam insulation is used as rooftop insulation, it must be separated from the attic by an approved ignition barrier. *See page 2-17.*

Closed-Cavity Roof Insulation

Closed roof cavities, like vaulted ceilings or flat roofs, can be insulated from the top, bottom, eaves, or ridge.

1. Closed roof cavities must be blown with high-density fiberglass, cellulose, or rock wool, using a fill-tube. The fill tube must reach to within 12 inches of the ends of the roof cavity.
2. When insulation fills closed roof cavities, existing cavity vents must be sealed.



Insulating closed roof cavities: Access closed roof cavities from their ends or through drilled holes in the ceiling.

Open-Cavity Roof Insulation from the Interior

These specifications are intended for insulating vaulted ceilings and flat roofs (after interior sheeting is removed) and insulating between rafters in attics.

1. In closed roof cavities, rooftop insulation should not be installed instead of roof-cavity insulation. Insulation is always less effective when there is an air space between the insulation and the home's interior.
2. Roofs must be insulated to a minimum of R-20, or the highest thermal resistance approaching R-20 that is achievable.

3. All air leaks must be sealed to minimize heat loss and moisture migration before or after the insulation is installed.
4. Insulation may be rigid foam, spray foam, fiberglass, rock wool, or a combination of these materials.
5. Rigid-board insulation must be cut to fit tightly between beams or rafters. Exception: Cut the foam panels $^1/_2$-inch short in both directions and careful fill the perimeter gaps with one-part foam.
6. Gaps between insulation boards and between insulation and other building components, when greater that $^1/_8$ inch in width, must be filled with one-part foam. Gaps less than $^1/_8$ inch in width must be caulked.
7. Fibrous insulation must be covered to prevent the spread of fibers in human-contact areas.
8. Foam insulation and rigid fibrous insulation with flammable facings must be covered by an approved ignition barrier. *See page 2-17.*

2.4 Wall Insulation

These specifications describe closed-cavity and open-cavity wall-insulation methods. Open-cavity methods are for walls that have no sheathing on one or both sides.

2.4.1 General Wall Insulation Specifications

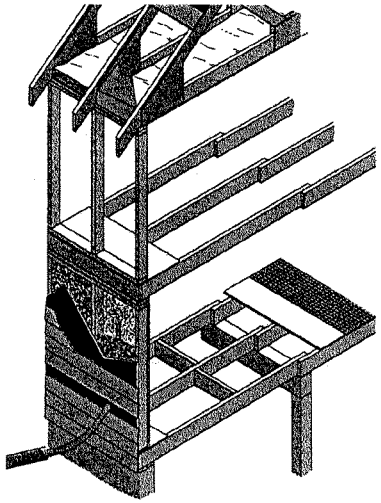
Observe the following general specifications when installing retrofit wall insulation.

1. Insulation must not be installed in wall cavities which:
   a. Serve as air ducts for heating, cooling, or ventilation;
   b. Contain live knob-and-tube wiring;
   c. Contain electric space heaters, unless fire stops are present or installed before installation is installed; or
   d. Contain chimneys, unless the insulation is non-combustible fiberglass or mineral wool.
2. Do not install sidewall insulation until moisture problems are corrected. Inspect walls for evidence of moisture damage, such as the following.
   a. Mold or dry rot;
   b. Deteriorated interior or exterior wall finish; and
   c. Damp drywall or plaster.
3. Inspect of the wall's interior and exterior surfaces for structural weakness. Reinforce weak areas before blowing insulation, including the following.
   a. Re-attach loose electrical boxes.
   b. Re-nail loose casing and baseboard.
   c. Re-nail exterior trim.
   d. Reinforce loose plaster, drywall, paneling, or siding.
4. Seal all major air leaks through walls before installing insulation.
5. Look for flaws in wall construction and interior sheathing that would allow insulation to escape from wall cavities into closets, cabinets, crawl spaces, pocket-door cavities, or other areas not intended for insulation.
6. Seal all gaps around windows and other exterior-wall penetrations that may leak water and dampen the insulation.

2.4.2 Blowing Dense-Packed Insulation

Insulation must be densely packed in wall cavities to resist settling and to reduce convection of air within the insulation.

1. Probe all holes to look for blockages. If blockages are found, the installer must drill additional holes to ensure complete coverage.
2. Install wall insulation using a fill-tube in order to achieve a uniform high density and complete coverage of the entire wall cavity with no voids. The fill tube must reach into the cavity within 12 inches of the top and bottom of the cavity.
3. Holes should be drilled through the sheathing rather than through siding. Remove siding in a professional manner with minimum damage. If some siding is likely to be broken or damaged beyond repair, replacement siding should be obtained in advance.



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

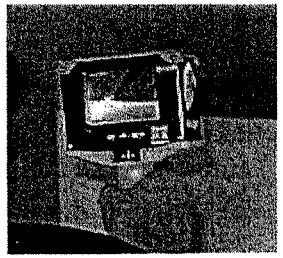
4. Installers must take care to minimize damage to the weather-resistant barrier under the siding and over the sheathing. Instead of removing a piece of this barrier, installer should cut a flap with the hinge on the top. Install a plug and staple this flap back in place after installing the insulation.
5. When blowing from the exterior is difficult or impossible, consider interior drill and blow. When blowing from the home's interior, erect barriers to contain dust, and cover carpets and household items with drop clothes.

6. To prevent settling, cellulose insulation must be blown at a minimum density of at least 3.5 pounds per cubic foot and fiberglass at a minimum density of 1.5 pounds per cubic foot.

Closed-Cavity Wall-Insulation Quality Control

The inability of the installer to see into closed wall cavities while insulating for feedback about the coverage is a major cause of defects, such as low density and voids in the insulation. This fact makes quality control during and after installation particularly important to the success of blown retrofit wall insulation. Inspectors should use one of the following methods to assess the coverage and density of wall insulation.

1. Inspector may verify the correct density of the insulation by bag usage, bag weight, and surface area of wall covered during installation. This verification takes place during an in-progress inspection.
2. The inspector may scan the walls using an infrared scanner. The installer will be recalled to fill any significant voids.

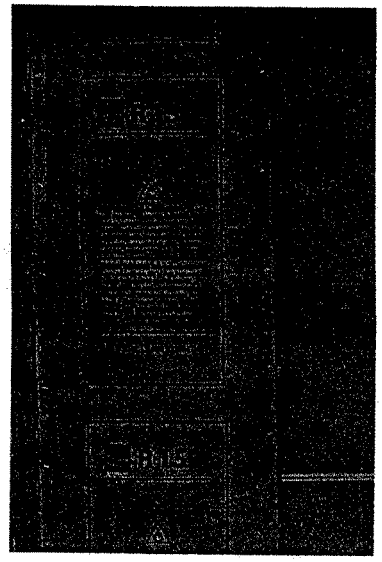


Infrared scanner: Allows the user to see temperature differences, which verify insulation's coverage in a wall cavity.

2.4.3 Open-Cavity Wall Insulation

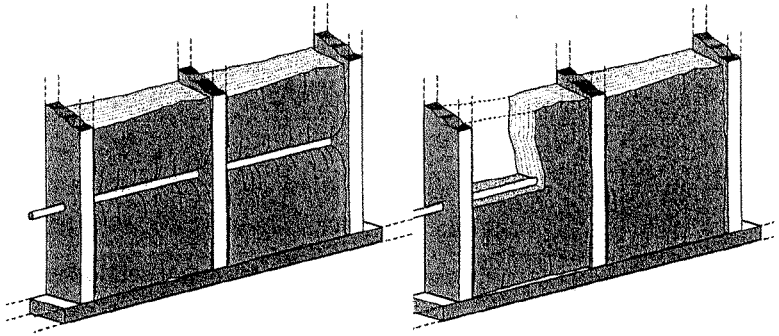
Observe the following specifications when insulating open-cavity walls with fiberglass batts.

1. Fiberglass batts, installed in 2-by-4 wall cavities, must be rated at R-15.
2. Fiberglass insulation and facings are combustible and must be covered with $^1/_2$-inch gypsum board or other code-approved fire barrier.
3. All significant cracks and gaps in the wall structure must be sealed before the insulation is installed.
4. Seal all holes in electrical boxes before insulating.
5. Batt insulation must be cut accurately to fill the cavity and must not have noticeable gaps (>$^1/_8$ inch) from being too small. Batts also must not must not exhibit bunching from being too large.
6. Installers must split batts around wiring rather than letting the wiring bunch the batt to one side of the cavity.



R-15 fiberglass batts: Install R-15 batts in open walls and attach them to the face of the stud as shown here.

7. Insulate behind and around obstacles with scrap pieces of batt or liquid foam before installing batts.



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

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

8. Staple faced insulation to outside face of studs; inset stapling is not permitted.

2.5 Floor Insulation

Insulate the floor only if you can do so without creating moisture problems or aggravating existing ones. The following specifications apply to existing floor insulation, in addition to newly installed insulation.

2.5.1 Preparing for Under-Floor Insulation

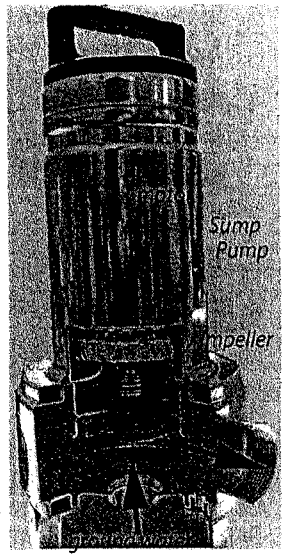
Solving moisture problems and insulating supply water pipes are necessary preparations for under-floor insulation.

Solving Moisture Problems

Observe the following specifications for avoiding the deteriorating effects of moisture in crawl spaces on insulation and other building materials.

1. All drainage problems, ground-water problems, wood-deterioration, and structural problems must be solved before insulation is installed in the floor.
2. Install gutters and downspouts as needed to prevent further damage by drainage and splash from roofs.
3. All crawl spaces must have a ground-moisture barrier.
   a. Existing ground-moisture barriers must cover at least 90% of the surface area of the ground in the crawl space.
   b. New ground-moisture barriers must cover the entire ground surface.
   c. Ground-moisture barriers must not come in contact with wood structural members, such as posts.
   d. Overlap seams 1 foot and seal with construction adhesive, acoustical sealant butyl caulk, or duct mastic.
4. Adhere and seal ground moisture barrier to foundation wall with construction adhesive, acoustical sealant butyl caulk, or duct mastic. Mechanical fastening with wood strips and concrete fasteners may be required in some situations.
5. Crawl spaces with a history of flooding must be equipped with a sump pump. The sump pump should be located in an area where it will collect water from the entire crawl space and pump it to a drain outdoors.

6. All combustion vents, clothes-dryer vents, and exhaust fan vents that terminate in the crawl space must be vented through the exterior foundation wall to outdoors as part of home performance or weatherization.



Sump pump: These handy pumps pump water out of a sump or hole where water collects in a basement or crawl space.

Crawl-Space Ventilation

Crawl-space ventilation must meet the following requirements before under-floor insulation is installed.

1. Where a ground-moisture barrier is installed and moisture isn't excessive, the crawl-space vent openings may have a vent area equal to 1 square foot of vent to 300 square feet of crawl-space area.
2. Where a ground-moisture barrier is installed and crawl space is dry, crawl-space vent opening may be reduced to a ratio of $^{1}/_{1500}$ (square foot of vent per square feet of crawl-space area).
3. Vent openings must be covered with corrosion-resistant quarter-inch screens or equivalent to exclude rodents and birds.

2.5.2 Installing Under-Floor Insulation

Observe the following specifications for insulating under floors.

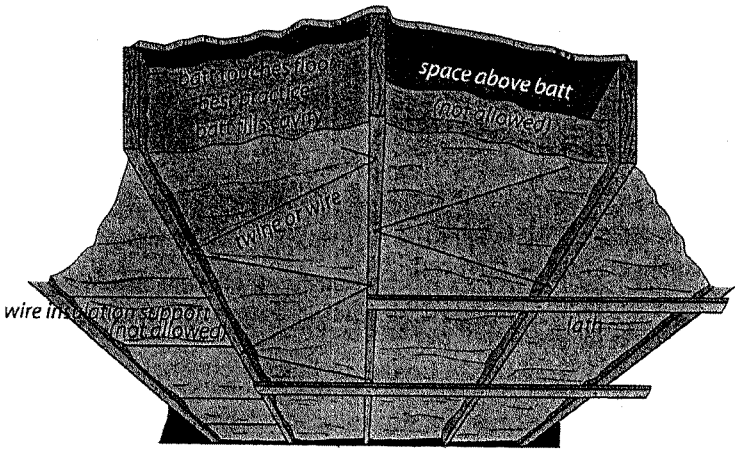
1. All significant air leaks through the floor must be sealed before or during floor insulation, using strong airtight materials.
2. Insulation may be unfaced fiberglass batts, dense-packed blown fiberglass insulation, or sprayed foam insulation.

3. Batts must either fill the complete depth of each cavity or have a thermal resistance of at least R-21.
4. Batts must be neatly installed, fitting tightly together at joints, fitting closely around obstructions, contacting the subfloor, and filling all the space within the floor cavity.
5. Engineered joists and trusses must not be insulated with fiberglass batts.
6. Blown fiberglass must be in continuous contact with the subfloor. This requires dense packing through a rigid vapor-permeable barrier covering the bottom of the joists such as drywall, OSB, or perforated foam board. This is the only approved way of insulating between engineered floor joists or trusses with fibrous insulation.
7. Sprayed foam insulation must be continuously applied to the subfloor and rim-joist area in not less than 2 inches or R-10 thermal resistance.

Fastening Under-Floor Batt Insulation

Fasteners for floor insulation must resist gravity, the weight of insulation, and moisture condensation.

1. Insulation must be in continuous contact with the underside of the floor
2. Batt insulation, installed in floors, must be supported by twine, plastic mesh, wire, or wood lath.
   a. Twine must be made of polypropylene or polyester and have a breaking strength of at least 150 pounds.
   b. Wire must be copper or stainless steel with a minimum diameter of 0.04 inches or size 18 AWG.
   c. Twine or wire must be installed in a zig-zag pattern. The staples must be no more than 12 inches apart for joists on 24-inch centers and 18 inches apart for joists on 16-inch centers.



Installing batts in floor cavities: Batts may be supported by twine, wire, or lath as shown here. The insulation should fill the cavity or at least be in continuous contact with the floor.

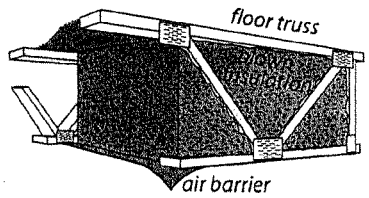
   d. Wood lath must be at least $^5/_{16}$ inch thick by 1 inch wide, number 1 grade. Joints in the lath must be made on a floor joist.
3. Fasteners for wire, twine, or lath must penetrate floor joists $^5/_8$ inch or more.
   a. All fasteners must be hot-dipped galvanized nails or corrosion-resistant staples (nickel, bronze, or aluminum).
   b. Staples must be at least 18 gauge and be power-driven. Hand staples don't reliably penetrate far enough.
4. When insulation doesn't fill the joist cavity, twine or wire must be stapled at the correct level to the sides of floor joists to hold the insulation tight against the under-floor.

2.5.3 Blown-In Floor Insulation

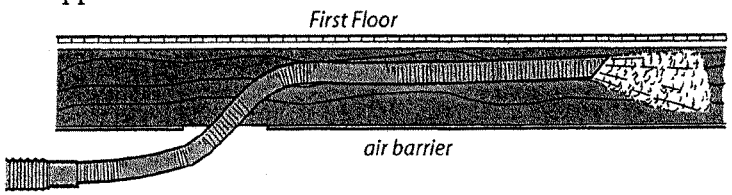
Installers may prefer to blow fiberglass insulation into the floor rather than installing batts, to insulate more easily and effectively around obstacles, for example. Cellulose is not permitted

because of moisture and settling concerns. Observe these specifications for blown-in floor insulation.

1. All major air leaks in the floor assembly must be sealed prior to installing insulation.
2. The entire under-floor surface must be covered by a vapor-permeable air barrier: house wrap, perforated $^1/_4$-inch foam board, or equivalent material.
3. The air barrier must be supported by twine, installed in a zig-zag pattern, not more that 12 inches on center. Perforated foam board must be supported by wood strips, spaced no further than 24 inches apart.
4. Twine, supporting house wrap, must be fastened with staples at least $^5/_8$ inches in length and made of 18-gauge corrosion-resistant metal.
5. Install rock wool or fiberglass blowing wool through X or V-shaped holes in the air barrier. Insulation must fill the entire cavity.
6. Use a fill tube for installing the blown insulation. Insulation must travel no more than 12 inches from the end of the fill tube to its final destination.
7. All penetrations in the air barrier must be sealed with an approved material.



Blown floor insulation: This method works particularly well with floor trusses.



Blowing floor cavity: Uninsulated floor cavities can be blown with fiberglass or mineral wool insulation, using a fill tube.

CHAPTER 3: WINDOW REPLACEMENT

This chapter is divided into two sections. The first section contains specifications for shading windows to reduce solar gain for the purpose of reducing air-conditioning costs and increasing comfort. The second section contains specifications for window replacement to reduce thermal transmittance through the window and increase their solar heat gain coefficient (SHGC).

3.1 WINDOW SHADING SPECIFICATIONS

These specifications recognize four window-shading options as common cost-effective measures. However, other window-shading options that meet the specifications, presented here, are also encouraged.

3.1.1 SOLAR SCREENS

Solar screens are fabric mounted in a metal frame, which is similar to an insect-screen frame.

1. Solar screens must be mounted on the outdoor side of the window frame or sash.
2. Solar screens should be removable.
3. Solar screens must be equipped with a material designed and tested to provide a shading coefficient of 0.50 or less.

3.1.2 WINDOW FILMS

Window films are plastic films treated with metalized materials, designed to reduce solar heat gain and glare through the windows.

1. Window films must be installed by qualified and experienced technicians.

2. Window films must be installed according to specifications established by the International Window Film Association.
3. Window films must achieve a finished window solar heat gain coefficient of 0.40 or less or a shading coefficient of 0.50 or less.
4. Window films should have a visible light transmittance (VT) of between 0.40 and 0.80. The VT should be chosen according to customer preference for preserving visible light and/or reducing unwanted glare.

3.1.3 Awnings

Awnings provide shading according to their projection and drop over the window.

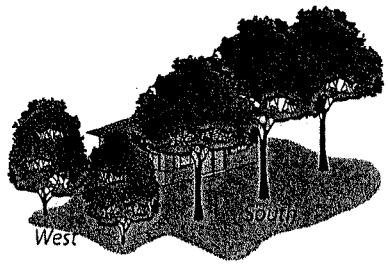
1. Awnings must be installed according to building codes governing their projection and height near walkways.
2. Contractors should use recognized calculation procedures to determine the projection and drop of awnings to achieve a 0.50 shading coefficient or less.

3.1.4 Trees

Trees are the most complex choice of window shading because of all the non-energy issues related to their use.

1. Trees must block solar heat from the azimuth and altitude of the sun during the cooling season.
   a. East and west-facing windows should be shaded by broad trees that block low sun angles.
   b. In general, trees should shade south-facing windows from high sun angles and be near enough to the home to shade the windows during the peak cooling period of the day

2. Trees should be of adequate height and size, when planted, to begin shading the windows immediately.
3. The contractor should consult with the homeowner, nursery experts, and landscape architects as necessary to select a tree, appropriate for the site, climate, and customer preferences. Consider the following factors in selecting trees for shading.
   a. The tree's resistance to stress factors present at the site, including soil-compaction, wind, and drought.
   b. Recommended soil type and preparation for the particular species of tree.
   c. Potential for roots to invade sewer lines.
   d. Potential for branches to grow into overhead utility lines.
   e. Cleanup of leaves, seeds, and fruit.
4. Educate customers about the watering and fertilization requirements of the tree.



Trees for shade: Choose tall trees with spreading canopies for the south facing wall and shorter wider trees for shading east and west.

3.2 Window-Replacement Specifications

The purpose of these specifications is to guide the selection and installation of replacement windows. Improper window installation can cause air leakage, sound leakage, and water leakage. Water leakage is a particularly serious concern because it deteriorates building components around the window. Existing window openings may have existing moisture damage and air

leakage. These conditions require repair during window removal and replacement.

Included here are specifications for two special window-safety considerations.

1. Windows in high-risk areas, such as around doors and walkways, must have safety glass.
2. Windows are part of fire escape planning for homes, so this egress function must be recognized and accommodated.

3.2.1 Window Installation Options

Consider the following three (3) options for replacing windows in homes with membrane-drainage systems, which utilize a weather-resistant barrier (such as Tyvek or asphalt felt) behind the siding.

The existing condition of the window and siding are the most important consideration for selecting one of the three options below. The third option is acceptable, the second is better, and the first is best.

1. Ideally, windows should be replaced during siding replacement so that the flashing can be integrated correctly with the exterior wall's weather-resistant barrier (usually house wrap or asphalt-impregnated felt).
   a. Use this method whenever moisture damage to both siding and window is evident.
   b. Replace all moisture-damaged components during window replacement, including framing members if necessary.
2. If the existing window is moisture-damaged or has other problems, the existing window should be completely removed to expose the rough opening.
   a. Use this method whenever moisture damage is observed to the existing window sill, jambs, or exterior trim.
   b. Flash the rough opening and integrate this flashing with the exterior wall's weather-resistant barrier.
   c. Replace all moisture-damaged components during window replacement, including framing and siding.
3. A replacement window may be installed within the existing window jambs and sill, when the existing window frame is undamaged by moisture and well integrated into the building exterior.
   a. Window jambs and sill must show no signs of deterioration from moisture.
   b. The manufacturer of the window should approve this replacement process; the manufacturer's instructions should be carefully observed.

The option, chosen for replacement-window installation, also depends on the following:

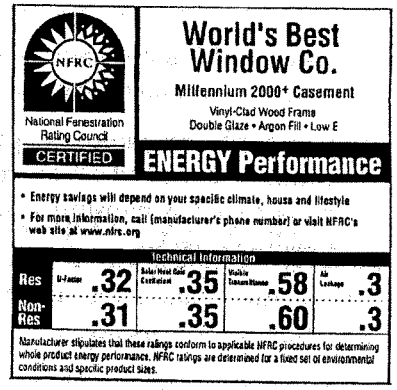
- Annual rainfall,
- Window orientation with reference to wind, rain, and sun, and
- The distance of the window's head jamb from a horizontal protective roof overhang.

The more exposed the window is to weather, the more effort is merited to optimize its installation.

3.2.2 Replacement Window Specifications

New windows, installed by weatherization and home-performance contractors, must be energy-efficient.

1. Replacement windows, facing west, east, or south in air-conditioned homes, should have a solar heat-gain coefficient (SHGC) of less than or equal to 0.40.
2. Replacement windows must have a U-factor less than or equal to 0.35.



NFRC label: The key selection criteria for window shopping is displayed on the NFRC label.

3. Window glass should have a visible light transmittance (VT) of between 0.40 and 0.80. The VT should be chosen according to customer preference for preserving visible light and/or reducing unwanted glare.

Window Accessory Specifications

Accessories are extra components used by installers to attach the window, seal the window into the home's weather-resistant barrier, and complete the window installation.

1. Windows must be shimmed as necessary using flat shims of the correct thickness to give the proper support at the sill and where fasteners are installed.
2. All fasteners used for window installation must be corrosion resistant, according to ASTM B 633, B 766 or B456.
3. Flashing for new windows must be reinforced, coated flexible flashing, designed for exterior water protection.
4. Sealants should be compatible with the materials they seal.
5. In joints more than $^3/_{16}$ inch in width, backer rod must be used to control sealant depth and prevent three-sided adhesion by the caulking.
6. All sides of exterior wood, used in the installation, must be primed with exterior primer or other equivalent wood sealer.
7. Metal window components must be protected from dissimilar metals or corrosive materials.

3.2.3 Preparing for Window Replacement

Preparing for replacement window installation includes the following steps.

1. Installer removes window sashes, and the frame if necessary, and the siding if necessary, depending on the window-replacement method chosen.
2. Installer must use whatever accessories are necessary to insure the proper fit, drainage, leveling, fastening, and finish.

Removing the Old Window

Existing windows should be removed properly without damaging surrounding building materials.

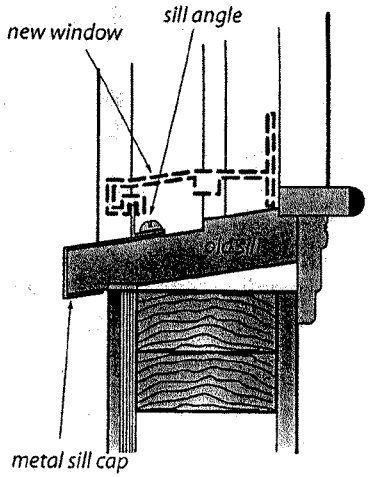
1. Installers must exercise care in removing windows to minimize damage to the home's interior finish, siding, exterior trim, and the weather-resistant barrier.
2. Installers must repair moisture damage to the rough opening before installing the new window.
3. Installers must recognize the hazard of lead paint and protect occupants from dust.

3.2.4 Installing the Replacement Window

The most important considerations for installing a new window is that the window installation is weathertight and airtight.

Installing Replacement Windows: Existing Jambs and Sill

When the contractor and homeowner are confident about the dryness of the window rough framing and existing window, replacement windows are often installed within the existing jambs and sill.



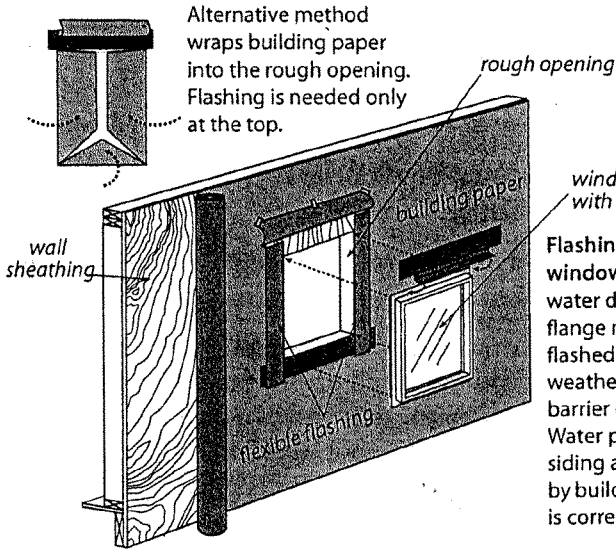
Replacement window and sill angle: The sill angle supports the window level and the sill cap covers and protects the aged sill.

1. The existing sill must be equipped with whatever leveling devices are necessary to provide a continuous, level, solid surface to support the new window sill.
2. The existing sill should be protected with metal and plastic flashing if necessary for drainage and to protect the protruding wood sill.
3. The replacement window should be sealed to continuous blocking during installation from either the interior or exterior.
4. Correctly sized shims must be used where the side jambs of the replacement window are fastened into the side jambs of the old window.
5. The space between the new window frame and old window frame should be sealed with caulking and backer rod on the sides and top.

Installing Replacement Windows Within the Rough Opening

When the window jambs, sill, or exterior trim are weathered or moisture-damaged, the existing window must be removed and the new window installed in the rough opening.

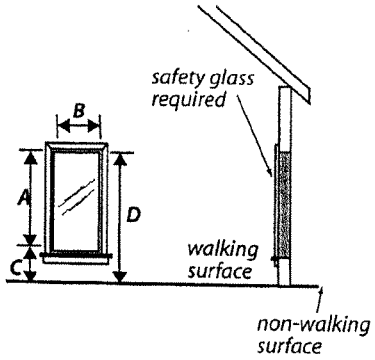
1. Installer must use whatever shimming assembly is necessary to support the replacement window on a solid, level, and water-resistant sill surface.
2. The new window must be flashed around its perimeter with approved flashing, installed from bottom to top like shingles in a way that doesn't permit water, flowing downhill with gravity, to enter any joint.



Flashing a flanged window: To prevent water damage, the flange must be flashed into the weather-resistant barrier of the home. Water penetrates the siding and is stopped by building paper that is correctly installed.

3. The window flashing should fit between the siding and the home's weather-resistant barrier on the window's bottom and sides and underneath the home's weather-resistant barrier on top of the window.

4. Installer must apply caulking or butyl putty tape on the window flange before installing the window. Follow the manufacturer's recommendations on sealant and its application.
5. When caulking is the window sealant, the window must be installed immediately after caulking application before the caulking becomes contaminated or forms a skin.



A x B = greater than 9 ft^2, and
C = less than 18 inches, and
D = more than 36 inches

Windows near walking surfaces: Safety glass is required in areas where the activity level is high.

6. The heads of fasteners must be wide enough in diameter to span the holes or slots in the window flange.
7. Installers must avoid deforming the window flange during fastening, by over-driving the fasteners.
8. Installers must insulate and air-seal the space between the window frame and the rough opening or old window jambs and sill. One-part foam and foam backer rod with caulking are approved methods. Stuffing this gap with fiberglass insulation is approved for insulating but caulking and backer rod must form the air seal.
9. Windows, exposed to wind-driven rain or without overhangs above them, must have a rigid cap flashing to prevent rainwater from draining onto the window. The cap flashing must overlap the sides of the window enough to divert water away from all horizontal joints bordering window, exterior window trim, and siding.

3.3 Window Safety Specifications

Windows have special requirements for fire escape and breakage-resistance in areas that are statistically prone to glass breakage.

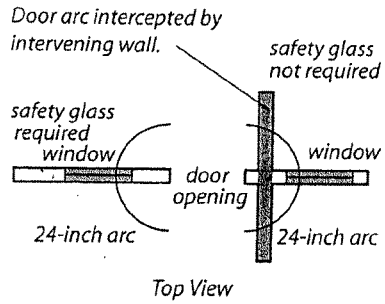
3.3.1 Windows Requiring Safety Glass

Safety glass must be used for window or glass replacement when the danger of breakage is high. Safety glass must be either laminated glass or tempered glass bearing a permanent label identifying it as safety glass.

Instead of safety glazing, glazed panels may have a protective bar installed on the accessible sides of the glazing 34 to 38 inches above the floor. The bar shall be capable of withstanding a horizontal load of 50 pounds per linear foot without contacting the glass and be a minimum of $1^1/_2$ inches in width.

Safety glass or a protective bar is required in the following conditions.

1. Glazing in entrance doors.
2. Glazing in fixed and sliding panels of sliding doors and panels in swinging doors other than wardrobe doors.
3. Glazing in fixed or operable panels adjacent to a door where the nearest exposed edge of the glazing is within a 24-inch arc of the vertical edge of the door in a closed position and where the bottom edge of the glazing is less than 60 inches above the floor or walking surface



Safety glass around doors: Doors create hazards for glass with the movement of people and things through them.

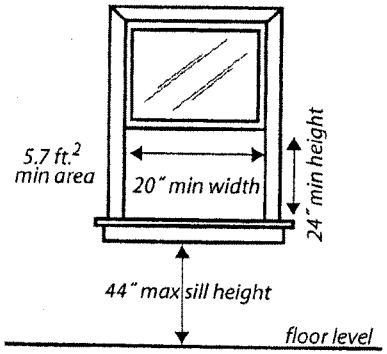
unless there is an intervening wall or permanent barrier between the door and the glazing.

4. Glazing in an individual fixed or operable panel other than those covered above that meet all of the following conditions:
   a. An exposed area of an individual pane greater than 9 square feet;
   b. An exposed bottom edge less than 18 inches above the floor;
   c. An exposed top edge greater than 36 inches above the floor; and
   d. One or more walking surfaces within 36 inches horizontally of the plane of the glazing.
5. Glazing in any portion of a building wall enclosing showers, hot tubs, whirlpools, saunas, steam rooms, and bathtubs where the bottom exposed edge is less than 5 feet above a standing surface or drain inlet.

3.3.2 Fire Egress Windows

Windows are the designated fire escape for many homes and should offer a minimum opening for a person's escape from a fire. The following specifications must be observed when replacing windows, regardless of the compliance of existing windows with fire-egress specifications.

1. Windows installed in bedrooms must observe the specifications for egress windows described here.
2. Each bedroom must have one egress window.
3. Egress windows must provide an opening that is at least 20 inches wide and at least 24 inches high.
4. Egress windows must provide an opening with a clear area of at least 5.7 square feet.
5. The finished sill of the egress window must be no higher off the floor than 44 inches.



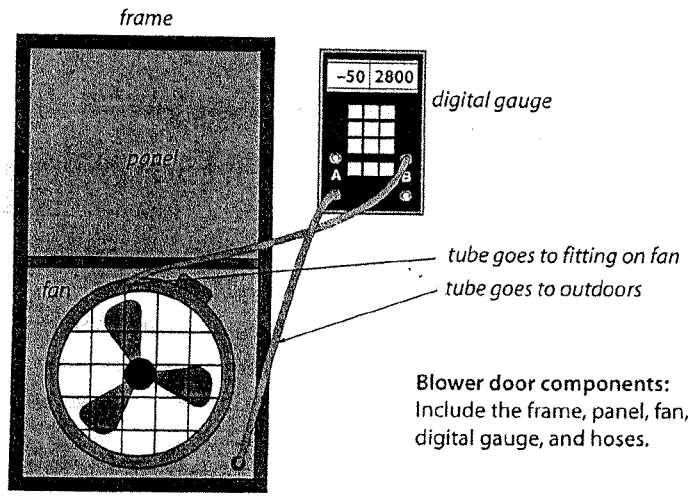
Egress windows: Windows for fire escape must be large enough and a convenient distance from the floor.

CHAPTER 4: AIR-LEAKAGE AND VENTILATION SPECIFICATIONS

Air leakage and ventilation are linked because most homes depend on air leakage to provide the ventilation needed to dilute pollutants and remove moisture. Contractors must perform blower door tests and estimate a minimum ventilation level (MVL) for each home and provide whole-house ventilation if necessary.

The MVL is a calculated minimum air-leakage rate adequate to provide sufficient ventilation without using fans. The home's actual air-leakage rate can be estimated using a blower door. Comparing the calculated MVL with the blower-door estimated air-leakage rate allows the building analyst to determine how much whole-house ventilation airflow to provide.

See "Airtightness and Mechanical Ventilation" on page 61.



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

4.1 Blower Door Testing Specifications

Blower door testing is required for certain home performance work, including the following.

1. Air sealing to reduce excessive air leakage or to seal leaks in attics or floors before insulating.
2. Duct sealing.
3. Dense-packed wall insulation.

The following blower door procedures must be documented if the above measures are undertaken.

1. Measurement of initial air-leakage rate by the blower door.
2. Air-leakage procedures undertaken.
3. Measurement of final air-leakage rate by the blower door.
4. Determination of minimum ventilation level (MVL) and comparison to final air-leakage rate in CFM_{50}, to evaluate the need for whole-house ventilation. *See "Determining the Need for Whole-House Ventilation" on page 61.*

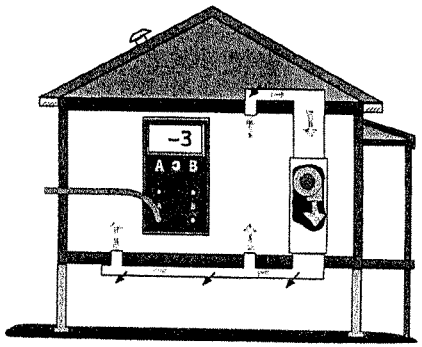
4.2 House Pressure Specifications

House pressures drive air through leaks in the building shell and can backdraft open-combustion gas appliances. House pressures are caused by the air handler, chimneys, exhaust fans, clothes dryer, wind, and stack effect.

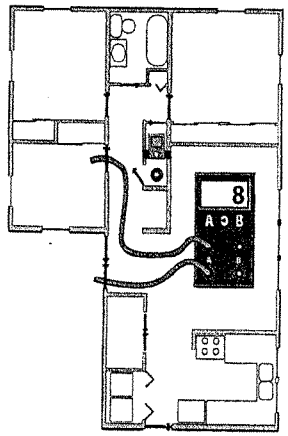
The air handler is the most prevalent source of house pressures. Air-handler-induced house pressures include pressures from duct leakage into and out of intermediate zones and unbalanced airflow between supply registers and return registers.

House pressure testing is required under the following circumstances.

1. Whenever open-combustion appliances are present in the home.
2. Whenever air-sealing is performed.
3. Whenever duct-sealing is performed.



Unbalanced air leakage: With interior doors open this air handler is depressurizing the home. This means that supply leaks are larger than return leaks. When the air handler causes house pressures, air leakage through the shell increases dramatically.



Blocked return path: With interior doors closed, the large positive pressure in the bedroom is caused by the lack of an air return register in the bedroom. The home's central zone becomes depressurized.

4.2.1 Mitigating House Pressures

Observe the following specifications about mitigating house pressures.

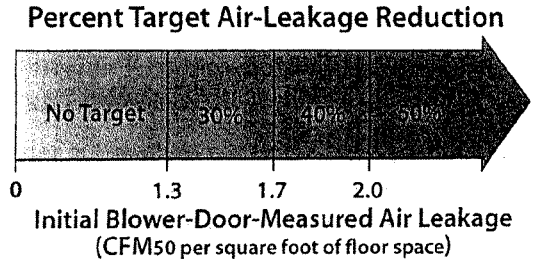
1. House pressures occurring in combustion appliance zones must be limited to the values in *"CAZ Depressurization Limits" on page 56.*
2. Other house pressures must be limited to 3 pascals between rooms and 2 pascals between the house and outdoors, in order to reduce the driving force for air leakage.
3. Document the testing and implementation process of mitigating house pressures.

Table 4-1: CAZ Depressurization Limits

Venting Condition	Limit (pa.)
Orphan open-combustion, natural draft water heater	–2
Open-combustion, natural draft furnace or boiler vented commonly with open-combustion water heater	–3
Individually vented open-combustion, natural draft furnace or boiler	–5
Fan-assisted-draft furnace or boiler commonly vented with open-combustion water heater	–5
Individually vented fan-assisted-draft furnace, boiler, or water heater	–15

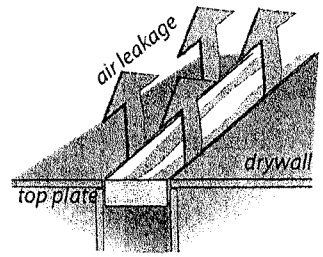
4.3 Air-Sealing Specifications

The most important issues for air sealing are using acceptable materials and installing the materials properly. Also important is sealing leaks in a cost-effective way, which requires sealing the biggest leaks first and sealing leaks through the home's ceiling and bottom floor before or instead of leaks in between. Blower door testing must accompany all air sealing to promote safety and cost-effectiveness. Follow the air-leakage reduction targets shown here to promote the cost effectiveness of air-sealing.

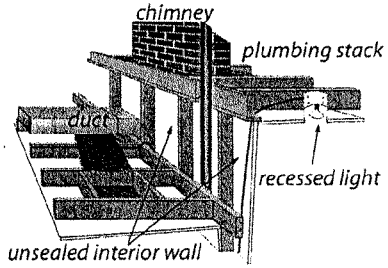


4.3.1 Sealing Bypasses

Bypasses are large gaps in the thermal boundary. They are the high-priority air leaks and must be sealed by strong materials, firmly fastened to the building's structure.



Interior wall top-plate leakage: The many linear feet add up.



Two-level attic leakage areas: Inspect and seal these areas.

1. Air-sealing methods and materials must provide a strong, airtight, permanent, safe, and code-compliant seal.
2. Bypasses in ceilings and floors must be sealed before insulation is installed.
3. Air leaks in walls between conditioned and unconditioned areas, such a exterior walls, knee walls, and walls between attached garages and conditioned rooms, must be sealed before the walls are insulated.
4. Bypasses around chimneys must be sealed with sheet metal and high-temperature silicone caulking.
5. Stuffing bypasses or smaller air leaks with fiberglass is not acceptable unless the fiberglass is a backing for spray foam or caulk.

4.3.2 Weatherstripping and Sealants

Weatherstripping and sealants reduce noticeable drafts in the living area. These leaks are less important than the bypasses discussed previously, except in the cases of pull-down stairways,

whole-house fans, and attic skuttle holes. The most important issues in installing sealants and weatherstripping are to use durable materials and to install them in the correct way.

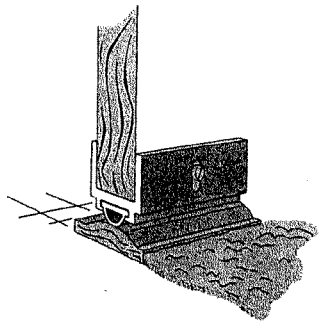
Weatherstripping

1. Weatherstripping must be installed in one continuous strip, if possible, and must maintain the continuity of its air seal around the perimeter of the door or window.
2. Weatherstripping must be installed so that there is no noticeable gaps or cracks between its metal strip and the surface it is mounted to.
3. Weatherstripping must not interfere with the smooth operation of doors, windows, or skuttle holes.
4. Door weatherstrip must be designed to allow for some small seasonal movement in the door. For example, vinyl flaps, silicone bulbs, bronze v-strip, and fabric-clad foam rubber permit a little seasonal movement without losing their seal.
5. Door-bottom seals should consist of a threshold and door bottom or sweep that form a tight seal without the door bottom or sweep scraping on the floor. Installers should install door bottoms, sweeps, and thresholds so that they don't interfere with foot-wiping rugs or mats.
6. Thresholds must fit tightly between door jambs with no visible gaps on the ends or underneath.
7. Self-adhesive weatherstrip is not allowed.

Spring Bronze

Silicone Bulb Weatherstrip

Neoprene/Vinyl Flap Weatherstrip



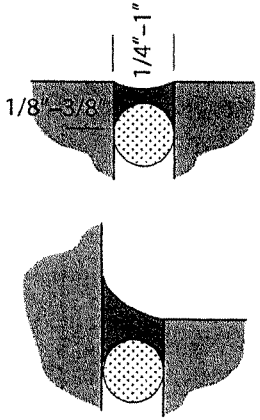
Threshold and Door Bottom

Acceptable weatherstrip examples: Weatherstrip should provide a good seal and be flexible and durable.

Caulking and Liquid Foam

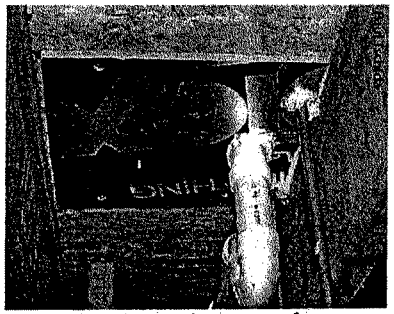
Caulking is preferred when the crack is less than $^1/_8$ inch. Liquid foam is preferred when the crack is greater than $^1/_8$ inch.

1. All dirt, caulking, loose or peeling paint, and other debris must be removed from the crack or joint before caulking or liquid foam is applied.
2. Cracks, deeper than $^1/_2$ inch must be filled with foam backer rod before caulking is applied. Liquid foam may be applied without backing.
3. Exterior caulking, used as a sealant around windows, must have sufficient adhesion and flexibility to bond to the substrates on both sides of the joint and to remain bonded, despite the substrates' movement from temperature changes. One-component polyurethane and polysulfide caulks are recommended.
4. Large irregular gaps and holes should be covered with rigid sheeting, fastened with screws or nails and then sealed and adhered around the perimeter with liquid foam. One-part foam works well for gaps up to about an inch. Two-part foam can seal whole air-porous surfaces and also works well as an air seal and adhesive around patches' perimeters.



Caulking and backer rod: Backer rod is required when sealing gaps more than 1/4 inch to 1/2 inch wide and more than 3/8 inch deep.

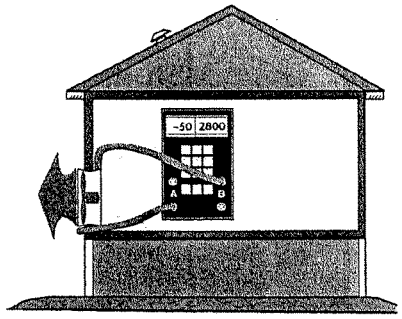
Foam sheeting and two-part foam: A fast and easy plug to large bypasses.



Foam sheeting and one-part foam: Seals effectively around plumbing.

4.4 Airtightness and Mechanical Ventilation

Either natural air leakage or natural air leakage aided by an exhaust fan must provide adequate ventilation to all weatherized homes. Continuous exhaust ventilation is the recommended option for moderately tight and tight homes to simplify design and implementation and also to reduce the chance of exceeding house depressurization limits. Supply ventilation is also a good option where winter temperatures aren't severe. Balanced ventilation, using a heat-recovery ventilator, is the best option for a tight home in a severe climate.



Blower door test: Blower door testing is used to evaluate air leakage and ventilation. This house has 2800 CFM_{50} of air leakage.

4.4.1 Determining the Need for Whole-House Ventilation

The procedure, outlined here, is based on ASHRAE Standard 62-89, which suggest methods of calculating a minimum ventilation level (MVL) from a home's square footage and number of bedrooms. If the procedure outlined here indicates the need for ventilation, consider the following alternatives.

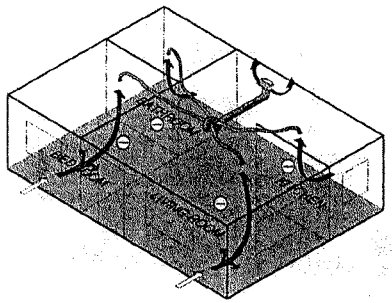
1. Install a continuously operating exhaust fan.

2. Install a cycling control on the forced-air HVAC system that has the following capability.

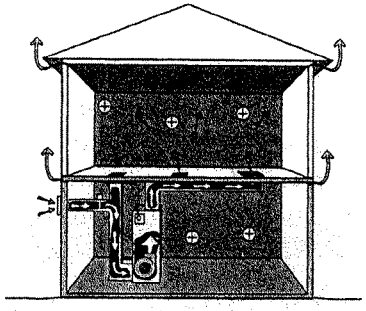
   a. Brings outdoor air into the ducted distribution during operation.

   b. Compares outdoor air delivered with outdoor air needed for ventilation.

   c. Operates the blower without heating or cooling if additional outdoor air is needed for ventilation.



Exhaust-only ventilation: A single- or multi-port ventilator pulls ventilation air through air leaks and exhaust home air outdoors. Continuous operation is the simplest and most satisfactory control strategy.



Supply only ventilation: The engineering on this supply-only option is more complex because the operation is intermittent.

4.4.2 Minimum Ventilation Level (MVL)

Evaluate a home's minimum ventilation level (MVL), based on ASHRAE Standard 62-89. The MVL is roughly about 1 (one) CFM_{50} per square foot of conditioned floor space. To calculate the precise MVL, take the higher of the two values obtained in steps 1 and 2 below.

1. Mechanical ventilation of 15 cfm per person. Assume occupancy of the number of bedrooms plus one or actual occupancy, whichever is higher. Multiply this figure by the n-value to get CFM_{50}. See *Table 4-2 on page 63* for n-values to use in these formulas. The n-value converts between airflow at 50 pascals and airflow at natural conditions.

2. Or, use the following formula to determine the MVL.

$$\text{MVL } CFM_{50} = \frac{0.35\ ACH_{50} \times \text{volume} \times n}{60}$$

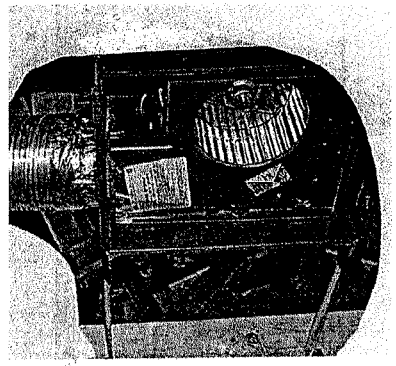
Table 4-2: n-values for Southern California

Zone	# of stories →	1	1.5	2	3
3	Well-shielded	25.8	23.2	20.6	18.1
	Normal	21.5	19.4	17.2	15.1
	Exposed	19.4	17.4	15.5	13.5
4	Well-shielded	29.4	26.5	23.5	20.6
	Normal	24.5	22.1	19.6	17.2
	Exposed	22.1	19.8	17.6	15.4

4.4.3 Fan Specifications

Fans, installed as part of home-performance work must vent to outdoors and include the following.

1. The ENERGYSTAR® seal.
2. A weatherproof termination fitting.
3. A backdraft damper, installed in the fan housing or termination fitting.



Specifying exhaust fans: Specify quiet energy-efficient fans.

4. Noise rating and ventilation efficacy as specified.

Table 4-3: Fan Capacity, Maximum Noise Rating, & Efficacy

Fan Capacity	Noise Rating (sones)	Efficacy cfm/Watt
<50 CFM	≤1 sone	≥2.8
50–100 CFM	≤1.5 sones	≥2.8
>100 CFM	≤2.0 sones	≥2.8

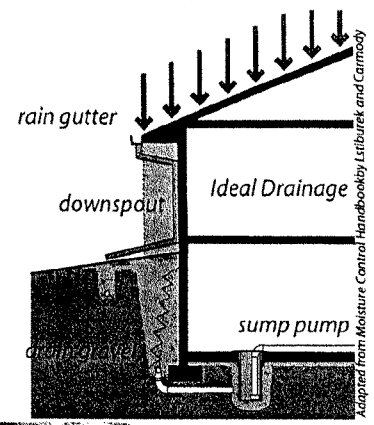
4.5 Moisture Mitigation Specifications

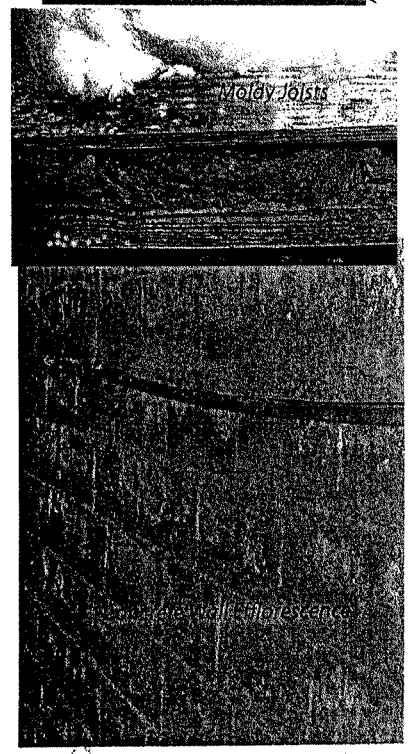
Ventilation can't mitigate serious moisture problems, which should be dealt with at their source. All homes must be assessed for moisture problems, which are manifested by the following observations.

1. Oxidation or rust on metals.
2. Mold and mildew.
3. Deformed wooden surfaces.
4. Peeling paint.
5. Concrete or masonry efflorescence.

If any of these effects are observed, take appropriate action, which may include the following.

1. Repair plumbing and roof leaks.
2. Install, clean, and/or repair rain gutters and downspouts as needed to prevent building damage from roof drainage and splash.
3. Improve drainage at the home's perimeter.





Signs of moisture problems: Analyze these problems before weatherizing a home.

4. Install a ground-moisture barrier in the crawl space.
5. Install a sump pump in the crawl space or basement.
6. Educate customer about reducing indoor and outdoor moisture sources.
7. Educate customer to use dehumidifiers for drying the home when dampness occurs.

CHAPTER 5: HVAC SPECIFICATIONS

Heating, ventilating, and air-conditioning (HVAC) systems, including, air conditioners, heat pumps, and ducts, offer some of the most promising energy-efficiency improvements for homes. Oversizing, low airflow, duct leakage, and incorrect refrigerant charge are common problems with simple solutions. This chapter covers the service and replacement of both air conditioners and heat pumps. Forced air systems, including furnaces, ducts, and registers are also covered in this chapter.

Some duct systems have such serious problems that they should be considered for complete replacement. Many duct systems are too small to efficiently serve the capacity of their air conditioners and furnaces. In homes with too-small ducts, a combination of shell retrofits and installation of a smaller system may be an appropriate strategy.

The sequence of testing and evaluation for HVAC service and replacement has a logic. First design the system properly if it is a replacement. Next, deal with duct airflow problems because you might either have to change the duct system substantially or replace it. Test the existing ducts or new ducts for leakage, and evaluate whether the ducts are located within the thermal boundary or not.

Decide whether duct sealing is important and if so, find and seal the leaks. Finally, if supply ducts are outside the thermal boundary, insulate them. The following list summarizes this logical sequence.

1. Evaluate and measure airflow.
2. Troubleshoot specific airflow problems.
3. Make necessary airflow improvements, including enlarging or replacing ducts.
4. Evaluate and/or measure duct air leakage.
5. Find duct leaks and seal them.

6. Consider insulating supply ducts.
7. Check and adjust refrigerant charge.
8. Measure and optimize combustion efficiency. *See "Gas Furnace Tune-Up" on page 93.*

5.1 Specification Summary

The following list is a summary of the most important specifications listed in this chapter.

Observe the following general specifications for HVAC service and replacement work.

1. All HVAC work, undertaken as part of home performance must comply with the following specifications.
   a. Building Performance Institute: *Technical Standards for Air Conditioning and Heat Pump Specialists.*
   b. California Title 24 Standards
   c. State and/or local building code, electrical code, mechanical code, and plumbing code.
2. Size systems and ducts according to methods outlined by the Air Conditioning Contractors of America (ACCA).
3. Verify that airflow, duct leakage, and charge are within specifications presented here.
4. Provide customers with owner's manuals and warranties for new equipment.
5. Take appropriate steps to minimize noise transmission from indoor and outdoor HVAC units.
6. Inform building occupants about contaminants, such as dust and chemical vapors, that could be spread through the ducted distribution system.

5.1.1 Thermostats

Thermostats can waste a lot of energy if they are located improperly, are the wrong type, or allow heating and cooling simultaneously. Consider the following specifications for thermostats.

1. Thermostats should be located in the return-air pathway, away from direct sun and other sources of heat.
2. Heating-and-cooling thermostats must be equipped with one of the following.
   a. Manual changeover switch
   b. Lockout to prevent simultaneous heating and cooling
3. Heat-pump thermostatic control must meet the following specifications.
   a. An outdoor thermostat must lock out resistance heating whenever the compressor is capable of providing comfort.
   b. Resistance heating must be locked out whenever the thermostat calls for cooling.
4. Programmable thermostats can be cost-effective for customers with the following characteristics.
   a. Customers don't currently adjust heating and/or cooling thermostat setpoint.
   b. Customers readily understand programming simple electronic devices.
   c. Customers are gone from the home during predictable hours.
   d. Customers don't mind deep heating setback at night.
5. Explain thermostat operation, including changeover switch, auxiliary heat indicator, and emergency heat indicator.

6. If a programmable thermostat is installed, the customer must be educated in its use.

5.2 Equipment Design and Sizing

Replacing central air-conditioners and heat pumps should be accompanied by improvements in the shell to reduce the cooling and heating loads. Many HVAC systems are oversized and have undersized ducts. Building-shell improvements should allow the installation of a new smaller HVAC system, with a design airflow through the ducts of 400-to-480 cfm per ton. To combine the benefits of shell improvements and proper sizing, consider the following specifications.

1. For mild coastal climates, undertake shell improvements that allow at least 1200 square feet of floor space to be cooled by each ton of air conditioning.
2. For inland desert climates, undertake shell improvements that allow at least 900 square feet of floor space to cooled by each ton of air conditioning.
3. System sizing-and-selection must be undertaken as specified by the Air Conditioning Contractors of America (ACCA).
4. Duct sizing must also be undertaken as specified by ACCA.

5.2.1 Ratings for Air Conditioners and Heat Pumps

This section presents minimum ratings for both central and room air conditioners and heat pumps. Room air conditioners and heat pumps are quite appropriate and efficient in small homes and for homes undergoing major energy retrofits, like cool roofs, increased insulation levels, and window shading to below 0.50 shading coefficient.

Replacement air conditioners and heat pumps must be labeled with the ENERGY STAR seal and have the following minimum ratings.

Table 5-1: Minimum System Ratings for Home Performance

System Type	SEER	EER	HSPF
Split-system air conditioner	13.0	11.0	–
Packaged air conditioner	12.0	10.5	–
Split-system heat pump	13.0	11.0	8.0
Packaged heat pump	12.0	10.5	7.7
Room air conditioner	–	10.8	–
Room heat pump	–	9.4	–

5.3 System Airflow

Evaluate airflow and correct airflow problems prior to sealing and insulating ducts or adjusting refrigerant charge. Tackle these obvious problems before measuring airflow.

1. Clean dirty filters and modify the filter installation to allow easier filter changing, if this is difficult.
2. Remove obstructions to registers and ducts such as rugs, furniture, and

Adding a return duct: Return air is often inadequate in existing forced-air distribution systems.

objects placed inside ducts (children's toys, water pans for humidification, etc.).

3. Remove kinks from flex duct, and replace collapsed flex duct and fiberglass duct board. Repair poorly fastened, restricted, or poorly supported ducts.
4. If the blower is dirty, an air conditioning coil, if present, is probably also dirty. Clean the blower and coil.
5. To prevent excessive air velocity and noise in newly installed or retrofitted systems, observe the following.
   a. Expect no more than 200 cfm per square foot of return filter grille.
   b. Expect no more than 300 cfm per square foot of non-filter grille.
   c. Friction loss across return grilles shouldn't exceed 0.05 IWC or 2 pascals.
   d. Friction loss across supply grilles shouldn't exceed 0.08 IWC or 3 pascals.

5.3.1 Measuring Airflow

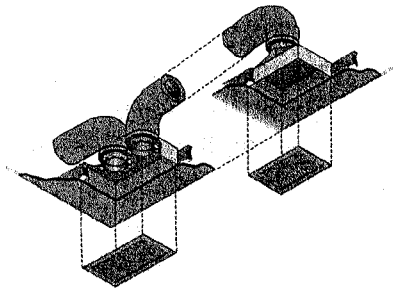
For HVAC repair and replacement, as a part of home performance, measure system airflow and meet the specifications listed here.

1. Airflow must be between 400 and 480 cfm per ton of air-conditioning capacity, according to one of the following measurement methods.
   a. Follow manufacturer's instructions for measuring system airflow using a fan and calibrated orifice, such as the Duct Blaster® by the Energy Conservatory.
   b. Follow manufacturer's instructions for measuring system airflow using a calibrated flow plate such as the Flow Grid® by the Energy Conservatory.
   c. Follow manufacturer's instructions for measuring return airflow at return registers using a flow capture hood.
2. Total external static pressure (TESP) should be within manufacturer's specified range, or be less than 0.5 IWC, or indicate that the air handler is moving 400 cfm per ton according to manufacturer's specifications.
   a. Measure total external static pressure with a manometer and compare with airflow table for the blower or air handler. This is a useful troubleshooting method. However TESP can't really estimate airflow accurately.
3. Provide adequate pathways for return air to reach the air handler without causing pressure differences between rooms of more than 3 pascals.
4. Take steps to increase airflow or reduce static pressure as discussed next.

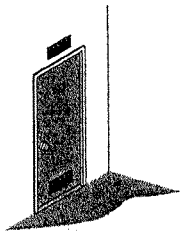
5.3.2 Increasing Airflow

Inadequate airflow is a common cause of comfort complaints and high electricity bills. Unbalanced airflow through ducts can pressurize or depressurize rooms, leading to increased air leakage through the building shell. When the air handler is on there should be a vigorous noticeable airflow from of each supply register. Return air needs a path back to the air handler from every room. Evaluate customer complaints and conditions you observe during a thorough duct inspection. Consider the following duct changes to increase system airflow and reduce the imbalance between supply and return.

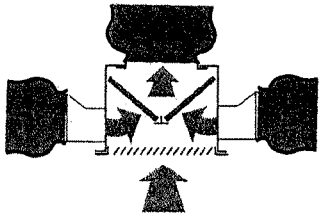
1. Increase the fan speed if the blower is not currently operating on the highest speed. Check registers for acceptable noise level.
2. Install additional supply ducts and return ducts as needed to provide conditioned air throughout the building, especially in additions to the building.



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

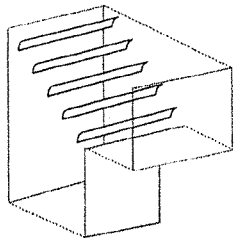


Installing transfer grilles in doors or through walls allows return air to escape from bedrooms.



You can expand an existing return register by connecting a return box and then run one or more branch returns into the box in a way that all the air is filtered.

Turning vanes dramatically improve airflow in square-duct bends.



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.

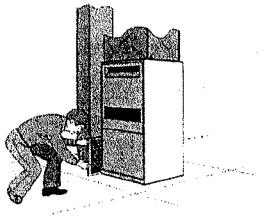
3. Replace ducts in poorly conditioned areas with larger ducts. Or, replace flex duct with same-diameter galvanized-steel duct fitted with exterior insulation.
4. Install a transfer grille between the bedroom and main body of house.

5. Install turning vanes or aerodynamically designed fittings at plenums.
6. Retrofit jumper return 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).
7. Undercut bedroom doors when customers approve.
8. Replace triangle junction boxes with sheet-metal wyes.
9. Lengthen supply plenums.

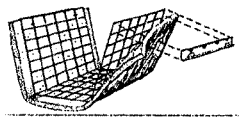
5.3.3 FILTERS

Correctly installed filters keep the heat exchanger, indoor coil and ducts clean, which is necessary for maintaining adequate airflow.

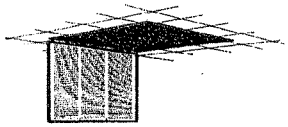
1. Install filters so that they completely fill the airway leading to the air handler. Permit no cracks, gaps, or holes by which air can flow around the filter.
2. Install air filters in locations where they are easy for the customer to change. Don't install filters in attics or crawl spaces.
3. Equip air filters slots with tight coverings.
4. If filter grilles are used, all return registers must have filters.
5. Avoid using filters with static-pressure drop of more than 0.20 inches of water column (IWC). The HVAC system and its ducts must be specially designed to accommodate such a filter if one is used.



Panel filter installed in filter slot in return plenum



Washable filter installed on a rack inside the blower compartment.

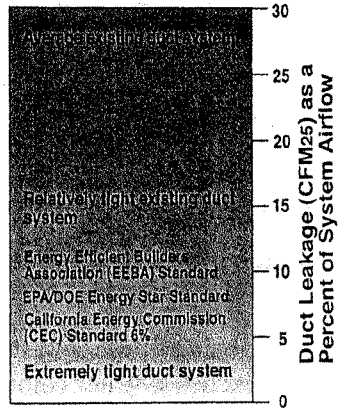


Panel filter installed in return register

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

5.4 Duct Sealing and Insulation

Air-sealing and insulating ducts can be cost-effective if undertaken prudently. Duct air-tightness testing is required for home performance work. Cost-effective duct sealing and insulation requires adherence to the minimum standards, listed here.



Duct leakage standards: Dividing the tested duct leakage in CFM_{25} by the system airflow provides the most common type of duct-leakage standard.

5.4.1 General Duct Specifications

Observe the following specification when assessing or improving all duct systems.

1. Forced-air system operation should not depressurize any building zone, served by a forced-air system or containing the system's air handling equipment, by more than 3 pascals with reference to outdoors over ambient conditions. *See "House Pressure Specifications" on page 54.*

Duct Air-Tightness Testing

Duct air-tightness testing is now required for both new installations and replacements.

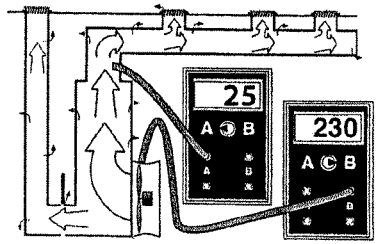
1. Duct modifications to improve airflow should precede duct air-sealing, to avoid the necessity of breaking freshly sealed joints.
2. Duct air-tightness must be measured with a duct-testing device, designed specifically for measuring duct air-tightness. The Duct Blaster® by the Energy Conservatory, or an approved equivalent testing device, is required for testing all homes with forced-air systems.

Duct Blaster connected to main return: Measures duct air leakage.

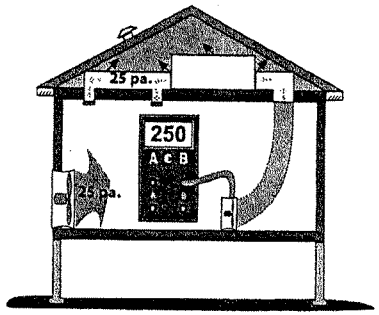
Duct Sealing Specifications

Observe the following specifications when sealing ducts.

1. Ensure that no major changes to the ducts will be required after sealing the ducts.
2. All accessible duct joints, within 20 feet of the supply and return plenums, must be sealed.
3. Original leakage value must be ≥10% of measured or estimated airflow with ducts located outside conditioned areas.
4. After the ducts are sealed, duct leakage must be reduced to ≤6% measured or estimated airflow or reduced by at least 40% of original value in CFM_{25}.



Total duct air leakage: Supply and return registers are taped and the duct is pressurized to 25 pascals.



Duct air leakage to outdoors: Supply and return registers are taped and both the ducts and house are pressurized to 25 pascals.

Duct-Sealing Materials and Installation

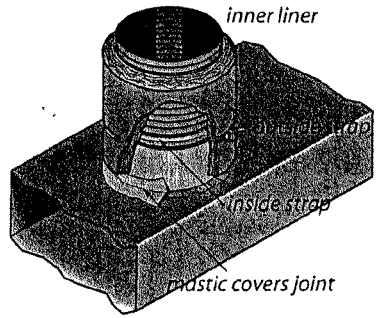
The following specifications are required for sealing ducts.

1. All duct materials and duct-sealing materials must be installed according to manufacturer's specifications.
2. Remove any loose duct tape prior to sealing.

3. Duct joints, except the plenum-air-handler joint, must be sealed with water-based mastic, designed and manufactured for sealing ducts and labeled UL 181.
   a. Mastic, labeled UL 181A-M, is designed for metal ducts.
   b. Mastic, labeled UL 181B-M, is designed for non-metal ducts.

Duct-sealing materials: Mastic and mesh tape are the most effective sealing products.

4. The mastic must be applied at a thickness of at least 20 mils (the thickness of a dime) or follow manufacturer's specifications for thickness.
5. The air handler and joints between the plenum and air handler must be sealed with silicone caulking or aluminum foil duct tape, marked UL 181-P.
6. Gaps between duct sections, larger than $^1/_8$ inch, must be reinforced with 2-inch-wide mesh tape that is compatible with water-based duct mastic.
7. Insulated flex duct must join to metal duct or fiberglass duct board, using a metal fitting. The flex duct's inner liner must be sealed to the metal fitting using a plastic strap tightened by a manufacturer-approved tool. The flex duct's outer liner must be fastened with a second tool-tightened plastic strap.



Flex-metal joint: A metal collar, two panduit straps and mastic are necessary for an airtight joint.

8. Splices in insulated flex duct must use a metal collar. Each flex-duct section must be sealed with plastic straps as described above.
9. Joints in fiberglass duct board must be sealed with FSK tape, specifically designed for this purpose. The tape may be covered with a layer of mastic to provide a more permanent and secure seal.

Duct Insulation

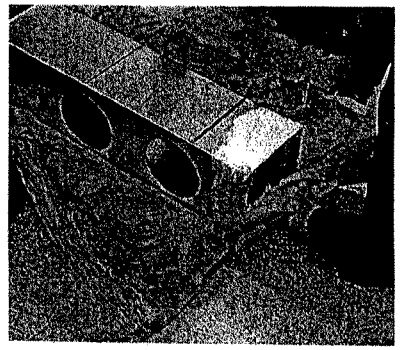
Observe the following specifications for insulating existing ducts, located outside the conditioned space of the home.

1. Duct insulation should follow duct air-sealing, because insulation blocks access to duct joints needing air-sealing. *See "Duct Insulation" on page 80.*
2. Accomplish duct-insulation retrofits with approved duct materials, such as the following.
   a. Manufactured or shop-fabricated galvanized steel insulated to R-8 on the exterior with faced insulation meeting flame spread of 25 or less and smoke-developed rating of 50 or less.
   b. Insulated flex duct with a thermal resistance of at least R-8 certified by the Air Diffusion Council (ADC).
   c. Covering the ducts with at least 6 inches of blown fibrous insulation.

5.4.2 Specifications for New Ducts

Observe the following specification for installing new ducts in existing homes.

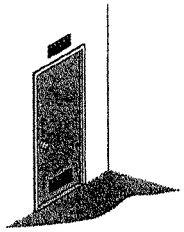
1. Duct systems must be designed, sized, and installed, using recognized industry standards, so that the calculated heating and/or cooling loads of each zone are satisfied.
2. New supply and return ducts, installed in existing homes, must be made of approved duct materials such as the following.
   a. Manufactured or shop-fabricated galvanized steel insulated to R-8 on the exterior with faced insulation meeting flame spread of 25 or less and smoke-developed rating of 50 or less.
   b. Insulated flex duct with a thermal resistance of at least R-8 certified by the Air Diffusion Council (ADC).
   c. Manufactured or shop-fabricated galvanized steel insulated to R-8, using interior duct liner installed according to duct-liner standards published by the Sheet Metal Associated Contractors of North America (SMACNA).
3. New ducts must be properly supported, according to SMACNA specifications.



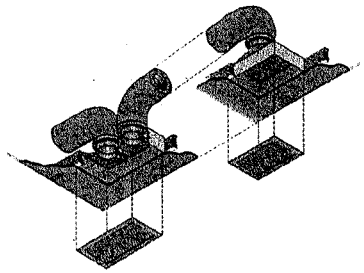
Insulated plenum: Extended plenum being insulated before installation.

R-8 flexduct: A thermal resistance of R-8 is required for new and replacement flex duct.

4. Each joint in the new duct system must be mechanically fastened and air-sealed around its perimeter.
5. Return air ducts or passive pressure-relief grilles should be installed in each zone and on each level. (Zones are areas of the home that can be separated from other areas by closed interior doors.)
6. Building cavities must not be used as return or supply ducts.



Transfer grilles: Installing transfer grilles in doors or through walls allows return air to escape from bedrooms.

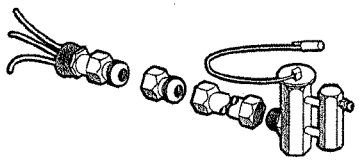


Jumper ducts: Jumper ducts can bring air from a restricted area of the home back to a main return register.

5.5 Refrigeration

A correctly installed and properly commissioned refrigeration system is essential to energy efficiency and satisfactory operation.

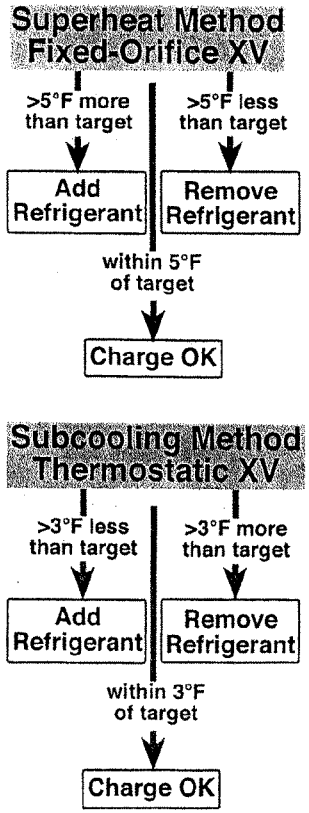
1. New central air conditioners and heat pumps must be equipped with thermostatic expansion valves (TXVs). TXVs perform better than fixed-orifice expansion devices during high temperatures and are less affected by deficient airflow or incorrect refrigerant charge.



TXVs: TXVs control the flow of refrigerant for better efficiency and performance under varying outdoor temperatures.

2. Select matching indoor and outdoor refrigeration coils, according to manufacturer's specifications, whenever one or both coils is replaced.
3. When replacing the system, check the manufacturer's specifications for refrigerant-line sizing and replace the refrigerant lines if they are too small.
4. Don't add refrigerant to systems, which are recently charged correctly or which are known to be leaking.
5. The liquid line must be equipped with a filter-drier.
6. Suction lines should be insulated to R-2 UV-resistant foam insulation fitted correctly for the pipe size.
7. Refrigerant piping passing through the air handler or the building shell must be supported and grommeted to prevent sound transmission and piping wear due to vibration.
8. Seal holes created for refrigerant lines in the building shell, the air handler, and ducts.
9. Whenever refrigerant is removed from a system for repair or replacement, evacuate the system to 500 microns. The system should hold this vacuum for five minutes without losing more than 200 microns of negative pressure.

10. For systems with fixed-orifice expansion valves, measure superheat and add or remove refrigerant, if necessary to achieve the correct superheat value within ±5° F.
11. For systems with TXVs, measure subcooling. Add or remove refrigerant, if necessary, to achieve the correct subcooling value within ±3° F. If the manufacturer's literature is unavailable to determine the correct subcooling value, use 10° F.



Charge checking: Evaluate charge and add or remove refrigerant to bring values within the ranges specified here.

CHAPTER 6: GAS APPLIANCE COMBUSTION

The purpose of these specifications is to ensure the safety of natural-gas combustion appliances. These specifications combine information developed by specialists working with the Canada Mortgage Housing Corporation, the DOE Weatherization Assistance Program (WAP), and the Building Performance Institute (BPI).

6.1 GENERAL COMBUSTION SPECIFICATIONS

Testing for gas leakage, carbon monoxide (CO), and draft are the basic components of combustion safety testing.

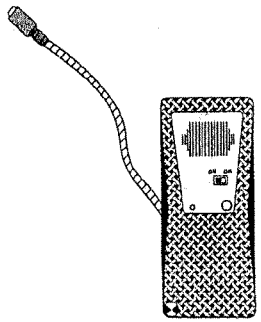
1. Natural gas leak testing is required for all homes with gas appliances.
2. Combustion testing is required for all homes with gas appliances.
3. Technicians and analysts must record key measurements before and after adjustment for the purpose of quality control.
4. Unvented space heaters must be disabled or removed from a home before the home is air-sealed.

Caution: Testing must be stopped whenever the ambient level of CO around the technician exceeds 35 parts per million (ppm). In this case, the occupants should be informed of the danger of the range according to the policy of the program.

6.2 NATURAL-GAS SUPPLY SAFETY

Leaking natural gas is a fire hazard and also dilutes oxygen in the air, causing a health and safety hazard. Gas leakage also wastes energy.

1. Inspect all gas fittings and joints in the gas supply lines as well as gas piping and fittings within the appliances, using an electronic combustible gas detector and soap bubbles.
2. All gas leaks must be repaired as part of home-performance work.
3. Flexible gas lines must be replaced if they are kinked, corroded, have soldered connections, or show visible signs of wear.



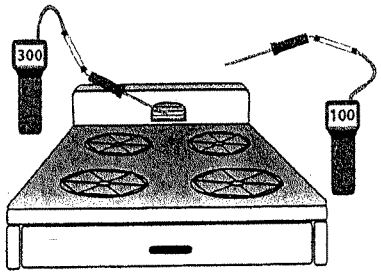
Electronic gas leak detector: Sniffs out gas leaks in homes.

4. Flexible gas lines manufactured before 1973 must be replaced. The date is stamped on a date ring attached to the flexible gas line.

6.3 CO-Testing for Ranges and Ovens

Ranges and ovens exhaust their combustion products into the kitchen and are a health and safety threat if they produce particular levels of CO. Exhaust fans are recommended for exhausting combustion by-products and cooking odors from gas ranges and ovens. Observe the following specifications for testing and mitigation of range and oven CO.

1. When the measured CO level is between 100 and 300 parts per million (ppm), measured at the oven vent while the oven is lit or one foot above the burners while they are lit, the following two (2) steps are required.



CO from ranges: Three steps are required for CO levels above 100 ppm.

   a. Either undertake cleaning, removal of obstructions (aluminum foil), and burner adjustments to reduce the CO level, or recommend a service call by a gas combustion specialist to mitigate the CO problem.

   b. Install a CO alarm in the kitchen.

2. In the case of CO greater than 300 ppm, install an exhaust fan with a capacity of 100 cubic feet per minute (cfm) in the kitchen, in addition to the two steps above.
3. Kitchen exhaust fans, installed as part of home-performance work, must vent to outdoors and be equipped with the following.

Advanced 4-speed range fan: Lower speeds for continuous ventilation and higher ones for spot ventilation.

   a. Solid galvanized-steel ducting to the outdoors.

   b. A weatherproof termination fitting.

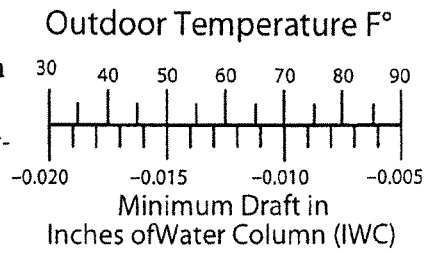
   c. Two speeds so that the lower speed can be used for continuous ventilation if needed. *See "Determining the Need for Whole-House Ventilation" on page 61.*

   d. Noise rating of less than 2 sones.

Table 6-1: CAZ Depressurization Limits

Venting Condition	Limit (pa.)
Individually vented open-combustion, natural draft water heater	–2
Open-combustion, natural draft furnace or boiler, vented commonly with open-combustion water heater	–3
Individually vented open-combustion, natural draft furnace or boiler	–5
Fan-assisted-draft furnace or boiler, commonly vented with open-combustion water heater	–5
Individually vented fan-assisted-draft furnace, boiler, or water heater	–5
Sealed combustion gas appliances	–30

6.4 CO, Draft, Spillage Testing for Open-Combustion Vented Gas Appliances



This section specifies action levels and actions to be taken in cases of excessive CO, inadequate draft, and/or persistent spillage. Draft is the measured pressure in the chimney or vent connector with reference to the combustion appliance zone (CAZ). Spillage is combustion by-products that leak out of the chimney or combustion chamber when the draft is weak, particularly at start-up.

6.4.1 CO in Natural-Gas Open-Combustion Appliances

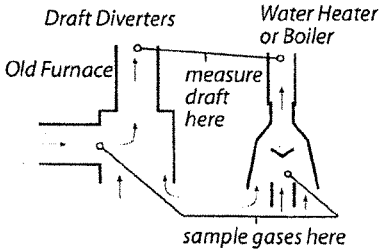
Testing for CO is required in all homes with gas appliances. Document the CO test by recording parts per million of CO, and take action according to the requirements in *"Action Levels for CO, Draft, and Spillage" on page 92.*

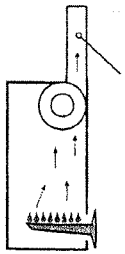
CO is a threat to health and safety, depending on the following factors.

1. The level of CO production in undiluted flue gases as measured by a CO testing device.
2. Venting performance as measured during a worst-case test.
3. Venting performance during normal venting conditions (not worst-case).
4. The proximity of the open-combustion appliance to the living space. Open-combustion space heaters, which emit CO, are particularly dangerous.

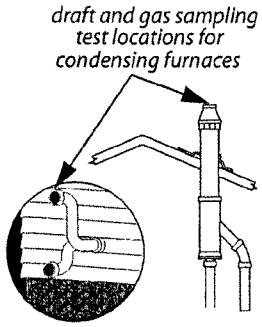
6.4.2 CO, Draft, and Spillage Testing Requirements

Most combustion appliances have naturally drafting chimneys, which exhaust combustion gases using the small negative pressure (draft) caused by the buoyancy of the hot gases. This draft may be reversed by competing pressures in the home from the air handler, exhaust fans, clothes dryers, and other chimneys. Spillage is a serious health and safety problem when the combustion gases contain CO.





Where to sample gases and measure draft: Location varies according to the type of furnace.



1. Open-combustion gas appliances must be tested for draft, spillage, and excessive CO.
2. For furnaces with draft diverters: measure CO in undiluted flue gases emerging from the exhaust port of the heat exchanger. Measure draft in the vent connector.
3. For 80+ AFUE furnaces without draft diverters: measure CO and draft in the vent connector or chimney.
4. For 90+ AFUE condensing furnaces, test for CO and draft inside the exhaust pipe termination, which is located outside the home.
5. Test for spillage when the appliance burner ignites. Spillage is temporary backdrafting of combustion by-products into the CAZ. Spillage can be detected by the fogging of a mirror, smoke, or a positive draft reading. Spillage should end with 30 seconds of startup.
6. Measure and document draft measurements in open-combustion appliances during worst-case conditions. Worst-case conditions include operating the air handler, exhaust fans, and opening and closing interior doors until the highest achievable negative pressure is recorded in the CAZ.
7. If the draft in an appliance fails during worst-case conditions, measure and document the draft again during natural conditions.
8. Take required actions, according to test results and observations, as specified in *Table 6-2 on page 92.*

Table 6-2: Action Levels for CO, Draft, and Spillage

Testing Results			Required Action
CO Level	And/ Or	Draft / Spillage	
0 – 25 ppm	and	Passes	Proceed with work.
26 – 100 ppm	and	Passes	Recommend that the CO problem be fixed.
26 – 100 ppm	and	Fails at worst-case only	Recommend a service call for the appliance and/or repairs to the home to correct the problem.
100 – 400 ppm	or	Fails under normal conditions	**Stop Work:** Work may not proceed until the system is serviced and the problem is corrected.
>400 ppm	and	Passes	**Stop Work:** Work may not proceed until the system is serviced and the problem is corrected.
>400 ppm	and	Fails under any conditions	**Emergency:** Shut off the fuel to the appliance and ask the homeowner to call for service immediately.

Courtesy: Building Performance Institute Inc.

6.5 Heat-Exchanger Leak-Testing

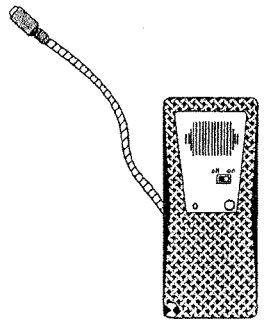
The heat exchangers of natural gas furnaces may be a health and safety hazard if they have leaks and if the furnace burners are producing carbon monoxide. Heat exchanger leakage is most easily detected through flame interference caused by blower activation. The blower interferes with the flame of a leaking heat exchanger by moving air through the leak.

1. Observe the flame at the moment when the blower is activated by the blower control.
2. If the flame changes or moves when the blower is activated, make further observations and/or take further tests.
3. If a leak is present, replace the heat exchanger or the furnace as part of home-performance work.

6.6 Natural-Gas Supply Safety

Leaking natural gas is a fire hazard and also dilutes oxygen in the air, causing a health and safety hazard. Gas leakage also wastes energy.

1. Inspect all gas fittings and joints in the gas supply lines as well as gas piping and fittings within the appliances, using an electronic combustible gas detector and soap bubbles.
2. All gas leaks must be repaired as part of home-performance work.
3. Flexible gas lines must be replaced if they are kinked, corroded, have soldered connections, or show visible signs of wear.



Electronic gas leak detector: Sniffs out gas leaks in homes.

4. Flexible gas lines manufactured before 1973 must be replaced. The date is stamped on a date ring attached to the flexible gas line.

6.7 Gas Furnace Tune-Up

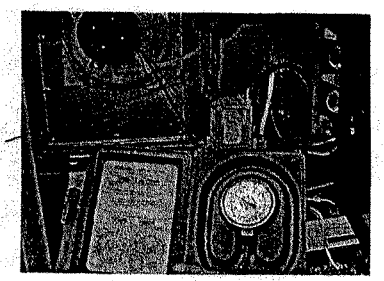
Gas furnaces should be tuned up when combustion analysis and visual inspection indicates the need for a tune-up. A furnace tune-up must employ a combustion analyzer and be documented on a furnace tune-up form. The combustion analyzer must measure CO, draft, flue-gas temperature, and oxygen. The technician should observe the specifications for furnace operation listed in *Table 6-3 on page 96*.

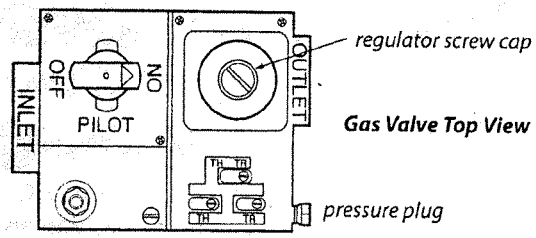
Take the following initial steps in tuning the furnace.

1. Clean or change the filter if it is dirty.
2. Take whatever steps are necessary to ensure that the filter completely covers the return register or opening into the air handler.
3. Clean the blower if it is dirty.
4. Improve airflow to rooms as appropriate.
5. Set the fan-off temperature at 90° F or slightly higher, if needed to provide warm enough delivery-air temperature for occupant comfort.
6. Set fan-on temperature to 120-130° F or a time delay of 45 seconds or less.
7. Set the thermostat's heat anticipator to the amperage of the control circuit, or follow the thermostat manufacturer's procedure for optimizing cycle length for comfort and energy efficiency.
8. Reduce CO by adjusting primary air, cleaning or aligning burners, or improving draft.
9. Monitor CO, flue-gas temperature, oxygen, and draft with an electronic combustion analyzer. Prepare to adjust gas pressure and/or to adjust airflow through the furnace and ducts, in order to achieve the following simultaneous results.
   a. Adjust temperature rise and flue-gas temperature, if necessary, to conform to values provided in *Table 6-3 on page 96* for the type of furnace you are tuning.

   b. Adjust gas pressure, if necessary, to conform to the range of oxygen and CO values provided in *Table 6-3 on page 96*.

Measuring gas pressure: Either bellows-type or liquid manometers are used to measure gas pressure.





regulator screw cap

Gas Valve Top View

pressure plug

10. Check the draft at a worst-case condition, and take whatever steps necessary to correct spillage.
11. If the furnace can't be adjusted to meet the specifications provided here, recommend replacement.

Table 6-3: Combustion Standards for Gas Furnace Tune-Ups

Gas Combustion Performance Indicator	< 75 AFUE	80+ AFUE	90+ AFUE
Oxygen (% O_2)	5–10%	4–9%	4–9%
Stack temperature (°F)	350°–450°	325°–425°	90°–120°
Carbon monoxide (CO) parts per million (ppm)	≤ 100 ppm	≤ 100 ppm	≤ 100 ppm
Steady-state efficiency (SSE) (%)	68–78%	79–83%	91–97%
Gas pressure (inches water column or IWC)	3.2–4.2 IWC*	3.2–4.2 IWC*	3.2–4.2 IWC*
Propane pressure (inches water column or IWC)	10–11 IWC*	10–11 IWC*	10–11 IWC*
Temperature Rise (°F)	40°–70°	40°–70°	30°–60°
Typical Draft (IWC/pascals)	–0.02 IWC –5 pascals	–0.02 IWC –5 pascals	+0.3 IWC +75 pascals
* pmi = per manufacturer's instructions			

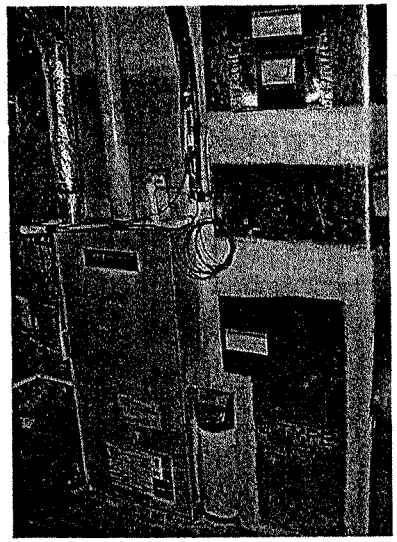
6.8 Gas Furnace Installation

Gas furnaces and space heaters may be installed as part home-performance work for the following reasons.

1. The existing furnace or space heater has health and safety problems including:
   a. Cracked heat exchanger
   b. Persistent CO or draft problems
   c. Deteriorated chimney
2. Existing gas furnace or space heater is inefficient and replacement is cost-effective.

Gas furnaces, installed under home performance, must meet the following specifications.

1. Gas furnaces must bear the ENERGY STAR seal.
2. Gas furnaces must be a minimum of 90% annual fuel utilization efficiency (AFUE).
3. Gas furnaces must be sealed-combustion. Sealed-combustion furnaces must be connected as two-pipe systems with combustion air coming from outdoors through a dedicated pipe.



90+ ENERGY STAR furnace: Condensing combustion technology provides these most efficient furnaces.

4. Existing defects and deficiencies in gas piping and electrical wiring must be remedied as part of the installation of a new furnace.
5. Measure CO, oxygen, and flue-gas temperature of the new furnace with a combustion analyzer. Make necessary adjustments to meet specifications described in *"Gas Furnace Tune-Up" on page 93.*
6. The open-combustion gas water heater may vent into a chimney that is too large after furnace replacement because a new sealed-combustion furnace no longer vents into the chimney. In this case, the chimney must be relined if necessary, to comply with National Fire Protection Association (NFPA) venting specifications as listed in the *International Fuel Gas Code* for the gas input and vent sizing for the water heater by itself without the old furnace.
7. The water heater's draft and CO level must also be tested as described in *"CO in Natural-Gas Open-Combustion Appliances" on page 88* after the furnace is installed.

Gas space heaters, installed under home performance, must meet the following specifications.

1. Gas space heaters must have an AFUE of at least 80%.
2. Gas space heaters must be sealed-combustion, fan-assisted units.

CHAPTER 7: BASELOAD ENERGY

In mild and warm climates, baseload energy is most often the consumer's most expensive energy category.

7.1 WATER HEATER ENERGY SAVINGS

Water heating is often the largest energy user for homes in mild climate. No home performance evaluation is complete without an evaluation of the water-heating system.

7.1.1 WATER HEATER BLANKETS

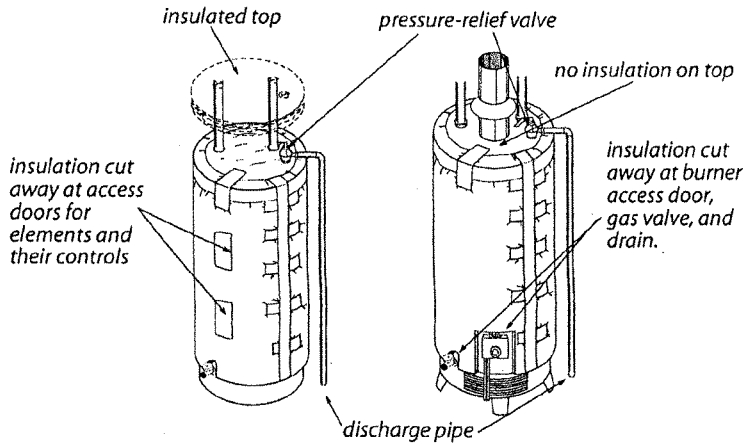
Install an insulation blanket on all heaters that are outside the heated space, unless the manufacturer's label prohibits it. Follow these guidelines to avoid fire hazards and to simplify future service.

GAS WATER HEATERS

- Keep insulation at least 2 inches away from the gas valve and the burner access panel. Do not install insulation below the burner access panel.
- Do not cover the pressure relief valve.
- Do not insulate the tops of gas- or oil-fired water heaters to avoid obstructing the draft diverter.

ELECTRIC WATER HEATERS

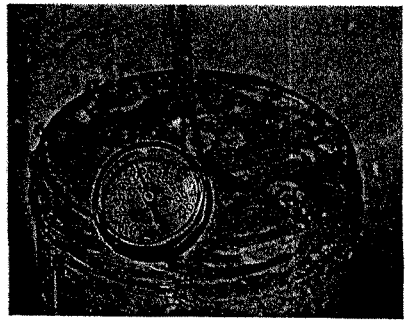
- Cut the blanket around the thermostat and heating element access plates, or cover the plates and mark their location on the insulation facing.
- Do not cover the pressure relief valve.
- Cover the top of the water heater with insulation if it doesn't obstruct the pressure relief valve.



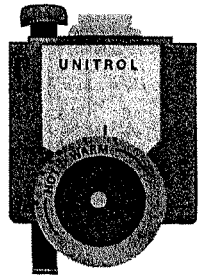
Water heater insulation: Insulation should be installed carefully so it doesn't interfere with the burner, elements, draft diverter, or pressure relief valve.

7.1.2 Measuring and Adjusting Hot Water Temperature

- Measure the water heater's water temperature at the nearest faucet to the water heater, and reduce the temperature to 125° F with the customer's permission.
- Make a mark at the current setting and move the control to a lower temperature. Note the difference between electric and gas controls shown here.
- Set both upper and lower thermostats to the same temperature on electric water heaters. Shut off power to the water heater before opening thermostat access panels.



Setting hot-water temperature: Getting the temperature correct can take a few re-adjustments and measurements.

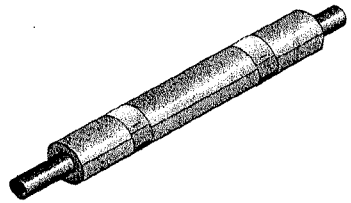


Gas water heater control

Electric water heater control

7.1.3 Water-Heater Pipe Insulation

Perform this measure to slow convection of hot water into the water lines near the tank.

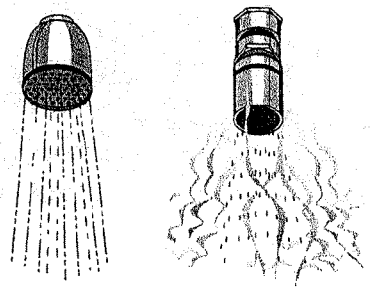


- Insulate the first 6 feet of both hot and cold water pipes. With a boiler-and-sidearm heater, insulate all pipes on the circulating loop.
- Use pipe wrap with a R-value of at least 2. Cover elbows, unions and other fittings to same thickness as pipe.
- Keep pipe insulation at least 3 inches away from combustion vent pipe.
- Use the correct diameter of insulation sleeve so it fits tightly.
- Fasten with zip ties or wire. Tape seams, joints, and ends of pipe sleeves.

7.1.4 Water-Saving Shower Heads

Most families use more hot water in the shower than for any other use. A low-flow shower head reduces this consumption.

Replace high-flow shower heads with a water-saving shower head rated for a flow of 1.5 to 2.5 gallons per minute. Avoid installing the cheapest shower heads as they often provide a less satisfying shower and are prone to clogging.



Water-saving shower heads: The showerhead on the right uses less water and so reduces water heating expense.

Use caution in removing the existing shower head from old, fragile plumbing systems. To be safe, do not attempt to remove the neck that connects the shower head to the fitting inside the wall, but replace just the showerhead itself.

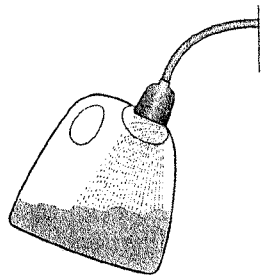
Measuring Shower Flow Rate

You can determine flow rate by measuring the time it takes to fill a one-gallon plastic milk jug. If the jug fills in less than 20 seconds, your flow rate is more than 3 gallons per minute.

- Cut a large round hole in the top of the jug.
- Start the shower and set it to your judgement of a normal showering rate.
- Start a stopwatch at the same time you move the jug underneath the shower, capturing its entire flow.
- Note the number of seconds and divide 60 by that number to find gallons per minute.

Measuring shower flow rate: If you divide 60 by the number of seconds needed to fill a gallon jug, you will calculate flow in gallons per minute.

$$\frac{1\ \text{gal}}{15\ \text{sec}} \times \frac{60\ \text{sec}}{1\ \text{min}} = 4\ \frac{\text{gal}}{\text{min}}$$



7.1.5 Gas Water Heaters

Gas water heaters often have weak draft and are the first appliances to backdraft in worst-case conditions. For this reason, sealed-combustion (direct-vent) water heaters should be selected instead of open-combustion models in the following types of homes.

1. Tight homes, or
2. Homes with inadequate chimneys or persistent spillage problems.

Observe the following requirements and recommendations when installing gas water heaters.

1. The minimum acceptable gas water heater is an open-combustion storage water heater with 2 inches of foam insulation surrounding the tank and a minimum Energy Factor of ≥0.60.
2. A sealed-combustion storage water heater with 2 inches of foam insulation surrounding the tank and a minimum Energy Factor (EF) of ≥0.60 is safer option from a draft and venting perspective.
3. A sealed-combustion tankless water heater with a Recovery Efficiency of greater than 80% (equal to EF of >0.80) is a safer and more efficient choice.

4. Defects and deficiencies in gas piping, chimney, electrical wiring, and hot-water piping must be corrected as part of water-heater installation.
5. The new gas storage water heater should have internal or external heat traps to prevent hot-water circulation into supply piping.
6. Installers and customers are encouraged to consider solar domestic water heating.

7.1.6 Electric Water Heaters

Electric water heaters are an inefficient way to heat water when generation, transmission, and distribution losses are included in the analysis. Replacing them with solar water-heating systems is the best long-term option. In the meanwhile observe the following specification.

1. Replacement electric water heaters must have an Energy Factor of ≥0.90.
2. The new electric water heater should have internal or external heat traps to prevent hot-water circulation into supply piping.

7.2 Lighting Improvement

Incandescent lighting is very inefficient and should be replaced with fluorescent lighting whenever possible as part of home performance work.

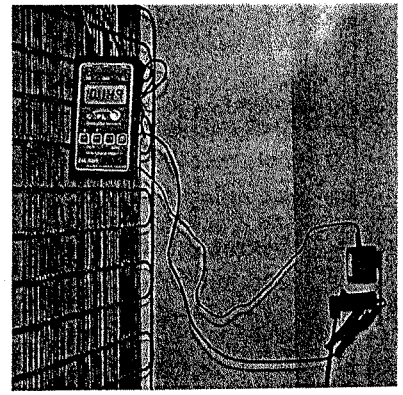
1. Replacement fixtures should be designed for four-pin compact fluorescent lamps.
2. Incandescent light bulbs should be replaced with compact fluorescent lamps (CFLs) whenever possible.
3. Size the CFLs to 20-to-35 percent of the wattage of the existing incandescent bulb, depending on whether light levels should be reduced or increased.

4. Encourage home owners to choose light colors for interior paint, furnishings, and floor coverings to enhance light quality.
5. Consider occupancy/vacancy sensor switches for bathrooms, garages, and utility rooms.
   a. Switches must be manual-on, automatic-off with manual off switch in addition to the automatic one.
   b. Time delay should be no more than 15 minutes.
   c. The switch can't be locked in the on position.
   d. Explain the switch operation and encourage occupants to use the manual off feature.

7.3 Refrigerator Evaluation

There are two common ways of evaluating refrigerator energy consumption for replacement. The first is to visit the web site of the Association of Home Appliance Manufacturers, www.aham.org for their appliance dating information. The second is to follow the metering procedure presented here.

Refrigerators that are replaced should be taken to a facility that is licensed to reclaim their refrigerant.



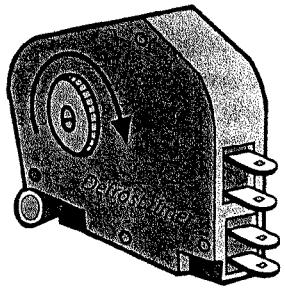
Recording Watthour Meter: Measures energy consumption over time. The better units can also calculate monthly consumption, or record maximum current draw to help identify the defrost cycle.

7.3.1 Refrigerator Metering Protocol

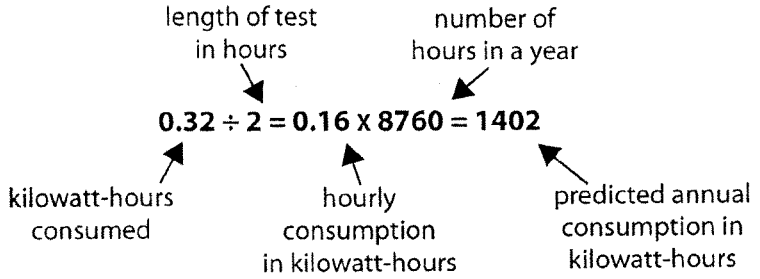
At least two hours are needed to accurately measure refrigerator energy consumption. A recording watt-hour meter is used to measure consumption.

If the refrigerator is an automatic defrost model, an inaccurate reading could result if the unit goes into the electric defrost mode during the test period. This test protocol includes provisions to account for this defrost mode.

1. Determine if the refrigerator is equipped with automatic defrost. This is usually stated on the manufacturer's data plate or on the outside of the unit. If it is *not* so equipped (manual defrost), proceed to step 3.
2. If the unit is equipped with automatic defrost, follow this sub-procedure.
   a. Locate the defrost timer. This small electrical box is usually located behind the front kick-plate, though you may need to move some wires and use a flashlight to see it. It may also be located on the rear of the unit or inside the main compartment behind the lighting panel.



   b. Open the defrost timer and locate the advance pinion. This shaft usually has a screwdriver slot to allow you to manually advance the timer.
   c. Turn the timer clockwise (you can break the timer if you turn counter-clockwise) until you hear a loud click. This turns the defrost heaters on. Turn it 10-20 degrees further until it clicks loudly again, turning the heaters off.
   d. You can now perform your measurement since the timer won't call for defrost heat again for several hours.
3. Connect the refrigerator to a recording watt-hour meter. Run the test for at least two hours. You don't need to stop at exactly two hours, and a longer measurement is O.K. During the test, avoid opening the refrigerator, or do so briefly.
4. At the end of the test, read the kilowatt/hours of consumption measured by the meter. Divide this number by the number of hours in the test. This gives you the number of kilowatt-hours consumed each hour. Multiply this number times the total number of hours in a year (8760 hours per year). The product of this calculation is the annual kilowatt-hours expected to be consumed by the unit.
5. Plug the refrigerator back into its outlet.



Refrigerator consumption example: In this example, a 2-hour measurement was performed. During this time, the appliance consumed 0.32 kilowatt-hours of electricity, or 0.16 kilowatt-hours for every hour. The annual total of 1402 kilowatt-hours is well beyond the 450 kilowatt-hours per year consumed by today's most efficient refrigerators.

7.4 Laundry Energy Improvements

The washer often uses a significant amount of hot water if customers wash clothes with hot or warm water. Dryers accumulate

lint over time and require more time and energy to dry clothes as the lint accumulates.

7.4.1 Horizontal Axis Washers

Horizontal axis washing machines represent a 50-to-75 percent reduction in water and energy use over vertical-axis washers. Horizontal-axis washing machines should be considered as home performance options.

7.4.2 Clothes Dryer Maintenance and Improvement

Clothes dryers typically use from 800 to 2000 kilowatt-hours per year. Lint in the vent and in the dryer itself can double drying time if left to accumulate over a period of 5 to 10 years.

1. Inspect the termination fitting of the dryer vent and remove as much lint as you can from the fitting and connected pipe.
2. If a flexible duct has lint built up inside the duct, re-pipe the dryer in 4-inch galvanized steel.
3. If the vent contains significant amounts of lint, unplug the dryer, open the back of the dryer and remove lint.

7.5 Pool Energy Efficiency

Swimming pools and spas consume energy for filtering and heating. Most pools have a main filtering pump and a smaller pump called a sweep.

7.5.1 Pool Heating

Consider the following energy improvements for pools that are heated by electricity, natural gas, or propane and the energy costs are substantial.

1. Install an insulating pool cover, if the customers are willing and able to install and remove it.
2. Install a solar pool heating system.

7.5.2 Pool Pumping

Consider the following changes, particularly for pools are using at least 3500 kilowatt-hours of electricity a year for pumping.

1. Ask the customer for permission to reduce the hours of operation as an experiment to find out if water quality is still acceptable.
2. Change the time clock to activate the pump during non-peak hours (not during 12 pm to 6 pm).
3. Install a smaller more efficient pump and use long-radius elbows at bends near the pump.