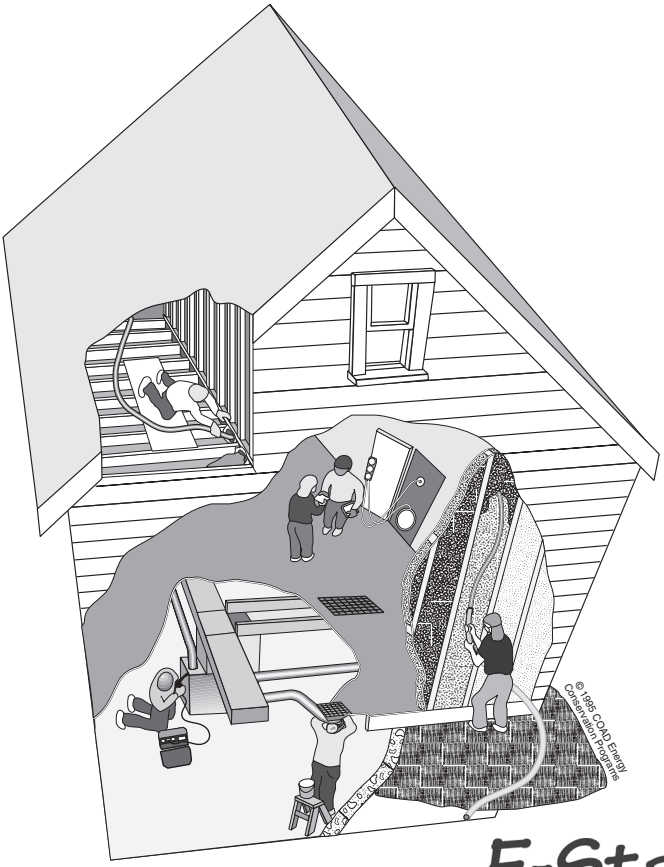
Regional Technical Forum Home-Performance Specs



E-Star™

Advancing Energy Efficiency in Housing

Shell Energy Conservation Measures and Combustion Safety for 1- to 4-Unit Buildings

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Chapter 1: Insulation

The specifications presented here concern the safety and effectiveness of insulation, installed in existing homes. Observe these general specifications.

1. Observe all relevant provisions of the Oregon Building Code or other applicable local codes, as well as the interpretations of local building-code officials.
2. To be effective, insulation must be installed between the the home's conditioned spaces and the outdoors or unconditioned areas such as attics, crawl spaces, and attached garages.
3. All insulation must have the approval of the building owner before installation begins.
4. Protect insulation from moisture. Take whatever steps are necessary to solve moisture problems before insulating.
5. Seal all air leaks in the building assembly to be insulated before insulating work begins.
6. Install insulation against the interior sheeting of the home. Don't allow an air gap between the home's interior and the insulation.
7. When installing insulation in wood-framed floors and walls, fill each cavity completely with insulation.

1.1 Blown Attic Insulation

Attic insulation is the most important energy conservation measure for reducing heating and cooling costs. 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. Housings of exhaust fans and recessed lights

f. Pocket doors

2. If the attic has less than R-19 insulation, add additional insulation to achieve R-38 or more.
3. Blown insulation must be installed at the highest achievable density, to reduce settling and convection within the insulation.
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.
5. Attic hatches must be substantially airtight and insulated to approximately the same level as the attic itself.
6. Installers must prevent blown insulation from escaping from the attic into the soffited eaves.

1.1.1 Rooftop Insulation

Sometimes it's necessary to insulate the rooftop in addition to insulating the roof cavity. However, rooftop insulation should not be installed instead of roof-cavity insulation.

1. Insulation must not be applied to roofs with ventilated cavities.
2. Drainage must be designed and built into the new insulation-and-roofing system.

3. Plastic foam roof insulation must be protected from temperatures exceeding 150° F. For example, plastic foam should never be in contact with metal roofing materials.

1.1.2 Kneewall Attic Insulation

Establishing a continuous thermal boundary around a kneewall attic can be challenging. Before installing insulation, seal all bypasses through the attic's walls, floor, and ceiling.

1. Installer must create a strong airtight seal between each floor joist, underneath the kneewall. Rectangles of 2-inch foam, sealed with one-part or two-part liquid foam, are recommended. Plugging the spaces with loose-fill insulation is not acceptable.
2. Insulate the access door to through the kneewall to at least R-8 with foam insulation. Weatherstrip the door.

Kneewall attics present five distinct areas to install insulation.

1. End walls of the finished attic must be dense-packed with blown insulation.
2. Kneewalls must be either blown with high-density fiberglass or insulated with high density batts (R-13). in either case, the wall must be sheeted with an vapor-permeable air barrier: Tyvek® or equivalent.
3. Sloped roof must be blown with high-density fiberglass.
4. 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 covered with floor boards.
5. The small attic above the collar beam must be insulated as described in *"Blown Attic Insulation" on page 1-3*.

1.1.3 Attic Insulation Safety

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

1. Installer must determine that the ceiling is strong enough to hold the additional insulation.
2. Before an attic is insulated, all electrical connections must be enclosed in electrical boxes with cover plates.
3. Installer must protect heat-producing fixtures from attic insulation with solid, non-combustible enclosures. Heat producing fixtures include the following.
   a. Recessed light fixtures and fans
   b. Doorbell transformers
   c. Miscellaneous line voltage electrical devices
   d. B-vent gas chimney
4. The solid enclosures, surrounding heat-producing fixtures must comply with the following specifications.
   a. Enclosures must keep insulation at least 3 inches but not more than 4 inches away from the sides of heat-producing fixtures.
   b. Open-top enclosures must extend at least 4 inches above the final insulation level.
   c. Closed-top enclosures must extend at least 24 inches from the heat-producing fixture's highest point.
5. Observe the following exceptions to 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.

b. Non-combustible fiberglass and rock wool insulation can be blown up against masonry and B-vent chimneys. Non-combustible insulation conforms to the standard test method ASTM E136.82.

6. No electrical fixture or chimney may be surrounded by liquid foam insulation. This practice could cause overheating of the fixture or chimney and expose the insulation to higher temperatures than manufacturers recommend.

7. Insulation must not cover live knob-and-tube wiring. Fiberglass batts may be laid under and/or tented over knob-and-tube wiring as long as the insulation remains 3 inches away from the wires.

8. Kitchen range exhaust fans, vented through the ceiling, must be connected to a duct of not thinner than 30-gauge galvanized steel. This duct must be substantially airtight and terminate directly to the outdoors, using a termination fitting designed for this purpose. The termination fitting should be equipped with a backdraft damper.

1.1.4 Moisture Source-Reduction and Attic Ventilation

Moisture source-reduction is very important to preserving the thermal resistance and durability of insulation. The ground around and under the home is typically the largest moisture source. Improvements to dry the ground or to prevent moisture from traveling up into the home are far more important than attic ventilation. *See "Inspecting and Solving Moisture Problems" on page 1-12.*

1. All roof leaks, and other major moisture problems such as water drainage toward the home or standing water in crawl-spaces, must be mitigated before installing attic insulation.

2. If the attic is currently vented and shows no signs of moisture problems, additional attic ventilation is neither required nor recommended.
3. Technicians must identify air leaks into the attic and seal them to prevent moisture migration and save energy. Visual inspection of these areas is often sufficient to locate attic air leaks.
   a. Ceiling surfaces and roof sheathing, which is water damaged or spotted.
   b. Attic insulation that has turned black as a result of air movement through the insulation.
   c. Attic floor underneath the insulation to locate thermal by-passes and cavities requiring air sealing.
4. Diagnostic blower door testing can be used to assess attic air leakage when visual inspection is not sufficient.
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.
6. Newly installed insulation must not block the ventilation pathways from the soffit into the attic.

1.2 Wall Insulation

Retrofit wall insulation is one of the most cost-effective weatherization and home-performance measures. Specifications, listed here, describe closed-cavity and open-cavity wall-insulation methods. Open-cavity methods are for walls that have no sheathing on one side.

1.2.1 General Wall Insulation Specifications

Observe the following general specifications when installing retrofit insulation in walls.

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.

2. The installer must perform a thorough visual inspection of the interior and exterior surfaces of the wall. The installer must 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, and paneling.

3. The installer must 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.

4. The installer must seal all major bypasses through walls before installing insulation.

5. The installer must seal all gaps around windows and other wall penetrations that may leak water into the wall.

6. Inspect walls for evidence of moisture damage, such as mold, deteriorated interior or exterior wall finish, softened drywall or plaster. Sidewall insulation must not be installed until moisture problems are corrected.

1.2.2 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. Installer must probe all holes to look for blockages. If blockages are found, the installer must drill additional holes to ensure complete coverage.
2. Installers must 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 plates.
3. Siding removal and drilling through sheathing is preferable to drilling through siding. Installers must remove siding in a professional manner without damaging the siding beyond repair. If siding is likely to be broken or damaged beyond repair, replacement siding should be obtained in advance.
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 to avoid creating a horizontal crack that draining water can flow into. Re-staple this flap 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 household items with drop clothes.
6. To prevent settling, cellulose insulation must be blown at a minimum density of 3.5 pounds per cubic foot and fiberglass at a minimum density of 1.5 pounds per cubic foot.

Wall-Insulation Quality Control

The inability of the installer to see into the wall cavity 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 must verify the correct density of the insulation by bag usage, bag weight, and surface area of wall covered during installation.
2. The inspector must scan the walls using an infrared scanner. The installer will be recalled to fill any significant voids.

1.2.3 Open-Cavity Wall Insulation

Although fiberglass batts with a kraft or foil facing has been more common than unfaced friction-fit batts, the latter offer the advantage of filling the cavity more uniformly.

1. Insulation, exposed to living areas, should have a ASTM flame spread rating of 25 of less.
2. All significant cracks and gaps in the wall structure must be sealed before installation is installed.
3. Batt insulation must be cut accurately to fill the cavity and must not have noticeable gaps (>$^{1}/_{8}$-inch) from being too small and also must not exhibit bunching from being too large.
4. Fiberglass batts, installed in 2-by-4 wall cavities, must be rated at least R-13; R-15 is preferred.
5. Fiberglass batts should be unfaced friction-fit batts to facilitate the continuous contact between wall sheeting and the insulation. Facing creates small convection cavities because of its crinkliness.
6. Installers must split batts around wiring rather than letting the wiring bunch the batt to one side of the cavity. Insulate behind and around obstacles with scrap pieces of batt or liquid foam before installing batts.

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

1.3 Floor and Foundation Insulation

The durability of the floor and foundation is more important than the thermal resistance of these critical building components. Insulate the floor or foundation only if you can do so without creating moisture problems or aggravating existing ones. The following specifications apply to existing floor and foundation insulation in addition to newly installed insulation.

1.3.1 Preparing for Under-Floor Insulation

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

Inspecting and 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 or foundation.
2. 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, be lapped up the foundation wall at least 6 inches, and sealed to the foundation walls with acoustical sealant or equivalent effective sealant.
   c. New ground-moisture barriers must be overlapped 12-inches and sealed at these overlaps with acoustical sealant or equivalent effective sealant.

d. Ground-moisture barriers must not come in contact with wood structural members, such as posts.

3. Crawl spaces with a history of flooding must be equipped with a sump pump. The sump pump must be located in an area where it will collect water from the entire crawl space and pump it to a drain outdoors.

4. All exposed ducts must be sealed and insulated to R-8 as a part of the underfloor-insulation project. *See "Duct Insulation Specifications" on page 4-37.*

Crawl-Space Ventilation

Crawlspace ventilation must meet the following requirements before underfloor insulation is installed.

1. Where a ground-moisture barrier is installed and ground moisture is not excessive, crawl-space vent opening may be reduced to a ratio of between 1/300 and 1/1500 (square feet of vent per square feet of crawl-space area).

2. Vent openings must be covered with corrosion-resistant $^{1}/_{4}$-inch screens.

3. Contractors may install mechanical ventilation when passive ventilating methods are not practical or effective.

Insulating Water Pipes

Prior to floor insulation, water supply pipes must be insulated with foam or fiberglass insulation. Take particular care insulating pipes that are near the perimeter of the building or that hang down below the floor.

1. Foam pipe sleeves must have a thermal resistance of at least R-3. Pipe sleeves must be sized correctly and fit snugly around the pipes.

2. Foam pipe sleeves must be secured with plastic ties, twine, or wire at least every 12 inches.
3. Foam pipe sleeves must be neatly mitred together at elbows and be secured within 3 inches of elbows.
4. Fiberglass insulation must be a minimum of R-7.
5. Fiberglass pipe insulation must have a vinyl or FSK covering if installed where it human contact is probable.
6. Supply pipes may be wrapped with unfaced fiberglass insulation in crawl spaces and other areas where human contact is unlikely.

1.3.2 Installing Under-Floor Insulation

Observe the following specifications for insulating under floors.

1. All bypasses and significant air leaks through the floor must be sealed before the floor is insulated, using strong airtight materials.
2. Insulation must be unfaced fiberglass batts or fiberglass loose-fill insulation blown at a density of at least 1.5 pounds per cubic foot.
3. Insulation must completely fill the floor cavities from end to end, side to side, and must fill the complete depth of each cavity. The insulation must be in continuous contact with the subfloor.

Fastening Under-Floor Insulation

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

1. Batt insulation, installed in floors, must be supported by twine, wire, or wood lath.
   a. Twine must be made of polypropylene or polyester and have a breaking strength of at least 150 pounds.

b. The wire must be copper or stainless steel with a minimum diameter of 0.04 inches or size 18 AWG.

c. The 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.

2. Wood lath must be at least $^{5}/_{16}$-inch thick by 1 inch wide. Joints in the lath must be made on a floor joist.

3. Fasteners 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.

1.3.3 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. 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 breathable air barrier: Tyvek® or equivalent.

3. The air barrier must be supported by twine, installed in a zig-zag pattern, not more that 12 inches on center.

4. Twine must be fastened with staples at least $^{5}/_{8}$ inches in length and made of 18 gauge corrosion-resistant metal.

5. Install fiberglass blowing wool through X or V-shaped holes in the air barrier. Cellulose is not permitted because of moisture and settling concerns.

6. Use a fill tube for installing the fiberglass 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 tape, approved for sealing seams in the air-barrier material.

1.3.4 Crawl-Space Foundation Insulation

The decision to insulate crawl-space walls usually comes with the decision to seal crawl-space vents, at least during the winter. Sealed crawl spaces are becoming more common when the home's footing and foundation remain dry and the crawl space has an effective ground-moisture barrier. Observe the following specifications for insulating foundation walls.

1. Seal crawl space vents permanently only with knowledge and permission of building codes and local building officials.
2. Insulate the crawl-space walls and the rim-joist area with plastic foam insulation, having a thermal resistance of at least R-8. Fiberglass batts or blankets aren't permitted because of moisture concerns.
3. Use only Class A foam-insulation materials with flame spread less than 25 and smoke-developed rating less than 450.
4. Fasten the insulation to the foundation wall, according to manufacturer's recommendations. Use adhesive that is compatible with the particular plastic foam insulation being used. At a minimum apply the adhesive in walnut-sized globs, 12 inches apart in both directions.
5. The rim joist area, from the sole plate up to and including the joint between the rim joist and subfloor, must be air-sealed as well as insulated. All joints must be sealed. Two-part liquid foam, sprayed in place over the

entire rim-joist area is an effective way to seal and insulate the rim joist area in one operation. A rectangle of 2-inch foam board, cut one inch short in both dimensions and foamed around its edges with one-part foam also works very well.

Chapter 2: Window Installation

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

Included here are specifications for two special window-safety considerations. Windows in high-risk areas, such as around doors and walkways, must have safety glass. Windows are part of fire escape planning for homes, so this egress function must be recognized and observed.

2.1 Window Replacement

For both weatherization and home performance jobs, window replacement is a low priority from the perspective of cost-effectiveness. Window replacement sometimes exhausts homeowner's or energy program's budgets without offering sufficient energy savings to return the initial investment within 20 years. Window replacement should be delayed, unless the following conditions exist.

1. Windows are damaged or weathered beyond repair or rehabilitation.
2. Existing windows are a severe energy or comfort problem, such as single-pane aluminum windows in a cold climate.
3. The home is energy-efficient except for the windows.

The above conditions don't prohibit home-performance contractors from replacing windows because their clients want new windows. However, the higher priorities of home-performance contracting shouldn't be neglected because the high cost of the window replacement consumes the entire home-performance budget.

2.1.1 Window Material Specifications

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

1. Replacement windows must be equipped with a fastening flange, which must be used to fasten the window to the home's sheathing.
2. Replacement windows must have a U-factor ≤ 0.30.
3. Replacement windows, facing east or west, in air-conditioned homes should have a solar heat-gain coefficient of ≤0.35.
4. Flashing for new windows must be reinforced, coated flexible flashing, designed for exterior water protection.
5. Sealants should be compatible with the materials they seal.
6. All fasteners used for window installation must be corrosion resistant, according to ASTM B 633, B 766 or B456.
7. Metal window components must be isolated from dissimilar metals or corrosive materials with a non-conductive coating or sealant material.
8. New windows may not be installed inside old window frames.
9. New window sashes may be installed in old window frames as long as the frame is in good condition and the thermal requirements are met.

2.1.2 Window Removal and Installation Preparation

The existing window must be completely removed to the rough opening.

1. Make certain that the dimensions of the rough opening are sufficient to install the new window before removing the old window.
2. Installers must exercise care in removing windows to minimize damage to the home's weather-resistant barrier, which is installed between siding and sheathing.
3. As part of window removal, the installer should remove fasteners in the siding within 12 inches of the window in all four directions, in order to facilitate installation of flashing for the new window.
4. Installers must repair moisture damage to the rough opening before installing the new window.
5. Installers must do whatever is necessary to render the rough opening square, plumb, and level.

2.1.3 Installing the New Window

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

1. Installer must use whatever shimming assembly is necessary to install the window square, plumb, and level.
2. The new window must be flashed around its perimeter with approved flashing, installed in weatherboard fashion so that joints overlap in a way that doesn't permit water, flowing downhill with gravity, to enter any joint.
3. The 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 install 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.
6. The heads of fasteners must be wide enough in diameter to span the holes or slots in the window flange.
7. Installers should avoid deforming the window flange during fastening, by over-driving the fasteners.
8. Installers must air-seal the space between the window frame and the rough opening. One-part foam and foam backer rod with caulking are approved methods. Stuffing the gap with fiberglass insulation is not permitted.
9. Windows must have a rigid cap flashing to divert water away from the window. The cap flashing must overlap the sides of the window enough to divert water away from the horizontal joints bordering window, exterior window trim, and siding.

2.2 Safety Specifications

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

2.2.1 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.

1. Glazed panels, greater than 9 sq. ft. when measured from the inside of the sashes, must be glazed with safety glass.

2. Windows within bathtub and shower enclosures must be glazed with safety glass.
3. Windows next to doors, in the same plane as the door, must be safety glass if the glazed panel is within 12 inches of the door and within 60 inches of the floor.
4. When glazing is installed within 18 inches from the floor and within a 36-inch horizontal distance from a walkway, such as a hallway or sidewalk, the glazing must be safety glass.

2.2.2 Fire Egress

Windows are the designated fire escape for many homes and should offer a minimum opening for a person's escape form 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 square feet for ground-floor windows and 5.7 square feet for windows above ground floor.
5. The finished sill of the egress window must be no higher off the floor than 44 inches.

Chapter 3: 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. Based on standards set by the Environmental Protection Agency (EPA) and the American Society of Heating, Refrigeration, and Air-Conditioning Engineers (ASHRAE), contractors must estimate a building tightness limit (BTL) for each home.

The BTL 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 BTL with the blower-door estimated air-leakage rate allows the building analyst to answer the following important weatherization and home-performance questions.

1. If the home is leakier than the BTL, how much we can air-seal before needing to install mechanical ventilation?
2. If the home is tighter than the BTL, how much mechanical ventilation do we need to provide?

See BTL Calculation Procedures. See table 3-2 on page 3-30.

3.1 Blower Door Testing Specifications

Blower door testing is required for all weatherization and home performance work.

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 on a blower-door-testing form.

1. Calculation of BTL. *See BTL Calculation Procedures.*
2. Measurement of initial air-leakage rate by the blower door. *See Blower Door Procedures.*
3. Air-leakage procedures undertaken. *See Air Sealing Procedures.*
4. Measurement of final air-leakage rate by the blower door.
5. Adoption of a ventilation strategy as explained in *Table 3-2 on page 3-30*.

3.2 House Pressure Specifications

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 pressures can backdraft open-combustion gas appliances and drive air through leaks in the building shell. House pressure testing is required under the following circumstances.

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

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 3-27*.

2. Other house pressures should be limited to 3 pascals between rooms and one pascal 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 3-1: 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
Sealed combustion appliances	–30

3.3 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 the middle. Blower door testing must accompany all air sealing to promote safety and cost-effectiveness.

3.3.1 Sealing Bypasses

Bypasses are large gaps in the thermal boundary. The must be sealed by strong materials, firmly fastened to the building's structure.

1. Air-sealing methods and materials must provide an 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 pony walls – 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 with fiberglass is not acceptable.

3.3.2 Weatherstripping and Sealants

Weatherstripping and sealants are often known as comfort air sealing because they reduce noticeable drafts in the living area. 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 or windows.
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 or cracks underneath.
7. Self-adhesive weatherstrip is not allowed.

Caulking and Liquid Foam

Caulking and filling gaps with liquid foam, for the purpose of air sealing, must be done from the home's interior. Caulking is preferred when the crack is less than 3/8 of an inch. Liquid foam is preferred when the crack is greater than 3/8 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.

3.4 Mechanical Ventilation Specifications

The RTF recognizes three levels of house airtightness and three strategies to provide adequate ventilation. Weatherization and home-performance contractors must do the following.

1. Calculate the necessary ventilation amount in cfm. *See BTL Calculation Procedures.*
2. Adopt the appropriate ventilation strategy from *Table 3-2 on page 3-30*.
3. Improve or provide ventilation equipment to achieve the necessary ventilation rate.
4. Document the decision-making and implementation process.

Table 3-2: Airtightness and Ventilation Strategies

Airtightness	Ventilation Strategy
1. Measured air leakage at or above BTL	Spot ventilation with bathroom and kitchen exhaust fans, openable windows, and customer education.
2. Measured air leakage between 70 and 100 percent of BTL	Continuous or timed ventilation, using exhaust fans, must provide difference between measured air leakage and BTL.
3. Measured air leakage below 70 percent of BTL	Continuous or timed ventilation, using exhaust fans or whole-house ventilation system, must provide 100 percent of BTL.
Derived from Building Performance Institute Specifications	

Exhaust fans, installed as part of weatherization or home-performance work, must vent to outdoors and be equipped with the following.

1. A weatherproof termination fitting.
2. A backdraft damper, installed in the fan housing or termination fitting.
3. Noise rating of less than 2 sones.

3.5 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 that are manifested in 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, including the following.

1. Repair plumbing and roof leaks.
2. Clean and repair rain gutters and downspouts.
3. Improve drainage at the home's perimeter.
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 4: Duct Sealing and Insulating Specifications

Air-sealing and insulating ducts can be very cost effective if these energy conservation measures are employed in a prudent manner. Cost-effective duct sealing requires duct air leakage measurement and adherence to the eligibility requirements, described here. Duct insulation is cost effective only for ducts, located outside the thermal boundary.

4.1 General Duct Sealing Specifications

These duct air-tightness specifications cover three distinct situations: new construction, new ducts in an existing home, and retrofit duct repair and sealing. For obvious reasons, the standards for new construction are stricter than standards for new ducts in an existing home, which are stricter than retrofit duct air-tightness standards. Retrofit duct-sealing specifications require a preliminary duct test to measure the baseline leakage and determine whether duct sealing is necessary.

The numerical duct air-tightness standards given here are based on testing by a duct tester. The duct system's supply and return registers are blocked temporarily, and the system is pressurized to 50 pascals with reference to outdoors for the Total Duct Leakage Test. The Duct Leakage to Outdoors Test is preferred and combines the Total Duct Leakage Test with a blower door test, which pressurizes the house to 50 pascals. Pressurizing both the house and ducts cancels the effect of duct leakage to indoors, which isn't a significant energy waster.

Table 4-1: Duct Air-Tightness Standards

Condition	Specification / Standard	
New Construction	Leakage must be <6% of floor area in CFM_{50} or <75 CFM_{50}, whichever value is greater, measured by either of the two duct-testing methods after the ducts are sealed.	
New Ducts – Existing Home	Leakage must be <10% of floor area in CFM_{50} as measured by either of the two duct-testing methods after the ducts are sealed.	
Retrofit Duct Sealing	To merit duct-sealing, original leakage value must be >15% of floor area in CFM_{50} or >250 CFM_{50}, whichever value is lesser, as measured by Duct Leakage to Outdoors Test.	Duct leakage must be reduced by at least 50% of original value in CFM_{50} after the ducts are sealed.
Oregon Department of Energy Premium-Efficiency Duct-System Standards October 2003		

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

1. Duct modifications to improve airflow should precede duct air-sealing to avoid breaking freshly sealed joints.
2. Duct insulation should follow duct air-sealing, because insulation blocks access to duct joints needing air-sealing.
3. New ducts must be made of approved duct materials such as
    a. Manufactured or shop-fabricated galvanized steel
    b. Insulated flex duct, with a thermal resistance of at least R-8
    c. Fiberglass duct board
4. Forced-air system operation must 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. Manufactured homes tested as sections at the factory are exempt.

5. 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.

4.1.1 Specifications for New Ducts

Observe the following specification for ducts in new 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 new or existing homes, must be made of approved duct materials such as:
    a. Manufactured or shop-fabricated galvanized steel
    b. Insulated flex duct, rated at R-8
    c. Fiberglass duct board
3. Each component of the duct system must be mechanically fastened and air-sealed to adjacent components.
4. Return air ducts or passive pressure-relief grills must be installed in each zone and on each level. Zones are areas of the home that can be separated from other areas by interior doors.
5. Building cavities must not be used as return or supply ducts.

4.1.2 Duct-Sealing Specifications

The following specifications are required for sealing ducts.

1. All duct materials, duct-sealing materials, and duct-insulation 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. 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.
4. The air handler and joints between the plenum and air handler must be sealed with aluminum foil duct tape, marked UL 181.
5. 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.
6. 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 tensioning device. The flex duct's outer liner must be fastened with a second tensioned plastic strap.
7. Splices in insulated flex duct must use a metal collar. Each flex-duct section must be sealed with plastic straps as described above.
8. Joints in fiberglass duct board must be sealed with FSK tape, specifically designed for this purpose, and/or with water-based duct mastic reinforced with 2-inch mesh tape.

4.2 Duct Insulation Specifications

These duct-insulation specifications are intended for ducts, located outside the thermal boundary in unconditioned spaces, such as the following areas.

1. Attics
2. Attached garages
3. Crawl spaces
4. Unoccupied and unconditioned basements

Observe the following specifications for insulating ducts in unconditioned spaces outside the thermal boundary.

1. All supply and return ducts must be insulated.
2. Ducts must be air-sealed before they are insulated.
3. Insulation must cover all exposed ducts without any significant areas of duct left bare.
4. Insulation material must be fiberglass with a thermal resistance of at least R–8.
5. Insulation for ducts must be faced with foil-skrim-kraft (FSK) or polyvinyl chloride (vinyl) flexible sheeting.
6. Insulation must be fastened and supported by mechanical means, such as stuck-ups, twine, or plastic straps.
7. Seams in the insulation must be sealed with 3-inch tape, either FSK or vinyl, depending on the insulation's facing material.
8. Tape must not be used to support the insulation without stuck-ups, twine, or plastic straps.

Chapter 5: Gas Appliance Combustion Specifications

The purpose of these specifications is ensure the safety of natural-gas combustion appliances, particularly the "open-combustion" type. Open-combustion appliances have their combustion chambers or flues open to the air inside the combustion appliance zone (CAZ). Open-combustion appliances include gas water heaters, gas space heaters, gas furnaces, and gas boilers, equipped with draft diverters. Appliances with fan-assisted over-fire draft, which are not supplied with combustion air from outdoors, are also this open-combustion type. Gas ranges and ovens are also discussed here because all of their combustion products flow directly into the kitchen.

5.1 General

1. Combustion testing is required for all homes with open-combustion gas appliances.
2. Technicians and analysts must record measurements of key testing parameters before and after adjustment for the purpose of quality control.
3. Technicians, who perform combustion testing and who adjust combustion appliances, must be certified to perform these tasks by the Regional Technical Forum (RTF).
4. Unvented space heaters must be disabled or removed from a home before the home is air-sealed under weatherization or home performance.

5.2 Carbon Monoxide (CO) Testing

This section specifies limits for carbon monoxide (CO), a poisonous gas, which results from incomplete combustion. When the limits listed here are exceeded, the actions specified in *Table 5-2 on page 5-44* must be taken prior to or during air-sealing or duct-sealing work.

Testing must be stopped whenever the ambient level of CO around the technician exceeds 35 parts per million (ppm).

5.2.1 CO in Ranges and Ovens

Ranges and ovens exhaust their combustion products into the kitchen and are a health and safety threat if they produce 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.
    a. Make 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, the following three (3) steps are required.
    a. Make 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.
    c. Install an exhaust fan with a capacity of 100 cubic feet per minute (cfm).

3. Kitchen exhaust fans, installed as part of weatherization or home-performance work, must vent to outdoors and be equipped with the following.
    a. Solid metal ducting to the outdoors.
    b. A weatherproof termination fitting.
    c. A backdraft damper, installed in the fan housing or termination fitting.
    d. Two speeds so that the lower speed can be used for continuous ventilation if needed.
    e. Noise rating of less than 2 sones.

5.2.2 CO in Natural-Gas Open-Combustion Appliances

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

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

1. Testing for CO is required in all homes with open-combustion gas appliances.
2. Document tested values for parts per million of CO, and take action according to the requirements in *"CO Action Levels with Required Actions" on page 5-44*.

Table 5-1: 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	–15
Sealed combustion gas appliances	–30

5.3 Draft and Spillage Testing

This section specifies action levels and actions to be taken in cases of inadequate draft and persistent spillage. Draft is the measured pressure in the chimney or vent connector with reference to the combustion appliance zone (CAZ). Most combustion appliances have naturally drafting chimneys, which exhaust combustion gases, using the small negative pressure caused by the buoyancy of the hot gases. This small draft may be reversed by pressures in the home from the air handler, exhaust fans, clothes dryers, and other chimneys. Spillage is a health and safety problem when the combustion gases contain CO. *See procedures for more information.*

1. Open-combustion gas appliances must be tested for draft and spillage.
2. Document draft measurements and observations of spillage during worst-case and normal conditions.
3. Take required actions, according to test results and observations, as specified in *Table 5-2 on page 5-44*.

Table 5-2: CO Action Levels with Required Actions

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.			

5.4 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 or weatherization work.

5.5 Natural-Gas Supply Safety

Leaking natural gas dilutes oxygen in the air, causing a health and safety hazard; it also wastes energy.

1. Inspect all gas fittings and joints in the gas supply lines and 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 or weatherization work.
3. Flexible gas lines must be replaced if they are kinked, corroded, have soldered connections, or show visible signs of wear.
4. Flexible gas lines manufactured before 1973 must be replaced. The date is stamped on a date ring attached to the flexible gas line.

5.6 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 5-3 on page 5-47*.

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 airflow through the furnace and/or gas pressure to achieve the following simultaneous results.
    a. Change temperature rise and flue-gas temperature, if necessary, to conform to values provided in *Table 5-3 on page 5-47* for the type of furnace you are tuning.
    b. Adjust gas pressure, if necessary, to conform to the range of oxygen values provided in *Table 5-3 on page 5-47* and to reduce CO to 100 ppm or less.
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 in *Table 5-3 on page 5-47*, recommend replacement.

Table 5-3: 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

5.7 Gas Furnace Installation

Gas furnaces and space heaters may be installed as part weatherization and 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. Fuel switching from electric heating to natural gas heating.
3. Existing gas furnace is inefficient and replacement is cost-effective.

Gas furnaces, installed under weatherization and 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.
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 5-45*.
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 re-lined, 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.
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 5-41* after the furnace is installed.

Gas space heaters, installed under weatherization and 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.

5.8 Gas Water Heater Installation

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

a. Tight homes,
b. Homes with sealed-combustion furnaces,
c. Previously all-electric homes, and
d. Homes with deteriorated 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 ≥0.62.
2. A safer choice is a sealed-combustion storage water heater with 2 inches of foam insulation surrounding the tank and a minimum Energy Factor (EF) of ≥0.62.
3. A safer and more efficient choice is a sealed-combustion tankless water heater with a Recovery Efficiency of greater than 80% (equal to EF of >0.80).
4. Defects and deficiencies in gas piping, chimney, electrical wiring, and hot-water piping must be corrected as part of water-heater installation.