MANUFACTURED HOUSING CONSENSUS COMMITTEE

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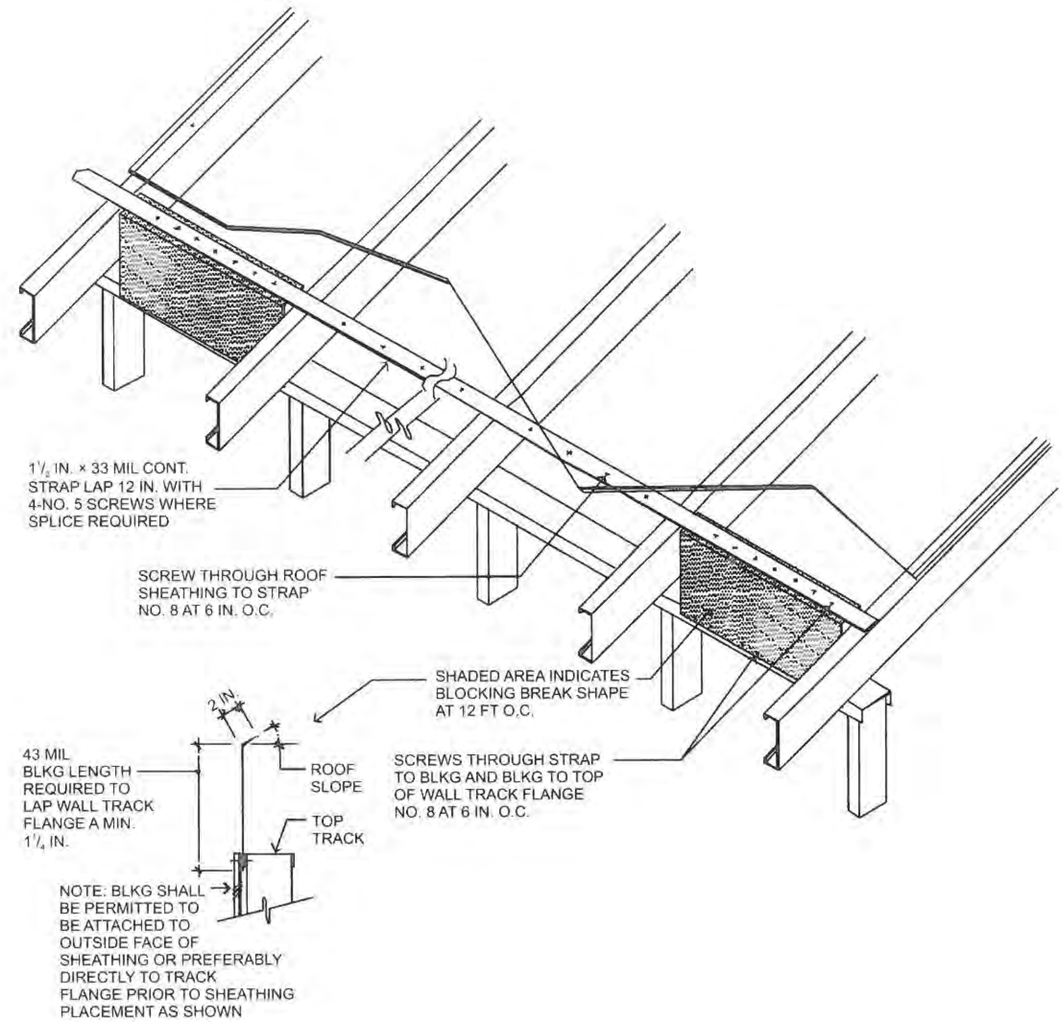
# 2018-2019 Cycle Substantiating Documents

As of August 2018

# LOG 155:

# Substantiating Documents




For SI: 1 mil = 0.0254 mm, 1 inch = 25.4 mm.

**FIGURE R804.3.8(3)**
**ROOF BLOCKING DETAIL**

## SECTION R805
## CEILING FINISHES

**R805.1 Ceiling installation.** Ceilings shall be installed in accordance with the requirements for interior wall finishes as provided in Section R702.

## SECTION R806
## ROOF VENTILATION

**R806.1 Ventilation required.** Enclosed *attics* and enclosed rafter spaces formed where ceilings are applied directly to the underside of roof rafters shall have cross ventilation for each separate space by ventilating openings protected against the entrance of rain or snow. Ventilation openings shall have a least dimension of $^1/_{16}$ inch (1.6 mm) minimum and $^1/_4$ inch (6.4 mm) maximum. Ventilation openings having a least dimension larger than $^1/_4$ inch (6.4 mm) shall be provided with corrosion-resistant wire cloth screening, hardware cloth, or similar material with openings having a least dimension of $^1/_{16}$ inch (1.6 mm) minimum and $^1/_4$ inch (6.4 mm) maximum. Openings in roof framing members shall conform to the requirements of Section R802.7.

**R806.2 Minimum area.** The total net free ventilating area shall not be less than $^1/_{150}$ of the area of the space ventilated except that reduction of the total area to $^1/_{300}$ is permitted provided that at least 50 percent and not more than 80 percent of the required ventilating area is provided by ventilators located in the upper portion of the space to be ventilated at least 3 feet (914 mm) above the eave or cornice vents with the balance of the required ventilation provided by eave or cornice vents. As an alternative, the net free cross-ventilation area may be reduced to $^1/_{300}$ when a Class I or II vapor barrier is installed on the warm-in-winter side of the ceiling.

**R806.3 Vent and insulation clearance.** Where eave or cornice vents are installed, insulation shall not block the free flow of air. A minimum of a 1-inch (25 mm) space shall be provided between the insulation and the roof sheathing and at the location of the vent.

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## SECTION R304 MINIMUM ROOM AREAS

**R304.1 Minimum area.** Habitable rooms shall have a floor area of not less than 70 square feet (6.5 $m^2$).

**Exception:** Kitchens.

**R304.2 Minimum dimensions.** Habitable rooms shall be not less than 7 feet (2134 mm) in any horizontal dimension.

**Exception:** Kitchens.

**R304.3 Height effect on room area.** Portions of a room with a sloping ceiling measuring less than 5 feet (1524 mm) or a furred ceiling measuring less than 7 feet (2134 mm) from the finished floor to the finished ceiling shall not be considered as contributing to the minimum required habitable area for that room.

## SECTION R305 CEILING HEIGHT

**R305.1 Minimum height.** *Habitable space*, hallways and portions of *basements* containing these spaces shall have a ceiling height of not less than 7 feet (2134 mm). Bathrooms, toilet rooms and laundry rooms shall have a ceiling height of not less than 6 feet 8 inches (2032 mm).

**Exceptions:**

1. For rooms with sloped ceilings, the required floor area of the room shall have a ceiling height of not less than 5 feet (1524 mm) and not less than 50 percent of the required floor area shall have a ceiling height of not less than 7 feet (2134 mm).
2. The ceiling height above bathroom and toilet room fixtures shall be such that the fixture is capable of being used for its intended purpose. A shower or tub equipped with a showerhead shall have a ceiling height of not less than 6 feet 8 inches (2032 mm) above an area of not less than 30 inches (762 mm) by 30 inches (762 mm) at the showerhead.
3. Beams, girders, ducts or other obstructions in *basements* containing *habitable space* shall be permitted to project to within 6 feet 4 inches (1931 mm) of the finished floor.

**R305.1.1 Basements.** Portions of *basements* that do not contain *habitable space* or hallways shall have a ceiling height of not less than 6 feet 8 inches (2032 mm).

**Exception:** At beams, girders, ducts or other obstructions, the ceiling height shall be not less than 6 feet 4 inches (1931 mm) from the finished floor.

## SECTION R306 SANITATION

**R306.1 Toilet facilities.** Every *dwelling* unit shall be provided with a water closet, lavatory, and a bathtub or shower.

**R306.2 Kitchen.** Each *dwelling* unit shall be provided with a kitchen area and every kitchen area shall be provided with a sink.

**R306.3 Sewage disposal.** Plumbing fixtures shall be connected to a sanitary sewer or to an *approved* private sewage disposal system.

**R306.4 Water supply to fixtures.** Plumbing fixtures shall be connected to an *approved* water supply. Kitchen sinks, lavatories, bathtubs, showers, bidets, laundry tubs and washing machine outlets shall be provided with hot and cold water.

## SECTION R307 TOILET, BATH AND SHOWER SPACES

**R307.1 Space required.** Fixtures shall be spaced in accordance with Figure R307.1, and in accordance with the requirements of Section P2705.1.

**R307.2 Bathtub and shower spaces.** Bathtub and shower floors and walls above bathtubs with installed shower heads and in shower compartments shall be finished with a nonabsorbent surface. Such wall surfaces shall extend to a height of not less than 6 feet (1829 mm) above the floor.

## SECTION R308 GLAZING

**R308.1 Identification.** Except as indicated in Section R308.1.1 each pane of glazing installed in hazardous locations as defined in Section R308.4 shall be provided with a manufacturer's designation specifying who applied the designation, designating the type of glass and the safety glazing standard with which it complies, which is visible in the final installation. The designation shall be acid etched, sandblasted, ceramic-fired, laser etched, embossed, or be of a type that once applied cannot be removed without being destroyed. A *label* shall be permitted in lieu of the manufacturer's designation.

**Exceptions:**

1. For other than tempered glass, manufacturer's designations are not required provided that the *building official* approves the use of a certificate, affidavit or other evidence confirming compliance with this code.
2. Tempered spandrel glass is permitted to be identified by the manufacturer with a removable paper designation.

**R308.1.1 Identification of multiple assemblies.** Multipane assemblies having individual panes not exceeding 1 square foot (0.09 $m^2$) in exposed area shall have not less than one pane in the assembly identified in accordance with Section R308.1. Other panes in the assembly shall be *labeled* "CPSC 16 CFR 1201" or "ANSI Z97.1" as appropriate.

**R308.2 Louvered windows or jalousies.** Regular, float, wired or patterned glass in jalousies and louvered windows shall be not less than nominal $^3/_{16}$ inch (5 mm) thick and not more than 48 inches (1219 mm) in length. Exposed glass edges shall be smooth.

**R308.2.1 Wired glass prohibited.** Wired glass with wire exposed on longitudinal edges shall not be used in jalousies or louvered windows.

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# Part I—Administrative

## CHAPTER 1

# SCOPE AND ADMINISTRATION

### PART 1—SCOPE AND APPLICATION

### SECTION R101 GENERAL

**R101.1 Title.** These provisions shall be known as the *Residential Code for One- and Two-family Dwellings* of **[NAME OF JURISDICTION]**, and shall be cited as such and will be referred to herein as "this code."

**R101.2 Scope.** The provisions of the *International Residential Code for One- and Two-family Dwellings* shall apply to the construction, *alteration*, movement, enlargement, replacement, repair, *equipment*, use and occupancy, location, removal and demolition of detached one- and two-family dwellings and *townhouses* not more than three stories above *grade plane* in height with a separate means of egress and their *accessory structures* not more than three stories above *grade plane* in height.

**Exceptions:**

1. Live/work units located in *townhouses* and complying with the requirements of Section 419 of the *International Building Code* shall be permitted to be constructed in accordance with the *International Residential Code for One- and Two-Family Dwellings*. Fire suppression required by Section 419.5 of the *International Building Code* where constructed under the *International Residential Code for One- and Two-family Dwellings* shall conform to Section P2904.
2. Owner-occupied lodging houses with five or fewer guestrooms shall be permitted to be constructed in accordance with the *International Residential Code for One- and Two-family Dwellings* where equipped with a fire sprinkler system in accordance with Section P2904.

**R101.3 Intent.** The purpose of this code is to establish minimum requirements to safeguard the public safety, health and general welfare through affordability, structural strength, means of egress facilities, stability, sanitation, light and ventilation, energy conservation and safety to life and property from fire and other hazards attributed to the built environment and to provide safety to fire fighters and emergency responders during emergency operations.

### SECTION R102 APPLICABILITY

**R102.1 General.** Where there is a conflict between a general requirement and a specific requirement, the specific requirement shall be applicable. Where, in any specific case, different sections of this code specify different materials, methods of construction or other requirements, the most restrictive shall govern.

**R102.2 Other laws.** The provisions of this code shall not be deemed to nullify any provisions of local, state or federal law.

**R102.3 Application of references.** References to chapter or section numbers, or to provisions not specifically identified by number, shall be construed to refer to such chapter, section or provision of this code.

**R102.4 Referenced codes and standards.** The codes and standards referenced in this code shall be considered part of the requirements of this code to the prescribed extent of each such reference and as further regulated in Sections R102.4.1 and R102.4.2.

**Exception:** Where enforcement of a code provision would violate the conditions of the *listing* of the *equipment* or *appliance*, the conditions of the *listing* and manufacturer's instructions shall apply.

**R102.4.1 Conflicts.** Where conflicts occur between provisions of this code and referenced codes and standards, the provisions of this code shall apply.

**R102.4.2 Provisions in referenced codes and standards.** Where the extent of the reference to a referenced code or standard includes subject matter that is within the scope of this code, the provisions of this code, as applicable, shall take precedence over the provisions in the referenced code or standard.

**R102.5 Appendices.** Provisions in the appendices shall not apply unless specifically referenced in the adopting ordinance.

**R102.6 Partial invalidity.** In the event any part or provision of this code is held to be illegal or void, this shall not have the effect of making void or illegal any of the other parts or provisions.

**R102.7 Existing structures.** The legal occupancy of any structure existing on the date of adoption of this code shall be permitted to continue without change, except as is specifically covered in this code, the *International Property Mainte-*

**DRAFT.** The pressure difference existing between the *appliance* or any component part and the atmosphere, that causes a continuous flow of air and products of combustion through the gas passages of the *appliance* to the atmosphere.

**Induced draft.** The pressure difference created by the action of a fan, blower or ejector, that is located between the *appliance* and the chimney or vent termination.

**Natural draft.** The pressure difference created by a vent or chimney because of its height, and the temperature difference between the flue gases and the atmosphere.

**DRAFT HOOD.** A device built into an *appliance*, or a part of the vent connector from an *appliance*, that is designed to provide for the ready escape of the flue gases from the *appliance* in the event of no draft, backdraft or stoppage beyond the draft hood; prevent a backdraft from entering the *appliance*; and neutralize the effect of stack action of the chimney or gas vent on the operation of the *appliance*.

**DRAFT REGULATOR.** A device that functions to maintain a desired draft in the *appliance* by automatically reducing the draft to the desired value.

**[RB] DRAFT STOP.** A material, device or construction installed to restrict the movement of air within open spaces of concealed areas of building components such as crawl spaces, floor-ceiling assemblies, roof-ceiling assemblies and *attics*.

**DRAIN.** Any pipe that carries soil and water-borne wastes in a building drainage system.

**DRAIN-BACK SYSTEM.** A solar thermal system in which the fluid in the solar collector loop is drained from the collector into a holding tank under prescribed circumstances.

**DRAINAGE FITTING.** A pipe fitting designed to provide connections in the drainage system that have provisions for establishing the desired slope in the system. These fittings are made from a variety of both metals and plastics. The methods of coupling provide for required slope in the system.

**DUCT SYSTEM.** A continuous passageway for the transmission of air that, in addition to ducts, includes duct fittings, dampers, plenums, fans and accessory air-handling *equipment* and *appliances*.

For definition applicable in Chapter 11, see Section N1101.6.

**[RB] DWELLING.** Any building that contains one or two *dwelling units* used, intended, or designed to be built, used, rented, leased, let or hired out to be occupied, or that are occupied for living purposes.

**[RB] DWELLING UNIT.** A single unit providing complete independent living facilities for one or more persons, including permanent provisions for living, sleeping, eating, cooking and sanitation.

**DWV.** Abbreviated term for drain, waste and vent piping as used in common plumbing practice.

**EFFECTIVE OPENING.** The minimum cross-sectional area at the point of water-supply discharge, measured or expressed in terms of diameter of a circle and if the opening is not circular, the diameter of a circle of equivalent cross-sectional area. (This is applicable to air gap.)

**ELBOW.** A pressure pipe fitting designed to provide an exact change in direction of a pipe run. An elbow provides a sharp turn in the flow path (see "Bend" and "Sweep").

**[RB] EMERGENCY ESCAPE AND RESCUE OPENING.** An operable exterior window, door or similar device that provides for a means of escape and access for rescue in the event of an emergency.

**[RB] ENGINEERED WOOD RIM BOARD.** A full-depth structural composite lumber, wood structural panel, structural glued laminated timber or prefabricated wood I-joist member designed to transfer horizontal (shear) and vertical (compression) loads, provide attachment for *diaphragm* sheathing, siding and exterior deck ledgers and provide lateral support at the ends of floor or roof joists or rafters.

**EQUIPMENT.** Piping, ducts, vents, control devices and other components of systems other than *appliances* that are permanently installed and integrated to provide control of environmental conditions for buildings. This definition shall also include other systems specifically regulated in this code.

**EQUIVALENT LENGTH.** For determining friction losses in a piping system, the effect of a particular fitting equal to the friction loss through a straight piping length of the same nominal diameter.

**[RE] ERI REFERENCE DESIGN.** A version of the rated design that meets the minimum requirements of the 2006 *International Energy Conservation Code*.

**[RB] ESCARPMENT.** With respect to topographic wind effects, a cliff or steep slope generally separating two levels or gently sloping areas.

**ESSENTIALLY NONTOXIC TRANSFER FLUIDS.** Fluids having a Gosselin rating of 1, including propylene glycol; mineral oil; polydimethy oil oxane; hydrochlorofluorocarbon, chlorofluorocarbon and hydrofluorocarbon refrigerants; and FDA-approved boiler water additives for steam boilers.

**ESSENTIALLY TOXIC TRANSFER FLUIDS.** Soil, water or gray water and fluids having a Gosselin rating of 2 or more including ethylene glycol, hydrocarbon oils, ammonia refrigerants and hydrazine.

**EVAPORATIVE COOLER.** A device used for reducing air temperature by the process of evaporating water into an airstream.

**EXCESS AIR.** Air that passes through the combustion chamber and the *appliance* flue in excess of what is theoretically required for complete combustion.

**EXHAUST HOOD, FULL OPENING.** An exhaust hood with an opening not less than the diameter of the connecting vent.

**EXISTING INSTALLATIONS.** Any plumbing system regulated by this code that was legally installed prior to the effective date of this code, or for which a *permit* to install has been issued.

**[RB] EXTERIOR INSULATION AND FINISH SYSTEMS (EIFS).** EIFS are nonstructural, nonload-bearing *exterior wall* cladding systems that consist of an insulation board attached either adhesively or mechanically, or both, to duration of a single supply operation and on the average time between successive operations.

**[RB] FLAME SPREAD.** The propagation of flame over a surface.

**[RB] FLAME SPREAD INDEX.** A comparative measure, expressed as a dimensionless number, derived from visual measurements of the spread of flame versus time for a material tested in accordance with ASTM E 84 or UL 723.

**FLEXIBLE AIR CONNECTOR.** A conduit for transferring air between an air duct or plenum and an air terminal unit, an air inlet or an air outlet. Such conduit is limited in its use, length and location.

**[RB] FLIGHT.** A continuous run of rectangular treads or winders or combination thereof from one landing to another.

**FLOOD-LEVEL RIM.** The edge of the receptor or fixture from which water overflows.

**FLOOR DRAIN.** A plumbing fixture for recess in the floor having a floor-level strainer intended for the purpose of the collection and disposal of waste water used in cleaning the floor and for the collection and disposal of accidental spillage to the floor.

**FLOOR FURNACE.** A self-contained furnace suspended from the floor of the space being heated, taking air for combustion from outside such space, and with means for lighting the *appliance* from such space.

**FLOW PRESSURE.** The static pressure reading in the water-supply pipe near the faucet or water outlet while the faucet or water outlet is open and flowing at capacity.

**FLUE.** See "Vent."

**FLUE, APPLIANCE.** The passages within an *appliance* through which combustion products pass from the combustion chamber to the flue collar.

**FLUE COLLAR.** The portion of a fuel-burning *appliance* designed for the attachment of a draft hood, vent connector or venting system.

**FLUE GASES.** Products of combustion plus excess air in *appliance* flues or heat exchangers.

**FLUSH VALVE.** A device located at the bottom of a flush tank that is operated to flush water closets.

**FLUSHOMETER TANK.** A device integrated within an air accumulator vessel that is designed to discharge a predetermined quantity of water to fixtures for flushing purposes.

**FLUSHOMETER VALVE.** A flushometer valve is a device that discharges a predetermined quantity of water to fixtures for flushing purposes and is actuated by direct water pressure.

**[RB] FOAM BACKER BOARD.** Foam plastic used in siding applications where the foam plastic is a component of the siding.

**[RB] FOAM PLASTIC INSULATION.** A plastic that is intentionally expanded by the use of a foaming agent to produce a reduced-density plastic containing voids consisting of open or closed cells distributed throughout the plastic for thermal insulating or acoustic purposes and that has a density less than 20 pounds per cubic foot (320 kg/m$^3$) unless it is used as interior trim.

**[RB] FOAM PLASTIC INTERIOR TRIM.** Exposed foam plastic used as picture molds, chair rails, crown moldings, baseboards, handrails, ceiling beams, door trim and window trim and similar decorative or protective materials used in fixed applications.

**FUEL-PIPING SYSTEM.** All piping, tubing, valves and fittings used to connect fuel utilization *equipment* to the point of fuel delivery.

**FULLWAY VALVE.** A valve that in the full open position has an opening cross-sectional area that is not less than 85 percent of the cross-sectional area of the connecting pipe.

**FURNACE.** A vented heating *appliance* designed or arranged to discharge heated air into a *conditioned space* or through a duct or ducts.

**[RB] GLAZING AREA.** The interior surface area of all glazed fenestration, including the area of sash, curbing or other framing elements, that enclose *conditioned space*. Includes the area of glazed fenestration assemblies in walls bounding conditioned *basements*.

**[RB] GRADE.** The finished ground level adjoining the building at all *exterior walls*.

**[RB] GRADE FLOOR OPENING.** A window or other opening located such that the sill height of the opening is not more than 44 inches (1118 mm) above or below the finished ground level adjacent to the opening.

**GRADE, PIPING.** See "Slope."

**[RB] GRADE PLANE.** A reference plane representing the average of the finished ground level adjoining the building at all *exterior walls*. Where the finished ground level slopes away from the *exterior walls*, the reference plane shall be established by the lowest points within the area between the building and the *lot line* or, where the *lot line* is more than 6 feet (1829 mm) from the building between the structure and a point 6 feet (1829 mm) from the building.

**GRAY WATER.** Waste discharged from lavatories, bathtubs, showers, clothes washers and laundry trays.

**GRIDDED WATER DISTRIBUTION SYSTEM.** A water distribution system where every water distribution pipe is interconnected so as to provide two or more paths to each fixture supply pipe.

**[RB] GROSS AREA OF EXTERIOR WALLS.** The normal projection of all *exterior walls*, including the area of all windows and doors installed therein.

**GROUND-SOURCE HEAT PUMP LOOP SYSTEM.** Piping buried in horizontal or vertical excavations or placed in a body of water for the purpose of transporting heat transfer liquid to and from a heat pump. Included in this definition are closed loop systems in which the liquid is recirculated and open loop systems in which the liquid is drawn from a well or other source.

**[RB] GUARD.** A building component or a system of building components located near the open sides of elevated walktems for generating useful electrical energy and recoverable thermal energy that is permanently connected and fixed in place.

**STORM SEWER, DRAIN.** A pipe used for conveying rainwater, surface water, subsurface water and similar liquid waste.

**[RB] STORY.** That portion of a building included between the upper surface of a floor and the upper surface of the floor or roof next above.

**[RB] STORY ABOVE GRADE PLANE.** Any *story* having its finished floor surface entirely above *grade plane*, or in which the finished surface of the floor next above is either of the following:

1. More than 6 feet (1829 mm) *above grade plane.*
2. More than 12 feet (3658 mm) above the finished ground level at any point.

**[RB] STRUCTURAL COMPOSITE LUMBER.** Structural members manufactured using wood elements bonded together with exterior adhesives.

Examples of structural composite lumber are:

**Laminated veneer lumber (LVL).** A composite of wood veneer elements with wood fibers primarily oriented along the length of the member, where the veneer element thicknesses are 0.25 inches (6.4 mm) or less.

**Parallel strand lumber (PSL).** A composite of wood strand elements with wood fibers primarily oriented along the length of the member, where the least dimension of the wood strand elements is 0.25 inch (6.4 mm) or less and their average lengths are not less than 300 times the least dimension of the wood strand elements.

**Laminated strand lumber (LSL).** A composite of wood strand elements with wood fibers primarily oriented along the length of the member, where the least dimension of the wood strand elements is 0.10 inch (2.54 mm) or less and their average lengths are not less than 150 times the least dimension of the wood strand elements.

**Oriented strand lumber (OSL).** A composite of wood strand elements with wood fibers primarily oriented along the length of the member, where the least dimension of the wood strand elements is 0.10 inch (2.54 mm) or less and their average lengths are not less than 75 times and less than 150 times the least dimension of the wood strand elements.

**[RB] STRUCTURAL INSULATED PANEL (SIP).** A structural sandwich panel that consists of a light-weight foam plastic core securely laminated between two thin, rigid wood structural panel facings.

**[RB] STRUCTURE.** That which is built or constructed.

**[RB] SUBSOIL DRAIN.** A drain that collects subsurface water or seepage water and conveys such water to a place of disposal.

**SUMP.** A tank or pit that receives sewage or waste, located below the normal *grade* of the gravity system and that must be emptied by mechanical means.

**SUMP PUMP.** A pump installed to empty a sump. These pumps are used for removing storm water only. The pump is selected for the specific head and volume of the load and is usually operated by level controllers.

**[RB] SUNROOM.** A one-story structure attached to a *dwelling* with a *glazing area* in excess of 40 percent of the gross area of the structure's *exterior walls* and roof.

For definition applicable in Chapter 11, see Section N1101.6.

**SUPPLY AIR.** Air delivered to a *conditioned space* through ducts or plenums from the heat exchanger of a heating, cooling or ventilating system.

**SUPPORTS.** Devices for supporting, hanging and securing pipes, fixtures and *equipment.*

**SWEEP.** A drainage fitting designed to provide a change in direction of a drain pipe of less than the angle specified by the amount necessary to establish the desired slope of the line. Sweeps provide a longer turning radius than bends and a less turbulent flow pattern (see "Bend" and "Elbow").

**TEMPERATURE- AND PRESSURE-RELIEF (T AND P) VALVE.** A combination relief valve designed to function as both a temperature-relief and pressure-relief valve.

**TEMPERATURE-RELIEF VALVE.** A temperature-actuated valve designed to discharge automatically at the temperature at which it is set.

**[RB] TERMITE-RESISTANT MATERIAL.** Pressure-preservative treated wood in accordance with the AWPA standards in Section R318.1, naturally durable termite-resistant wood, steel, concrete, masonry or other *approved* material.

**[RB] THERMAL ISOLATION.** Physical and space conditioning separation from *conditioned space(s)* consisting of existing or new walls, doors or windows. The *conditioned space(s)* shall be controlled as separate zones for heating and cooling or conditioned by separate *equipment.*

For definition applicable in Chapter 11, see Section N1101.6.

**[RE] THERMAL RESISTANCE, *R*-VALUE.** The inverse of the time rate of heat flow through a body from one of its bounding surfaces to the other for a unit temperature difference between the two surfaces, under steady state conditions, per unit area (h · ft$^2$ · °F/Btu) (m$^2$ · K)/W.

**[RE] THERMAL TRANSMITTANCE, *U*-FACTOR.** The coefficient of heat transmission (air to air) through a building envelope component or assembly, equal to the time rate of heat flow per unit area and unit temperature difference between the warm side and cold side air films (Btu/h · ft$^2$ · °F) W/(m$^2$ · K).

**[RB] THIRD-PARTY CERTIFICATION AGENCY.** An approved agency operating a product or material certification system that incorporates initial product testing, assessment and surveillance of a manufacturer's quality control system.

**[RB] THIRD PARTY CERTIFIED.** Certification obtained by the manufacturer indicating that the function and performance characteristics of a product or material have been determined by testing and ongoing surveillance by an

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the roof decking or sheathing, supported by not less than nominal 2-inch (51 mm) ledgers attached to the sides of the roof framing members, for a distance of not less than 4 feet (1219 mm) on each side of the wall or walls and any openings or penetrations in the roof are not within 4 feet (1219 mm) of the common walls.

3. A parapet is not required where roof surfaces adjacent to the wall or walls are at different elevations and the higher roof is more than 30 inches (762 mm) above the lower roof. The common wall construction from the lower roof to the underside of the higher roof deck shall have not less than a 1-hour fire-resistance rating. The wall shall be rated for exposure from both sides.

**R302.2.3 Parapet construction.** Parapets shall have the same fire-resistance rating as that required for the supporting wall or walls. On any side adjacent to a roof surface, the parapet shall have noncombustible faces for the uppermost 18 inches (457 mm), to include counterflashing and coping materials. Where the roof slopes toward a parapet at slopes greater than 2 units vertical in 12 units horizontal (16.7-percent slope), the parapet shall extend to the same height as any portion of the roof within a distance of 3 feet (914 mm), and the height shall be not less than 30 inches (762 mm).

**R302.2.4 Structural independence.** Each individual *townhouse* shall be structurally independent.

**Exceptions:**

1. Foundations supporting *exterior walls* or common walls.
2. Structural roof and wall sheathing from each unit fastened to the common wall framing.
3. Nonstructural wall and roof coverings.
4. Flashing at termination of roof covering over common wall.
5. *Townhouses* separated by a common wall as provided in Section R302.2, Item 1 or 2.

**R302.3 Two-family dwellings.** *Dwelling units* in two-family dwellings shall be separated from each other by wall and floor assemblies having not less than a 1-hour fire-resistance rating where tested in accordance with ASTM E 119 or UL 263. Fire-resistance-rated floor/ceiling and wall assemblies shall extend to and be tight against the *exterior wall*, and wall assemblies shall extend from the foundation to the underside of the roof sheathing.

**Exceptions:**

1. A fire-resistance rating of $^1/_2$ hour shall be permitted in buildings equipped throughout with an automatic sprinkler system installed in accordance with NFPA 13.
2. Wall assemblies need not extend through *attic* spaces where the ceiling is protected by not less than $^5/_8$-inch (15.9 mm) Type X gypsum board, an *attic* draft stop constructed as specified in Section R302.12.1 is provided above and along the wall assembly separating the *dwellings* and the structural framing supporting the ceiling is protected by not less than $^1/_2$-inch (12.7 mm) gypsum board or equivalent.

**R302.3.1 Supporting construction.** Where floor assemblies are required to be fire-resistance rated by Section R302.3, the supporting construction of such assemblies shall have an equal or greater fire-resistance rating.

**R302.4 Dwelling unit rated penetrations.** Penetrations of wall or floor-ceiling assemblies required to be fire-resistance rated in accordance with Section R302.2 or R302.3 shall be protected in accordance with this section.

**R302.4.1 Through penetrations.** Through penetrations of fire-resistance-rated wall or floor assemblies shall comply with Section R302.4.1.1 or R302.4.1.2.

**Exception:** Where the penetrating items are steel, ferrous or copper pipes, tubes or conduits, the annular space shall be protected as follows:

1. In concrete or masonry wall or floor assemblies, concrete, grout or mortar shall be permitted where installed to the full thickness of the wall or floor assembly or the thickness required to maintain the fire-resistance rating, provided that both of the following are complied with:
   1.1. The nominal diameter of the penetrating item is not more than 6 inches (152 mm).
   1.2. The area of the opening through the wall does not exceed 144 square inches (92 900 $mm^2$).
2. The material used to fill the annular space shall prevent the passage of flame and hot gases sufficient to ignite cotton waste where subjected to ASTM E 119 or UL 263 time temperature fire conditions under a positive pressure differential of not less than 0.01 inch of water (3 Pa) at the location of the penetration for the time period equivalent to the fire-resistance rating of the construction penetrated.

**R302.4.1.1 Fire-resistance-rated assembly.** Penetrations shall be installed as tested in the *approved* fire-resistance-rated assembly.

**R302.4.1.2 Penetration firestop system.** Penetrations shall be protected by an *approved* penetration firestop system installed as tested in accordance with ASTM E 814 or UL 1479, with a positive pressure differential of not less than 0.01 inch of water (3 Pa) and shall have an F rating of not less than the required fire-resistance rating of the wall or floor-ceiling assembly penetrated.

**R302.4.2 Membrane penetrations.** Membrane penetrations shall comply with Section R302.4.1. Where walls are required to have a fire-resistance rating, recessed fixtures shall be installed so that the required fire-resistance rating will not be reduced.

**Exceptions:**

1. Membrane penetrations of not more than 2-hour fire-resistance-rated walls and partitions by steel electrical boxes that do not exceed 16 square

4. One thickness of $^3/_4$-inch (19.1 mm) particleboard with joints backed by $^3/_4$-inch (19.1 mm) particleboard.
5. One-half-inch (12.7 mm) gypsum board.
6. One-quarter-inch (6.4 mm) cement-based millboard.
7. Batts or blankets of mineral wool or glass fiber or other *approved* materials installed in such a manner as to be securely retained in place.
8. Cellulose insulation installed as tested in accordance with ASTM E 119 or UL 263, for the specific application.

**R302.11.1.1 Batts or blankets of mineral or glass fiber.** Batts or blankets of mineral or glass fiber or other *approved* nonrigid materials shall be permitted for compliance with the 10-foot (3048 mm) horizontal fireblocking in walls constructed using parallel rows of studs or staggered studs.

**R302.11.1.2 Unfaced fiberglass.** Unfaced fiberglass batt insulation used as fireblocking shall fill the entire cross section of the wall cavity to a height of not less than 16 inches (406 mm) measured vertically. Where piping, conduit or similar obstructions are encountered, the insulation shall be packed tightly around the obstruction.

**R302.11.1.3 Loose-fill insulation material.** Loose-fill insulation material shall not be used as a fireblock unless specifically tested in the form and manner intended for use to demonstrate its ability to remain in place and to retard the spread of fire and hot gases.

**R302.11.2 Fireblocking integrity.** The integrity of fireblocks shall be maintained.

**R302.12 Draftstopping.** In combustible construction where there is usable space both above and below the concealed space of a floor-ceiling assembly, draftstops shall be installed so that the area of the concealed space does not exceed 1,000 square feet (92.9 m$^2$). Draftstopping shall divide the concealed space into approximately equal areas. Where the assembly is enclosed by a floor membrane above and a ceiling membrane below, draftstopping shall be provided in floor-ceiling assemblies under the following circumstances:

1. Ceiling is suspended under the floor framing.
2. Floor framing is constructed of truss-type open-web or perforated members.

**R302.12.1 Materials.** Draftstopping materials shall be not less than $^1/_2$-inch (12.7 mm) gypsum board, $^3/_8$-inch (9.5 mm) wood structural panels or other *approved* materials adequately supported. Draftstopping shall be installed parallel to the floor framing members unless otherwise *approved* by the *building official*. The integrity of the draftstops shall be maintained.

** **R302.13 Fire protection of floors.** Floor assemblies that are not required elsewhere in this code to be fire-resistance rated, shall be provided with a $^1/_2$-inch (12.7 mm) gypsum wallboard membrane, $^5/_8$-inch (16 mm) wood structural panel membrane, or equivalent on the underside of the floor framing member. Penetrations or openings for ducts, vents, electrical outlets, lighting, devices, luminaires, wires, speakers, drainage, piping and similar openings or penetrations shall be permitted.

**Exceptions:**

1. Floor assemblies located directly over a space protected by an automatic sprinkler system in accordance with Section P2904, NFPA 13D, or other approved equivalent sprinkler system.
2. Floor assemblies located directly over a crawl space not intended for storage or fuel-fired appliances.
3. Portions of floor assemblies shall be permitted to be unprotected where complying with the following:
   3.1. The aggregate area of the unprotected portions does not exceed 80 square feet (7.4 m$^2$) per story
   3.2. Fireblocking in accordance with Section R302.11.1 is installed along the perimeter of the unprotected portion to separate the unprotected portion from the remainder of the floor assembly.
4. Wood floor assemblies using dimension lumber or structural composite lumber equal to or greater than 2-inch by 10-inch (50.8 mm by 254 mm) nominal dimension, or other approved floor assemblies demonstrating equivalent fire performance.

**R302.14 Combustible insulation clearance.** Combustible insulation shall be separated not less than 3 inches (76 mm) from recessed luminaires, fan motors and other heat-producing devices.

**Exception:** Where heat-producing devices are *listed* for lesser clearances, combustible insulation complying with the listing requirements shall be separated in accordance with the conditions stipulated in the listing.

Recessed luminaires installed in the *building thermal envelope* shall meet the requirements of Section N1102.4.5 of this code.

## SECTION R303
## LIGHT, VENTILATION AND HEATING

**R303.1 Habitable rooms.** Habitable rooms shall have an aggregate glazing area of not less than 8 percent of the floor area of such rooms. Natural *ventilation* shall be through windows, skylights, doors, louvers or other *approved* openings to the outdoor air. Such openings shall be provided with ready access or shall otherwise be readily controllable by the building occupants. The openable area to the outdoors shall be not less than 4 percent of the floor area being ventilated.

**Exceptions:**

1. The glazed areas need not be openable where the opening is not required by Section R310 and a whole-house mechanical *ventilation* system is installed in accordance with Section M1507.
2. The glazed areas need not be installed in rooms where Exception 1 is satisfied and artificial light is provided that is capable of producing an average

# LOG 170:

# Substantiating Documents

**Appliance Standards and Rulemaking Federal Advisory Committee**
*Manufactured Housing Working Group*
Term Sheet
October 31, 2014

# 1. Background

On June 13, 2014, the U.S. Department of Energy (DOE) issued a Notice of Intent to establish a negotiated rulemaking working group (WG) under the Appliance Standards and Rulemaking Federal Advisory Committee (ASRAC) in accordance with the Federal Advisory Committee Act (FACA) and the Negotiated Rulemaking Act (NRA) to negotiate proposed federal standards for energy efficiency in manufactured homes. *See* 79 FR 33873. The stated purpose of the WG was to discuss and, if possible, reach consensus on a proposed rule for the energy efficiency of manufactured homes, as authorized by section 413 of the Energy Independence and Security Act of 2007 (EISA).

On July 16, 2014, DOE announced the members of the WG, which consisted of representatives of parties with a defined stake in the outcome of the proposed standards. *See* 79 FR 41456. Specifically, the WG consisted of 22 members, including one member from ASRAC and one DOE representative (see Appendix A). The WG met in-person during six sets of meetings held on August 4-5, August 21-22, September 9-10, September 22-23, October 1-2, and October 23-24. *See* 79 FR 48097 and 79 FR 59154.

The WG successfully reached consensus on proposed energy efficiency standards for manufactured housing. This document includes the WG's recommendations to ASRAC on the proposed standards.

# 2. Applicable Aspects of the 2015 IECC

### Recommendation

The WG reviewed the 2015 International Energy Conservation Code (IECC) for residential buildings for applicability to manufactured housing over the course of the six public meetings. The WG identified sections of the 2015 IECC that were not applicable or that the WG modified. Consensus was reached on these items, as recorded in Appendix B.

**Vote:** Consensus[1] (19-yes; 1-no; 2-abstain[2]): October 24, 2014.

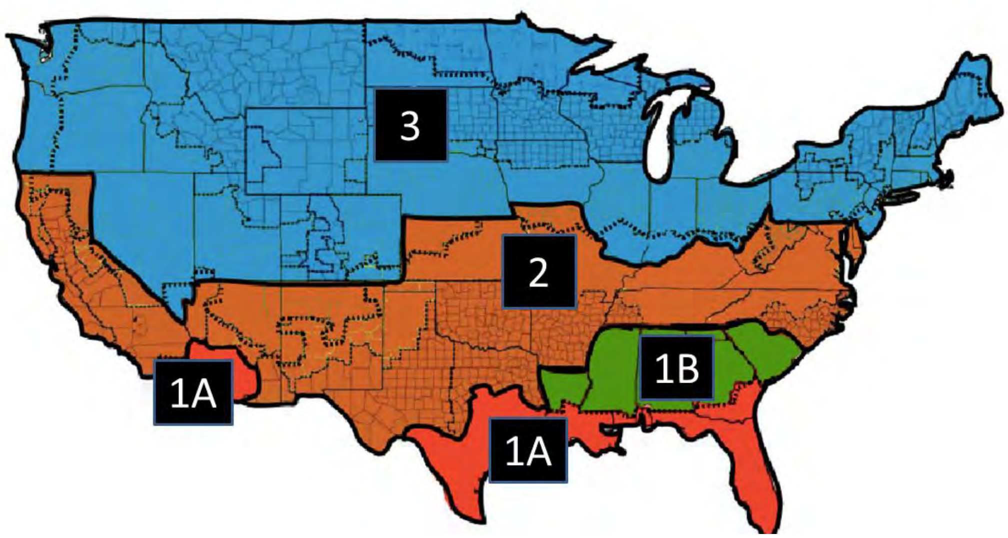
[1] For purposes of this WG, "consensus" was defined as at least a two-thirds "supermajority" in favor of the recommendation. Votes in favor of a recommendation included "thumbs-up" and "thumbs-sideways." Votes against a recommendation were indicated with a "thumbs-down."
[2] Some recommendations did not receive votes from all 22 members, either due to a decision to abstain from voting or absence from the meeting.

# 3. Climate Zones

## 3.1. Recommendation

The WG recommends that the energy efficiency standards be based on the four climate zones in Figure 3.1.

**Figure 3.1 Climate Zone Map**




**Vote:** Consensus (20-yes; 1-no; 1-abstain): October 23, 2014.

* The WG did not consider Alaska, Hawaii, and U.S. Territories. DOE will determine zoning of those states and territories when it develops a Notice of Proposed Rulemaking (NOPR).

## 3.2. Recommendation

The WG recommends using the naming convention of zone 1A, 1B, 2, and 3.

**Vote:** Consensus (20-yes; 0-no; 2-abstain): October 24, 2014.

# 4. Building Thermal Envelope Pathways to Compliance

## Recommendation

The WG recommends allowing both a prescriptive path option (see section 5) and a performance path option (see section 6) to ensure improved energy efficiency of a manufactured home's building thermal envelope. The prescriptive path would specify a portfolio of specific building thermal envelope energy efficiency measures (e.g., *R*-30 ceiling insulation). The performance path would specify an overall building thermal envelope *U*-value ($U_o$). Both building thermal envelope compliance pathways would also include the mandatory requirements summarized in section 7.

**Vote:** Consensus (20-yes; 0-no; 2-abstain): October 2, 2014.

# 5. Building Thermal Envelope Requirements: Prescriptive Path Option

### Recommendation

The WG recommends the prescriptive measures associated with the 4 climate zones outlined in Table 5.1. These measures would be the same for manufactured homes of all sizes (e.g., single- and multi-section manufactured homes).

**Table 5.1 Building Thermal Envelope Prescriptive Requirements**

| **Climate Zone** | **Ceiling (*R*-value)** | **Wall (*R*-value)** | **Floor (*R*-value)** | **Window (*U*-value)** | **Skylight (U-value)** | **Door (*U*-value)** | **Glazed Fenestration (SHGC)** |
|---|---|---|---|---|---|---|---|
| 1A | 30 | 13 | 13 | 0.35 | .75 | 0.40 | 0.25 |
| 1B | 30 | 13 | 13 | 0.35 | .75 | 0.40 | Pending DOE Analysis* |
| 2 | 30 | 21 | 19 | 0.35 | .55 | 0.40 | Pending DOE Analysis* |
| 3 | 38 | 21 | 30 | 0.32 | .55 | 0.40 | No Rating |

*The WG did not reach consensus on prescriptive specifications for SHGC in climate zones 1B and 2, and has recommended that DOE determine these values after further analysis when it develops a NOPR.

**Vote:** Consensus (20-yes; 1-no; 1-abstain): October 23, 2014.

## 5.1. Recommendation

The WG recommends the following footnotes apply to the prescriptive requirements listed in Table 5.1.

1. For conversion between units of length: 1 foot = 304.8 mm.
2. Table 5.1 includes the minimum *R*-values required to comply with DOE's proposed standards. *U*-value and SHGC specifications reflect maximum values.
3. The SHGC column of Table 5.1 applies to all glazed fenestration. Exception: Skylights may be excluded from building thermal envelope glazed fenestration SHGC requirements where the SHGC for such skylights does not exceed 0.30.
4. The floor *R*-value column assumes *R*-21 batt + *R*-14 blanket values to account for compression areas in the floor in climate zone 3.
5. The wall *R*-value column assumes a minimum truss heel height of 5.5 inches at the outside face of each exterior wall.
6. Each *R*-value column reflects the insulation manufacturers' published values. Uniform insulation thickness would not be mandatory as long as the required volume of insulation is installed with uniform density.

**Vote:** Consensus (19-yes; 1-no; 2-abstain) October 24, 2014.

## 5.2. Recommendation

The WG recommends DOE complete further analysis to determine *U*-values for use as an alternative to the *R*-values listed in Table 5.1. Under this alternative *U*-value approach to the prescriptive path option of ensuring improved energy efficiency of a manufactured home's building thermal envelope, a manufacturer would need to comply with the window, skylight, and door *U*-values and the glazed fenestration SHGC specifications included in Table 5.1.

**Table 5.2 *U*-Value Alternative for Ceiling, Wall, and Floor**

| Climate Zone | Ceiling (*U*-value) | Wall (*U*-value) | Floor (*U*-value) |
|---|---|---|---|
| 1A | Pending DOE Analysis* | Pending DOE Analysis* | Pending DOE Analysis* |
| 1B | Pending DOE Analysis* | Pending DOE Analysis* | Pending DOE Analysis* |
| 2 | Pending DOE Analysis* | Pending DOE Analysis* | Pending DOE Analysis* |
| 3 | Pending DOE Analysis* | Pending DOE Analysis* | Pending DOE Analysis* |

* The WG did not reach consensus on the *U*-values for Table 5.2 and has recommended DOE determine these values after further analysis when it develops a NOPR.

**Vote:** Consensus (20-yes; 1-no; 1-abstain): October 24, 2014.

# 6. Building Thermal Envelope Requirements: $U_o$ Performance Path Option

## 6.1. Recommendation

The WG recommends the $U_o$ values associated with the 4 climate zones in Table 6.1, and in connection with the number of sections in a manufactured home. The SHGC requirement shall be met in addition to $U_o$ compliance. An area weighted average SHGC of windows, skylights, and doors more than 50 percent glazed shall satisfy the glazed fenestration SHGC requirements of Table 5.1.

**Vote: (recommendation text):** Consensus (19-yes; 1-no; 2-abstain): October 24, 2014.

**Table 6.1 $U_o$ Values for Performance Path**

| Climate Zone | Single-Section $U_o$ | Multi-Section $U_o$ |
|---|---|---|
| 1A | 0.087 | 0.084 |
| 1B | 0.087 | 0.084 |
| 2 | 0.070 | 0.068 |
| 3 | 0.059 | 0.056 |

**Vote (recommendation table):** Consensus (20-yes; 1-no; 1-abstain): October 23, 2014.

## 6.2. Recommendation

The WG recommends that the calculation of $U_o$ follow the Battelle calculation method.[3] The Battelle calculation method produces an area-weighted average overall $U$-value for a home based on the thermal qualities and areas of material assemblies used in the home's construction.

**Vote:** Consensus (20-yes; 0-no; 2-abstain): October 24, 2014.

## 7. Other Mandatory Requirements

The WG recommends that the proposed regulations include the following requirements for all manufactured homes, regardless of the building thermal envelope compliance path selected:

### 7.1. Recommendation

The following requirements would establish compliant building thermal envelope air sealing. These proposed requirements are intended to provide a prescriptive path for reaching envelope tightness of 5 air changes per hour (ACH) when depressurized to 50 Pascals (Pa).

All manufactured homes would be required to be sealed against air leakage at all joints, seams, and penetrations associated with the building thermal envelope in accordance with the manufacturer's installation instructions, including ensuring that:

1. A continuous air barrier is established upon installation of all building thermal envelope (i.e., ceiling, walls, doors, and floor) opaque components.
2. Mating line surfaces (i.e., floor, exterior walls, and ceiling) are equipped with a continuous, durable gasket.
3. Gaps and penetrations in the ceilings, floors, and exterior surfaces of walls would be sealed with caulk, foam or gasket, or other suitable material. The following gaps and penetrations, at a minimum, would require sealing: ducts, flue shafts, plumbing, piping, electrical wiring, bathroom and kitchen exhaust fans, recessed lighting fixtures adjacent to unconditioned space, and light tubes adjacent to unconditioned space.
4. Rough openings around windows and exterior doors are sealed with caulk or foam.
5. Attic access panels and drop-down stairs are equipped with gaskets (i.e., not caulked) to produce a continuous air seal.
6. Duct system register boots that penetrate the building thermal envelope and/or air infiltration barrier are sealed to the air barrier or interior finish materials.
7. Sealing methods between dissimilar materials allow for differential expansion and contraction.

**Vote:** Consensus (15-yes; 2-no; 5-abstain): September 23, 2014

### 7.2. Recommendation

The WG recommends that duct leakage must be no greater than 4 cubic feet per minute (CFM) per 100 square feet of floor area at a 25 Pa test pressure.

[3] Conner C. C., Taylor, Z. T. "Overall U-Values and Heating/Cooling Loads – Manufactured Homes." Pacific Northwest Laboratory. 1992.

**Vote:** Consensus (19-yes; 0-no; 3-abstain): September 22, 2014

### 7.3. Recommendation

All hot water pipes outside conditioned space would be required to be insulated to at least *R*-3. In addition, all hot water pipes from a water heater to a distribution manifold would be required to be insulated to at least *R*-3.

**Vote:** Consensus (17-yes; 0-no; 5-abstain): September 23, 2014

*This term sheet has been approved by the ASRAC manufactured housing working group by consensus (20-yes, 1-no; 1-abstain) on October 24, 2014.*

# Appendix A: Working Group Members

Manufactured Housing Negotiated Rulemaking Working Group

**DOE and ASRAC Representatives**
Joseph Hagerman – Department of Energy
John Caskey - ASRAC, National Electrical Manufacturers Association

**Other Selected Members**
Bert Kessler - Palm Harbor Homes, Inc.
David Tompos - NTA, Inc.
Emanuel Levy - Systems Building Research Alliance
Eric Lacey - Responsible Energy Codes Alliance
Ishbel Dickens - National Manufactured Home Owners Association (NMHOA)
Keith Dennis - National Rural Electric Cooperative Association
Lois Starkey - Manufactured Housing Institute
Lowell Ungar - American Council for an Energy-Efficient Economy
Manuel Santana - Cavco Industries
Mark Ezzo - Clayton Homes, Inc.
Mark Weiss - Manufactured Housing Association for Regulatory Reform
Michael Lubliner - Washington State University Extension Energy Program
Michael Wade - Cavalier Home Builders
Peter Schneider - Efficiency Vermont
Richard Hanger - Housing Technology and Standards
Richard Potts - Virginia Department of Housing and Community Development
Rob Luter - Lippert Components, Inc.
Robin Roy - Natural Resources Defense Council
Scott Drake - East Kentucky Power Cooperative
Stacey Epperson - Next Step Network

# Appendix B: Applicable Aspects of the 2015 IECC

Overview:

Appendix B outlines the changes to the residential sections of the 2015 International Energy Conservation Code (IECC) discussed by the manufactured housing (MH) working group (WG). Each section is marked with a note in square brackets indicating the consensus action agreed to by the WG. The notes are listed and defined in Table 1 below.

**Table 1 Notation Descriptions**

| Notation | Description |
|---|---|
| Deleted by WG | Indicates the WG reached consensus that the section is not applicable to MH. |
| Included by WG | Indicates the WG reached consensus that the section is applicable to MH and required no revisions. |
| Revised the WG | Indicates the WG reached consensus that the section is applicable to MH but required revisions. |
| Added by WG | Indicates the WG reached consensus on adding a new section. |
| Deferred to DOE by WG | Indicates the WG reached consensus that the section should be addressed by DOE in the Notice of Proposed Rulemaking (NOPR). |
| Included in Concept by WG | Indicates the WG reached consensus on the conceptual nature of the section. DOE will need to revise the exact text and consider impacts of other provisions of the term sheet when developing the NOPR. |
| Not Discussed by WG | Indicates the WG did not discuss or reach consensus on the action for a section. DOE will need to determine how to address these sections in the NOPR. |
| Deleted – Term Sheet Supersedes | Indicates sections that were directly superseded by items in the term sheet. |

# IECC—RESIDENTIAL PROVISIONS

# CHAPTER 1 [RE] [Deleted by WG]

# CHAPTER 2 [RE] DEFINITIONS

**R201.1 Scope. [Revised by WG]** Unless stated otherwise, the following definitions are applicable to the Term Sheet.

**R201.2 Interchangeability. [Included by WG]** Words used in the present tense include the future; words in the masculine gender include the feminine and neuter; the singular number includes the plural and the plural includes the singular.

**R201.3 Terms defined in other codes. [Deleted by WG]**

**R201.4 Terms not defined. [Included by WG]** Terms not defined by this chapter shall have ordinarily accepted meanings such as the context implies.

## SECTION R202 GENERAL DEFINITIONS

**ABOVE-GRADE WALL. [Deleted by WG]**

**ACCESSIBLE. [Revised by WG]** Admitting close approach as a result of not being guarded by locked doors, elevation or other effective means

**ADDITION. [Deleted by WG]**

**AIR BARRIER. [Included by WG]** Material(s) assembled and joined together to provide a barrier to air leakage through the building envelope. An air barrier may be a single material or a combination of materials.

**ALTERATION. [Deleted by WG]**

**APPROVED. [Deleted by WG]**

**APPROVED AGENCY. [Deleted by WG]**

**AUTOMATIC.** Self-acting, operating by its own mechanism when actuated by some impersonal influence, as, for example, a change in current strength, pressure, temperature or mechanical configuration (see "Manual").

**BASEMENT WALL. [Deleted by WG]**

**BUILDING. [Deleted by WG]**

**BUILDING SITE. [Deleted by WG]**

**BUILDING THERMAL ENVELOPE. [Revised by WG]** Exterior walls, floor, roof and any other building elements that enclose conditioned space or provide a boundary between conditioned space and exempt or unconditioned space.

**C-FACTOR (THERMAL CONDUCTANCE). [Included by WG]** The coefficient of heat transmission (surface to surface) through a building component or assembly, equal to the time rate of heat flow per unit area and the unit temperature difference between the warm side and cold side surfaces (Btu/h $\cdot$ft$^2$ $\cdot$°F) [W/(m$^2$ $\cdot$K)].

**CIRCULATING HOT WATER SYSTEM. [Included by WG]** A specifically designed water distribution system where one or more pumps are operated in the service hot water piping to circulate heated water from the water-heating equipment to fixtures and back to the water-heating equipment.

**CLIMATE ZONE. [Included by WG]** A geographical region based on climatic criteria as specified in this code.

**CODE OFFICIAL. [Deleted by WG]**

**COMMERCIAL BUILDING. [Deleted by WG]**

**CONDITIONED FLOOR AREA. [Included by WG]** The horizontal projection of the floors associated with the *conditioned space*.

**CONDITIONED SPACE. [Included by WG]** An area, room or space that is enclosed within the building thermal envelope and that is directly or indirectly heated or cooled. Spaces are indirectly heated or cooled where they communicate through openings with conditioned spaces, where they are separated from conditioned spaces by uninsulated walls, floors or ceilings, or where they contain uninsulated ducts, piping or other sources of heating or cooling.

**CONTINUOUS AIR BARRIER. [Revised by WG]** A combination of materials and assemblies that restrict or prevent the passage of air through the building thermal envelope.

**CONTINUOUS INSULATION (ci). [Included by WG]** Insulating material that is continuous across all structural members without thermal bridges other than fasteners and service openings. It is installed on the interior or exterior, or is integral to any opaque surface, of the building envelope.

**CRAWL SPACE WALL. [Included by WG]** The opaque portion of a wall that encloses a crawl space and is partially or totally below grade.

**CURTAIN WALL. [Deleted by WG]**

**DEMAND RECIRCULATION WATER SYSTEM. [Included by WG]** A water distribution system where pump(s) prime the service hot water piping with heated water upon demand for hot water.

**DOE.** U.S. Department of Energy

**DUCT. [Included by WG]** A tube or conduit utilized for conveying air. The air passages of self-contained systems are not to be construed as air ducts.

**DUCT SYSTEM. [Included by WG]** A continuous passageway for the transmission of air that, in addition to ducts, includes duct fittings, dampers, plenums, fans and accessory air-handling equipment and appliances.

**DWELLING UNIT. [Deleted by WG]ENERGY ANALYSIS. [Included by WG]** A method for estimating the annual energy use of the *proposed design* and *standard reference design* based on estimates of energy use.

**ENERGY COST. [Included by WG]** The total estimated annual cost for purchased energy for the building functions regulated by this code, including applicable demand charges.

**ENERGY SIMULATION TOOL. [Revised by WG]** A DOE *approved* software program or calculation-based methodology that projects the annual energy use of a building.

**ERI REFERENCE DESIGN. [Deleted by WG]**

**EXTERIOR WALL. [Revised by WG]** Walls that enclose conditioned space.

**FENESTRATION. [Included by WG]** Products classified as either *vertical fenestration* or *skylights*.

**FENESTRATION PRODUCT, SITE-BUILT. [Deleted by WG]**

***F*-FACTOR. [Deleted by WG]**

**HEATED SLAB. [Deleted by WG]**

**HIGH-EFFICACY LAMPS. [Revised by WG]** Compact fluorescent lamps, T-8 or smaller diameter linear fluorescent lamps, or lamps with a minimum efficacy of:

1 60 lumens per watt for lamps over 40 watts;

2 50 lumens per watt for lamps over 15 watts to 40 watts; and

3. 40 lumens per watt for lamps 15 watts or less.

**HISTORIC BUILDING. [Deleted by WG]**

**INFILTRATION. [Included by WG]** The uncontrolled inward air leakage into a building caused by the pressure effects of wind or the effect of differences in the indoor and outdoor air density or both.

**INSULATED SIDING. [Included by WG]** A type of continuous insulation with manufacturer-installed insulating material as an integral part of the cladding product having a minimum *R*-value of R-2.

**INSULATING SHEATHING. [Included by WG]** An insulating board with a core material having a minimum *R*-value of R-2.

**LABELED.** The WG recommends using HUD language.

**LISTED.** The WG recommends using HUD language.

**LOW-VOLTAGE LIGHTING. [Included by WG]** Lighting equipment powered through a transformer such as a cable conductor, a rail conductor and track lighting.

**HOME MANUFACTURER. [Added by WG]** Any person engaged in manufacturing or assembling manufactured homes, including any person engaged in importing manufactured homes for resale.

**MANUAL. [Included by WG]** Capable of being operated by personal intervention (see "Automatic").

**PROPOSED DESIGN. [Deleted by WG]**

**RATED DESIGN. [Deleted by WG]**

**READILY ACCESSIBLE. [Deleted by WG]**

**REPAIR. [Deleted by WG]**

**REROOFING. [Deleted by WG]**

**RESIDENTIAL BUILDING. [Deleted by WG]**

**ROOF ASSEMBLY. [Deleted by WG]**

**ROOF RECOVER. [Deleted by WG]**

**ROOF REPAIR. [Deleted by WG]**

**ROOF REPLACEMENT. [Deleted by WG]**

***R*-VALUE (THERMAL RESISTANCE). [Included by WG]** The inverse of the time rate of heat flow through a body from one of its bounding surfaces to the other surface for a unit temperature difference between the two surfaces, under steady state conditions, per unit area ($h \cdot ft^2 \cdot °F/Btu$) [$(m^2 \cdot K)/W$].

**SERVICE WATER HEATING. [Included by WG]** Supply of hot water for purposes other than comfort heating.

**SKYLIGHT.** Glass or other transparent or translucent glazing material installed at a slope of less than 60 degrees (1.05 rad) from horizontal.

**SOLAR HEAT GAIN COEFFICIENT (SHGC). [Included by WG]** The ratio of the solar heat gain entering the space through the fenestration assembly to the incident solar radiation. Solar heat gain includes directly transmitted solar heat and absorbed solar radiation that is then reradiated, conducted or convected into the space.

**STANDARD REFERENCE DESIGN. [Deleted by WG]**

**SUNROOM. [Deleted by WG]**

**THERMAL ENVELOPE. [Deleted by WG]**

**THERMAL ISOLATION. [Included by WG]** Physical and space conditioning separation from *conditioned space(s)*. The *conditioned space*(s) shall be controlled as separate zones for heating and cooling or conditioned by separate equipment.

**THERMOSTAT. [Included by WG]** An automatic control device used to maintain temperature at a fixed or adjustable set point.

***U*-FACTOR (THERMAL TRANSMITTANCE). [Included by WG]** The coefficient of heat transmission (air to air) through a building component or assembly, equal to the time rate of heat flow per unit area and unit temperature difference between the warm side and cold side air films (Btu/h · ft2 · °F) [W/(m2 · K)].

**VENTILATION. [Included by WG]** The natural or mechanical process of supplying conditioned or unconditioned air to, or removing such air from, any space.

**VENTILATION AIR. [Included by WG]** That portion of supply air that comes from outside (outdoors) plus any recirculated air that has been treated to maintain the desired quality of air within a designated space.

**VERTICAL FENESTRATION. [Included by WG]** Windows (fixed or moveable), opaque doors, glazed doors, glazed block and combination opaque/glazed doors composed of glass or other transparent or translucent glazing materials and installed at a slope of a least 60 degrees (1.05 rad) from horizontal.

**VISIBLE TRANSMITTANCE [VT]. [Deleted by WG]**

**WHOLE HOUSE MECHANICAL VENTILATION SYSTEM. [Included by WG]** An exhaust system, supply system, or combination thereof that is designed to mechanically exchange indoor air with outdoor air when operating continuously or through a programmed intermittent schedule to satisfy the whole house ventilation rates.

**ZONE. [Included by WG]** A space or group of spaces within a building with heating or cooling requirements that are sufficiently similar so that desired conditions can be maintained throughout using a single controlling device.

# CHAPTER 3 [RE]
# GENERAL REQUIREMENTS

## SECTION R301
## CLIMATE ZONES [Deleted – Term Sheet Supersedes]

## SECTION R302
## DESIGN CONDITIONS

**R302.1 Interior design conditions. [Not Discussed by WG]** The interior design temperatures used for heating and cooling load calculations shall be a maximum of 72°F (22°C) for heating and minimum of 75°F (24°C) for cooling.

## SECTION R303
## MATERIALS, SYSTEMS AND EQUIPMENT

**R303.1 Identification. [Not Discussed by WG]** Materials, systems, and equipment shall be identified in a manner that will allow a determination of compliance with the applicable provisions of this code.

**R303.1.1 Building thermal envelope insulation. [Not Discussed by WG]** An R-value identification mark shall be applied by the manufacturer to each piece of *building thermal envelope* insulation 12 inches (305 mm) or greater in width. Alternately, the insulation installers shall provide a certification listing the type, manufacturer and R-value of insulation installed in each element of the *building thermal envelope*. For blown or sprayed insulation (fiberglass and cellulose), the initial installed thickness, settled thickness, settled R-value, installed density, coverage area and number of bags installed shall be listed on the certification. For sprayed polyurethane foam (SPF) insulation, the installed thickness of the areas covered and R-value of installed thickness shall be listed on the certification. For insulated siding, the R-value shall be labeled on the product's package and shall be listed on the certification. The insulation installer shall sign, date and post the certification in a conspicuous location on the job site.

**R303.1.1.1 Blown or sprayed roof/ceiling insulation. [Not Discussed by WG]** The thickness of blown-in or sprayed roof/ceiling insulation (fiberglass or cellulose) shall be written in inches (mm) on markers that are installed at least one for every 300 square feet (28 $m^2$) throughout the attic space. The markers shall be affixed to the trusses or joists and marked with the minimum initial installed thickness with numbers not 1 inch (25 mm) in height. Each marker shall face the attic access opening. Spray polyurethane foam thickness and installed R-value shall be listed on certification provided by the insulation installer.

**R303.1.2 Insulation mark installation. [Not Discussed by WG]** Insulating materials shall be installed such that the manufacturer's R-value mark is readily observable upon inspection.

**R303.1.3 Fenestration product rating. [Not Discussed by WG]** U-factors of fenestration products (windows, doors and skylights) shall be determined in accordance with NFRC 100.

**Exception:** Where required, garage door U-factors shall be determined in accordance with either NFRC 100 or ANSI/DASMA 105.

U-factors shall be determined by an accredited, independent laboratory, and labeled and certified by the manufacturer.

Products lacking such a labeled U-factor shall be assigned a default U-factor from Table R303.1.3(1) or R303.1.3(2). The solar heat gain coefficient (SHGC) and visible transmittance (VT) of glazed fenestration products (windows, glazed doors and skylights) shall be determined in accordance with NFRC 200 by an accredited, independent laboratory, and labeled and certified by the manufacturer. Products lacking such a labeled SHGC or VT shall be assigned a default SHGC or VT from Table R303.1.3(3).

**TABLE R303.1.3(1) [Included by WG]**
**DEFAULT GLAZED FENESTRATION *U*-FACTORS**

| FRAME TYPE | SINGLE PANE | DOUBLE PANE | SKYLIGHT | |
|---|---|---|---|---|
| | | | Single | Double |
| Metal | 1.20 | 0.80 | 2.00 | 1.30 |
| Metal with Thermal Break | 1.10 | 0.65 | 1.90 | 1.10 |
| Nonmetal or Metal Clad | 0.95 | 0.55 | 1.75 | 1.05 |
| Glazed Block | 0.60 | | | |

**TABLE R303.1.3(2)**
**DEFAULT DOOR *U*-FACTORS [Included by WG]**

| DOOR TYPE | *U*-FACTOR |
|---|---|
| Uninsulated Metal | 1.20 |
| Insulated Metal | 0.60 |
| Wood | 0.50 |
| Insulated, nonmetal edge, max 45% glazing, any glazing double pane | 0.35 |

**R303.1.4 Insulation product rating. [Not Discussed by WG]** The thermal resistance (*R*-value) of insulation shall be determined in accordance with the U.S. Federal Trade Commission *R*-value rule (CFR Title 16, Part 460) in units of $h \cdot ft^2 \cdot °F/Btu$ at a mean temperature of 75°F (24°C).

**R303.1.4.1 Insulated siding. [Not Discussed by WG]** The thermal resistance (*R*-value) of insulated siding shall be determined in accordance with ASTM C 1363. Installation for testing shall be in accordance with the manufacturer's instructions.

**R303.2 Installation. [Not Discussed by WG]** Materials, systems and equipment shall be installed in accordance with the manufacturer's instructions and the *International Building Code* or *International Residential Code*, as applicable.

**R303.2.1 Protection of exposed foundation insulation. [Not Discussed by WG]** Insulation applied to the exterior of basement walls, crawlspace walls and the perimeter of slab-on-grade floors shall have a rigid, opaque and weather-resistant protective covering to prevent the degradation of the insulation's thermal performance. The protective covering shall cover the exposed exterior insulation and extend not less than 6 inches (153 mm) below grade.

**R303.3 Maintenance information. [Not Discussed by WG]** Maintenance instructions shall be furnished for equipment and systems that require preventive maintenance. Required regular maintenance actions shall be clearly stated and incorporated on a readily accessible label. The label shall include the title or publication number for the operation and maintenance manual for that particular model and type of product.

**TABLE R303.1.3(3) [Not Discussed by WG]**
**DEFAULT GLAZED FENESTRATION SHGC AND VT**

| | SINGLE GLAZED | | DOUBLE GLAZED | | GLAZED BLOCK |
|---|---|---|---|---|---|
| | Clear | Tinted | Clear | Tinted | |
| SHGC | 0.8 | 0.7 | 0.7 | 0.6 | 0.6 |
| VT | 0.6 | 0.3 | 0.6 | 0.3 | 0.6 |

# CHAPTER 4 [RE]
# RESIDENTIAL ENERGY EFFICIENCY
## SECTION R401
## GENERAL
**R401.1 Scope. [Not Discussed by WG]** This chapter applies to residential buildings.
**R401.2 Compliance. [Not Discussed by WG]** Projects shall comply with one of the following:
1. Sections R401 through R404.
2. **[Deleted – Term Sheet Supersedes]**
3. **[Deleted – Term Sheet Supersedes]**

**R401.2.1 Tropical zone. [Deleted – Term Sheet Supersedes]**

**R401.3 Certificate (Mandatory). [Revised by WG]** Refer to the HUD code requirements for data plate/compliance certificates.

## SECTION R402
## BUILDING THERMAL ENVELOPE
**R402.1 General (Prescriptive). [Not Discussed by WG]** The *building thermal envelope* shall meet the requirements of Sections R402.1.1 through R402.1.5.

**Exception:** The following low-energy buildings, or portions thereof, separated from the remainder of the building by *building thermal envelope* assemblies complying with this section shall be exempt from the *building thermal envelope* provisions of Section R402.

1. Those with a peak design rate of energy usage less than 3.4 Btu/h・$ft^2$ (10.7 W/$m^2$) or 1.0 watt/$ft^2$ of floor area for space-conditioning purposes.
2. Those that do not contain *conditioned space*.

**R402.1.1 Vapor retarder. [Not Discussed by WG]** Wall assemblies in the *building thermal envelope* shall comply with the vapor retarder requirements of Section R702.7 of the *International Residential Code* or Section 1405.3 of the *International Building Code,* as applicable.

**R402.1.2 Insulation and fenestration criteria. [Not Discussed by WG]** The *building thermal envelope* shall meet the requirements of Table R402.1.2, based on the climate zone specified in Chapter 3.

**R402.1.3 *R*-value computation. [Not Discussed by WG]** Insulation material used in layers, such as framing cavity insulation, or continuous insulation shall be summed to compute the corresponding component *R*-value. The manufacturer's settled *R*-value shall be used for blown insulation. Computed *R*-values shall not include an *R*-value for other building materials or air films. Where insulated siding is used for the purpose of complying with the continuous insulation requirements of Table R402.1.2, the manufacturer's labeled *R*-value for insulated siding shall be reduced by R-0.6.

**R402.1.4 *U*-factor alternative. [Revised by WG]** An assembly with a U-factor equal to or less than that specified in the equivalent U-Factor table shall be permitted as an alternative to the R-value in the prescriptive table. The U-factor calculation shall be done using a method consistent with the ASHRAE handbook of fundamentals and shall include the thermal bridging effects of framing materials.

**R402.1.5 Total UA alternative. [Deleted – Term Sheet Supersedes]**

**R402.2 Specific insulation requirements (Prescriptive). [Not Discussed by WG]** In addition to the requirements of Section R402.1, insulation shall meet the specific requirements of Sections R402.2.1 through R402.2.13.

**R402.2.1 Ceilings with attic spaces. [Deleted – Term Sheet Supersedes]**

**TABLE R402.1.2**
**INSULATION AND FENESTRATION REQUIREMENTS BY COMPONENT[a] [Deleted – Term Sheet Supersedes]**

**TABLE R402.1.4**
**EQUIVALENT *U*-FACTORS[a] [Deleted – Term Sheet Supersedes]**

**R402.2.2 Ceilings without attic spaces. [Deleted by WG]**

**R402.2.3 Eave baffle. [Included by WG]** For air-permeable insulations in vented attics, a baffle shall be installed adjacent to soffit and eave vents. Baffles shall maintain an opening equal or greater than the size of the vent. The baffle shall extend over the top of the attic insulation. The baffle shall be permitted to be any solid material.

**R402.2.4 Access hatches and doors. [Revised by WG]** Access doors from conditioned spaces to unconditioned spaces such as attics and crawl spaces shall be weatherstripped and insulated to a level equivalent to the insulation on the surrounding surfaces. Access shall be provided to all equipment that prevents damaging or compressing the insulation. A woodframed or equivalent baffle or retainer is required to be provided when loose-fill insulation is installed, the purpose of which is to prevent the loose-fill insulation from spilling into the living space when the attic access is opened, and to provide a permanent means of maintaining the installed *R*-value of the loose-fill insulation.

**R402.2.5 Mass walls. [Deleted by WG]**

**R402.2.6 Steel-frame ceilings, walls and floors. [Deleted by WG]**

**R402.2.7 Walls with partial structural sheathing. [Deleted by WG]**

**R402.2.8 Floors. [Not Discussed by WG]** Floor framing-cavity insulation shall be installed to maintain permanent contact with the underside of the subfloor decking.

> **Exception:** The floor framing-cavity insulation shall be permitted to be in contact with the topside of sheathing or continuous insulation installed on the bottom side of floor framing where combined with insulation that meets or exceeds the minimum wood frame wall *R*-value in Table 402.1.2 and that extends from the bottom to the top of all perimeter floor framing members.

**R402.2.9 Basement walls. [Not Discussed by WG]** Walls associated with conditioned basements shall be insulated from the top of the *basement wall* down to 10 feet (3048 mm) below grade or to the basement floor, whichever is less. Walls associated with unconditioned basements shall meet this requirement unless the floor overhead is insulated in accordance with Sections R402.1.2 and R402.2.8.

**R402.2.10 Slab-on-grade floors. [Not Discussed by WG]** Slab-on-grade floors with a floor surface less than 12 inches (305 mm) below grade shall be insulated in accordance with Table R402.1.2. The insulation shall extend downward from the top of the slab on the outside or inside of the foundation wall. Insulation located below grade shall be extended the distance provided in Table R402.1.2 by any combination of vertical insulation, insulation extending under the slab or insulation extending out from the building. Insulation extending away from the building shall be protected by pavement or by not less than 10 inches (254 mm) of soil. The top edge of the insulation installed between the *exterior wall* and the edge of the interior slab shall be permitted to be cut at a 45-degree (0.79 rad) angle away from the *exterior wall.* Slab-edge insulation is not required in jurisdictions designated by the *code official* as having a very heavy termite infestation.

**R402.2.11 Crawl space walls. [Not Discussed by WG]** As an alternative to insulating floors over crawl spaces, crawl space walls shall be permitted to be insulated when the crawl space is not vented to the outside. Crawl space wall insulation shall be permanently fastened to the wall and extend downward from the floor to the finished grade level and then vertically and/or horizontally for at least an additional 24 inches (610 mm). Exposed earth in unvented crawl space foundations shall be covered with a continuous Class I vapor retarder in accordance with the *International Building Code* or *International Residential Code*, as applicable. All joints of the vapor retarder shall overlap by 6 inches
(153 mm) and be sealed or taped. The edges of the vapor retarder shall extend not less than 6 inches (153 mm) up the stem wall and shall be attached to the stem wall.

**R402.2.12 Masonry veneer. [Not Discussed by WG]** Insulation shall not be required on the horizontal portion of the foundation that supports a masonry veneer.

**R402.2.13 Sunroom insulation. [Not Discussed by WG]** *Sunrooms* enclosing conditioned space shall meet the insulation requirements of this code.

> **Exception:** For *sunrooms* with *thermal isolation*, and enclosing conditioned space, the following exceptions to the insulation requirements of this code shall apply:
>
> 1. The minimum ceiling insulation *R*-values shall be R-19 in *Climate Zones* 1 through 4 and R-24 in *Climate Zones* 5 through 8.
> 2. The minimum wall *R*-value shall be R-13 in all *climate zones*. Walls separating a *sunroom* with a *thermal isolation* from *conditioned space* shall meet the *building thermal envelope* requirements of this code.

**R402.3 Fenestration (Prescriptive). [Not Discussed by WG]** In addition to the requirements of Section R402, fenestration shall comply with Sections R402.3.1 through R402.3.6.

**R402.3.1 *U*-factor. [Deleted – Term Sheet Supersedes]**

**R402.3.2 Glazed fenestration SHGC. [Deleted – Term Sheet Supersedes]**

**R402.3.3 Glazed fenestration exemption. [Deleted – Term Sheet Supersedes]**

**R402.3.4 Opaque door exemption. [Not Discussed by WG]** One side-hinged opaque door assembly up to 24 square feet (2.22 $m^2$) in area is exempted from the *U*-factor requirement in Section R402.1.4. This exemption shall not apply to the *U*-factor alternative approach in Section R402.1.4 and the total UA alternative in Section R402.1.5.

**R402.3.5 Sunroom fenestration. [Not Discussed by WG]** *Sunrooms* enclosing *conditioned space* shall meet the fenestration requirements of this code.

> **Exception:** For *sunrooms* with *thermal isolation* and enclosing *conditioned space* in *Climate Zones* 2 through 8, the maximum fenestration *U*-factor shall be 0.45 and the maximum skylight *U*-factor shall

be 0.70. New fenestration separating the *sunroom* with *thermal isolation* from *conditioned space* shall meet the *building thermal envelope* requirements of this code.

**R402.4 Air leakage (Mandatory). [Not Discussed by WG]** The *building thermal envelope* shall be constructed to limit air leakage in accordance with the requirements of Sections R402.4.1 through R402.4.4.

**R402.4.1 Building thermal envelope. [Revised by WG]** The *building thermal envelope* shall comply with Sections R402.4.1.1. The sealing methods between dissimilar materials shall allow for differential expansion and contraction.

**R402.4.1.1 Installation. [Revised by WG]** The components of the *building thermal envelope* as listed in Table R402.4.1.1 shall be installed in accordance with the manufacturer's instructions and the criteria listed in Table R402.4.1.1, as applicable to the method of construction.

**R402.4.1.2 Testing. [Deleted by WG]**

**R402.4.2 Fireplaces. [Revised by WG]** Where using tight-fitting doors on masonry fireplaces, the doors shall be listed and labeled in accordance with UL 907.

**R402.4.3 Fenestration Air Leakage. [Deleted by WG]**

**R402.4.4 Rooms containing fuel-burning appliances. [Deferred to DOE by WG]** In Climate Zones 3 through 8, where open combustion air ducts provide combustion air to open combustion fuel burning appliances, the appliances and combustion air opening shall be located outside the building thermal envelope or enclosed in a room, isolated from inside the thermal envelope. Such rooms shall be sealed and insulated in accordance with the envelope requirements of
Table R402.1.2, where the walls, floors and ceilings shall meet not less than the basement wall *R*-value requirement.

The door into the room shall be fully gasketed and any water lines and ducts in the room insulated in accordance with Section R403. The combustion air duct shall be insulated where it passes through conditioned space to a minimum of R-8.

**Exceptions**:

1. Direct vent appliances with both intake and exhaust pipes installed continuous to the outside.
2. Fireplaces and stoves complying with Section R402.4.2 and Section R1006 of the *International Residential Code*.

**R402.4.5 Recessed lighting. [Not Discussed by WG]** Recessed luminaires installed in the *building thermal envelope* shall be sealed to limit air leakage between conditioned and unconditioned spaces. All recessed luminaires shall be IC-rated and *labeled* as having an air leakage rate not more than 2.0 cfm (0.944 L/s) when tested in accordance with ASTM E 283 at a 1.57 psf (75 Pa) pressure differential. All recessed luminaires shall be sealed with a gasket or caulk between the housing and the interior wall or ceiling covering.

**R402.5 Maximum fenestration *U*-factor and SHGC (Mandatory). [Included in Concept by WG]** The area-weighted average maximum fenestration *U*-factor permitted using tradeoffs from Section [Total UA/REScheck option] or [Uo option] shall be 0.40 in HUD Climate Zones 2 through 3 . The area-weighted average maximum fenestration SHGC permitted using tradeoffs from Section [Total UA/REScheck option] or [Uo option] in HUD Climate Zones 1 through 2 shall be 0.40.

## TABLE R402.4.1.1
## AIR BARRIER AND INSULATION INSTALLATION

| COMPONENT | AIR BARRIER CRITERIA | INSULATION INSTALLATION CRITERIA |
|---|---|---|
| General requirements | A continuous air barrier shall be installed in the building envelope.<br>The exterior thermal envelope contains a continuous air barrier.<br>Breaks or joints in the air barrier shall be sealed. [Included by WG] | Air-permeable insulation shall not be used as a sealing material. [Included by WG] |
| Ceiling/attic | The air barrier in any dropped ceiling/soffit shall be aligned with the insulation and any gaps in the air barrier shall be sealed.<br>Access openings, drop down stairs or knee wall doors to unconditioned attic spaces shall be sealed. [Included by WG] | The insulation in any dropped ceiling/soffit shall be aligned with the air barrier. [Included by WG] |
| Walls | The junction of the top plate and the ceiling along exterior walls shall be sealed.<br>The junction of the bottom plate and the floor along exterior walls shall be sealed. [Revised by WG] | *Air permeable exterior thermal envelope insulation for framed walls shall completely fill the cavity, including within stud bays caused by blocking lay flats or headers*. [Revised by WG] |
| Windows, skylights and doors | The space between window/door jambs and framing, and skylights and framing shall be sealed. [Included by WG] | |
| Rim joists | Rim joists shall include the air barrier. [Included by WG] | Rim joists shall be insulated. [Included by WG] |
| Floors [Revised by WG] | The air barrier shall be installed at any exposed edge of insulation. The bottom board may serve as the air barrier. [Revised by WG] | [Deleted by WG] |
| [Deleted by WG] Crawl space walls | [Deleted by WG] | [Deleted by WG] |
| Shafts, penetrations | Duct shafts, utility penetrations, and flue shafts that penetrate the air barrier shall be sealed. [Revised by WG] | |
| Narrow cavities | | Batts in narrow cavities shall be cut to fit, or narrow cavities shall be filled by insulation that on installation readily conforms to the available cavity space. [Included by WG] |
| Garage Separation [Deleted by WG] | [Deleted by WG] | |
| Recessed lighting | Recessed light fixtures installed in the building thermal envelope shall be sealed to the drywall. [Included by WG] | Recessed light fixtures installed in the building thermal envelope shall be air tight and IC rated. [Included by WG] |
| Plumbing and Wiring [Deleted by WG] | | [Deleted by WG] |
| Shower/tub on exterior wall | The air barrier installed at exterior walls adjacent to showers and tubs shall separate them from the showers and tubs. [Included by WG] | Exterior walls adjacent to showers and tubs shall be insulated. [Included by WG] |
| Electrical/phone box on exterior walls | The air barrier shall be installed behind electrical or communication boxes or the air barrier shall be sealed around the box penetration. [Revised by WG] | |
| HVAC register boots | HVAC register boots that penetrate building thermal envelope shall be sealed to the subfloor or drywall. [Included by WG] | |
| Concealed sprinklers [Deleted by WG] | [Deleted by WG] | |

## SECTION R403
## SYSTEMS

**R403.1 Controls (Mandatory). [Included by WG]** At least one thermostat shall be provided for each separate heating and cooling system.

**R403.1.1 Programmable thermostat. [Included by WG]**The thermostat controlling the primary heating or cooling system of the dwelling unit shall be capable of controlling the heating and cooling system on a daily schedule to maintain different temperature set points at different times of the day. This thermostat shall include the capability to set back or temporarily operate the system to maintain *zone* temperatures down to 55°F (13°C) or up to 85°F (29°C). The thermostat shall initially be programmed by the manufacturer with a heating temperature set point no higher than 70°F (21°C) and a cooling temperature set point no lower than 78°F (26°C).

**R403.1.2 Heat pump supplementary heat (Mandatory). [Included by WG]** Heat pumps having supplementary electric-resistance heat shall have controls that, except during defrost, prevent supplemental heat operation when the heat pump compressor can meet the heating load.

**R403.2 Hot water boiler outdoor temperature setback. [Not Discussed by WG]** Hot water boilers that supply heat to the building through one- or two-pipe heating systems shall have an outdoor setback control that lowers the boiler water temperature based on the outdoor temperature.

**R403.3 Ducts. [Not Discussed by WG]** Ducts and air handlers shall be in accordance with Sections R403.3.1 through R403.3.5.

**R403.3.1 Insulation (Prescriptive). [Not Discussed by WG]** Supply and return ducts in attics shall be insulated to a minimum of R-8 where 3 inches (76 mm) in diameter and greater and R-6 where less than 3 inches (76 mm) in diameter. Supply and return ducts in other portions of the building shall be insulated to a minimum of R-6 where 3 inches (76 mm) in
diameter or greater and R-4.2 where less than 3 inches (76 mm) in diameter.

**Exception:** Ducts or portions thereof located completely inside the *building thermal envelope.*

**R403.3.2 Sealing (Mandatory). [Not Discussed by WG]** Ducts, air handlers and filter boxes shall be sealed. Joints and seams shall comply
with either the *International Mechanical Code* or *International Residential Code*, as applicable.

**Exceptions:**

1. Air-impermeable spray foam products shall be permitted to be applied without additional joint seals.
2. For ducts having a static pressure classification of less than 2 inches of water column (500 Pa), additional closure systems shall not be required for continuously welded joints and seams, and locking-type joints and seams of other than the snap-lock and button-lock types.

**R403.3.2.1 Sealed air handler. [Not Discussed by WG]** Air handlers shall have a manufacturer's designation for an air leakage of no more than 2 percent of the design air flow rate when tested in accordance with ASHRAE 193.

**R403.3.3 Duct testing (Mandatory). [Deleted – Term Sheet Supersedes]**

**R403.3.4 Duct leakage (Prescriptive). [Deleted – Term Sheet Supersedes]**

**R403.3.5 Building cavities (Mandatory). [Included by WG]** Building framing cavities shall not be used as ducts or plenums.

**R403.4 Mechanical system piping insulation (Mandatory). [Deleted – Term Sheet Supersedes]**

**R403.4.1 Protection of piping insulation. [Not Discussed by WG]** Piping insulation exposed to weather shall be protected from damage, including that caused by sunlight, moisture, equipment maintenance and wind, and shall provide shielding from solar radiation that can cause degradation of the material. Adhesive tape shall not be permitted.

**R403.5 Service hot water systems. [Not Discussed by WG]** Energy conservation measures for service hot water systems shall be in accordance with Sections R403.5.1 and R403.5.4.

**R403.5.1 Heated water circulation and temperature maintenance systems (Mandatory). [Included by WG]** Heated water circulation systems shall be in accordance with Section R403.5.1.1. Heat trace temperature maintenance systems shall be in accordance with Section R403.5.1.2. Automatic controls, temperature sensors and pumps shall be accessible. Manual controls shall be readily accessible.

**R403.5.1.1 Circulation systems. [Included by WG]** Heated water circulation systems shall be provided with a circulation pump. The system return pipe shall be a dedicated return pipe or a cold water supply pipe. Gravity and thermosyphon circulation systems shall be prohibited. Controls for circulating hot water system pumps shall start the pump based on the identification of a demand for hot water within the occupancy. The controls shall automatically turn off the pump when the water in the circulation loop is at the desired temperature and when there is no demand for hot water.

**R403.5.1.2 Heat trace systems. [Included by WG]** Electric heat trace systems shall comply with IEEE 515.1 or UL 515. Controls for such systems shall automatically adjust the energy input to the heat tracing to maintain the desired water temperature in the piping in accordance with the times when heated water is used in the occupancy.

**R403.5.2 Demand recirculation systems. [Not Discussed by WG]** A water distribution system having one or more recirculation pumps that pump water from a heated water supply pipe back to the heated water source through a cold water supply pipe shall be a *demand recirculation water system*. Pumps shall have controls that comply with both of the following:

1. The control shall start the pump upon receiving a signal from the action of a user of a fixture or appliance, sensing the presence of a user of a fixture or sensing the flow of hot or tempered water to a fixture fitting or appliance.
2. The control shall limit the temperature of the water entering the cold water piping to 104ºF (40ºC).

**R403.5.3 Hot water pipe insulation (Prescriptive). [Deleted – Term Sheet Supersedes]**

**R403.5.4 Drain water heat recovery units. [Not Discussed by WG]** Drain water heat recovery units shall comply with CSA B55.2. Drain water heat recovery units shall be tested in accordance with CSA B55.1. Potable water-side pressure loss of drain water heat recovery units shall be less than 3 psi (20.7 kPa) for individual units connected to one or two showers. Potable water-side pressure loss of drain water heat recovery units shall be less than 2 psi (13.8 kPa) for individual units connected to three or more showers.

**R403.6 Mechanical Ventilation (Mandatory) [Revised by WG]** The building shall be provided with ventilation that meets the requirements of the 24 CFR Part 3280 Manufactured Home Construction and Safety Standards. Whole-house mechanical ventilation system fan efficacy shall meet the efficacy requirements of Table R403.6.1.

**Exception:** Where mechanical ventilation fans are integral to tested and listed HVAC equipment, they shall be powered by an electronically commutated motor.

**R403.6.1 Whole-house mechanical ventilation system fan efficacy. [Deleted by WG]**

**R403.7 Equipment sizing and efficiency rating (Mandatory). [Revised by WG]** Heating and cooling equipment shall be sized in accordance with ACCA Manual S based on building loads calculated in accordance with ACCA Manual J or other DOE approved heating and cooling calculation methodologies.

**R403.8 Systems serving multiple dwelling units (Mandatory). [Deleted by WG]**

**R403.9 Snow melt and ice system controls (Mandatory). [Deleted by WG]**

## TABLE R403.6.1 [Included by WG]
## MECHANICAL VENTILATION SYSTEM FAN EFFICACY

| FAN LOCATION | AIR FLOW RATE MINIMUM (CFM) | MINIMUM EFFICACY (CFM/WATT) | AIR FLOW RATE MAXIMUM (CFM) |
|---|---|---|---|
| Range hoods | Any | 2.8 | Any |
| In-line fan | Any | 2.8 | Any |
| bathroom, utility room | 10 | 1.4 | <90 |
| bathroom utility room | 90 | 2.8 | Any |

For SI: 1 cfm = 28.3 L/min.

**R403.10 Pools and permanent spa energy consumption (Mandatory). [Deleted by WG]**

**R403.10.1 Residential pools and permanent residential spas. [Deleted by WG]**

**R403.10.2 Heaters. [Deleted by WG]**

**R403.10.3 Time switches. [Deleted by WG]**

**R403.10.4 Covers. [Deleted by WG]**

**R403.11 Portable spas (Mandatory). [Deleted by WG]**

**R403.12 Residential pools and permanent residential spas. [Not Discussed by WG]** Residential swimming pools and permanent residential spas that are accessory to detached one- and two-family dwellings and townhouses three stories or less in height above grade plane and that are available only to the household and its guests shall be in accordance with APSP-15.

## SECTION R404
## ELECTRICAL POWER AND LIGHTING SYSTEMS

**R404.1 Lighting equipment (Mandatory). [Included by WG]** Not less than 75 percent of the lamps in permanently installed lighting fixtures shall be high-efficacy lamps or not less than 75 percent of the permanently installed lighting fixtures shall contain only high-efficacy lamps.

**Exception:** Low-voltage lighting.

**R404.1.1 Lighting equipment (Mandatory). [Not Discussed by WG]** Fuel gas lighting systems shall not have continuously burning pilot lights.

**SECTION R405 [Deleted – Term Sheet Supersedes]**

**SECTION R406 [Deleted – Term Sheet Supersedes]**

## CHAPTER 5 (RE)
## EXISTING BUILDINGS
## [Not Discussed by WG]
## SECTION R501
## GENERAL

**R501.1 Scope. [Not Discussed by WG]** The provisions of this chapter shall control the *alteration*, repair, addition and change of occupancy of existing buildings and structures.

**R501.1.1 Additions, alterations, or repairs: General. [Not Discussed by WG]** Additions, alterations, or repairs to an existing building, building system or portion thereof shall comply with Section R502, R503 or R504. Unaltered portions of the existing building or building supply system shall not be required to comply with this code.

**R501.2 Existing buildings. [Not Discussed by WG]** Except as specified in this chapter, this code shall not be used to require the removal, *alteration* or abandonment of, nor prevent the continued use and maintenance of, an existing building or building system lawfully in existence at the time of adoption of this code.

**R501.3 Maintenance. [Not Discussed by WG]** Buildings and structures, and parts thereof, shall be maintained in a safe and sanitary condition. Devices and systems that are required by this code shall be maintained in conformance to the code edition under which installed. The owner or the owner's authorized agent shall be responsible for the maintenance of buildings and structures. The requirements of this chapter shall not provide the basis for removal or abrogation of energy conservation, fire protection and safety systems and devices in existing structures.

**R501.4 Compliance. [Not Discussed by WG]** *Alterations*, *repairs*, *additions* and changes of occupancy to, or relocation of, existing buildings and structures shall comply with the provisions for *alterations*, *repairs*, *additions* and changes of occupancy or relocation, respectively, in the *International Residential Code*, *International Building Code*, *International Fire Code*, *International Fuel Gas Code*, *International Mechanical Code*, *International Plumbing Code*, *International Property Maintenance Code*, *International Private Sewage Disposal Code* and NFPA 70.

**R501.5 New and replacement materials. [Not Discussed by WG]** Except as otherwise required or permitted by this code, materials permitted by the applicable code for new construction shall be used. Like materials shall be permitted for repairs, provided hazards to life, health or property are not created. Hazardous materials shall not be used where the code for new construction would not permit their use in buildings of similar occupancy, purpose and location.

**R501.6 Historic buildings. [Not Discussed by WG]** No provision of this code relating to the construction, *repair, alteration,* restoration and movement of structures, and *change of occupancy* shall be mandatory for *historic buildings* provided a report has been submitted to the code official and signed by the owner, a registered *design professional*, or a representative of the State Historic Preservation Office or the historic preservation authority having jurisdiction, demonstrating that compliance with that provision would threaten, degrade or destroy the historic form, fabric or function of the *building*.

## SECTION R502

## ADDITIONS

**R502.1 General. [Not Discussed by WG]** Additions to an existing building, building system or portion thereof shall conform to the provisions of this code as those provisions relate to new construction without requiring the unaltered portion of the existing building or building system to comply with this code. Additions shall not create an unsafe or hazardous condition or overload existing building systems. An addition shall be deemed to comply with this code where the addition alone complies, where the existing building and addition comply with this code as a single building, or where the building with the addition uses no more energy than the existing building. Additions shall be in accordance with Section R502.1.1 or R502.1.2.

**R502.1.1 Prescriptive compliance. [Not Discussed by WG]** Additions shall comply with Sections R502.1.1.1 through R502.1.1.4.

**R502.1.1.1 Building envelope. [Not Discussed by WG]** New building envelope assemblies that are part of the addition shall comply with Sections R402.1, R402.2, R402.3.1 through R402.3.5, and R402.4.

**Exception:** Where nonconditioned space is changed to conditioned space, the building envelope of the addition shall comply where the UA, as determined in Section 402.1.4, of the existing building and the addition, and any alterations that are part of the project, is less than or equal to UA generated for the existing building.

**R502.1.1.2 Heating and cooling systems. [Not Discussed by WG]** New heating, cooling and duct systems that are part of the addition shall comply with Sections R403.1, R403.2, R403.3, R403.5 and R403.6.

**Exception:** Where ducts from an existing heating and cooling system are extended to an addition, duct systems with less than 40 linear feet (12.19 m) in unconditioned spaces shall not be required to be tested in accordance with Section R403.3.3.

**R502.1.1.3 Service hot water systems. [Not Discussed by WG]** New service hot water systems that are part of the addition shall comply with Section R403.4.

**R502.1.1.4 Lighting. [Not Discussed by WG]** New lighting systems that are part of the addition shall comply with Section R404.1.

**R502.1.2 Existing plus addition compliance (Simulated Performance Alternative). [Not Discussed by WG]** Where nonconditioned space is changed to conditioned space, the addition shall comply where the annual energy cost or energy use of the addition and the existing building, and any alterations that are part of the project, is less than or equal to the annual energy cost of the existing building when modeled in accordance with Section R405. The addition and any alterations that are part of the project shall comply with Section R405 in its entirety.

## SECTION R503
## ALTERATIONS

**R503.1 General. [Not Discussed by WG]** *Alterations* to any building or structure shall comply with the requirements of the code for new construction. *Alterations* shall be such that the existing building or structure is no less conforming to the provisions of this code than the existing building or structure was prior to the *alteration*. Alterations to an existing building, building system or portion thereof shall conform to the provisions of this code as they relate to new construction without requiring the unaltered portions of the existing building or building system to comply with this code. Alterations shall not create an unsafe or hazardous condition or overload existing building systems. *Alterations* shall be such that the existing building or structure uses no more energy than the existing building or structure prior to the *alteration*. Alterations to existing buildings shall comply with Sections R503.1.1 through R503.2.

**R503.1.1 Building envelope. [Not Discussed by WG]** Building envelope assemblies that are part of the alteration shall comply with Section R402.1.2 or R402.1.4, Sections R402.2.1 through R402.2.12, R402.3.1, R402.3.2, R402.4.3 and R402.4.4.

**Exception:** The following alterations need not comply with the requirements for new construction provided the energy use of the building is not increased:

1. Storm windows installed over existing fenestration.
2. Existing ceiling, wall or floor cavities exposed during construction provided that these cavities are filled with insulation.
3. Construction where the existing roof, wall or floor cavity is not exposed.
4. Roof recover.

5. Roofs without insulation in the cavity and where the sheathing or insulation is exposed during reroofing shall be insulated either above or below the sheathing.
6. Surface-applied window film installed on existing single pane fenestration assemblies to reduce solar heat gain provided the code does not require the glazing or fenestration assembly to be replaced.

**R503.1.1.1 Replacement fenestration. [Not Discussed by WG]** Where some or all of an existing fenestration unit is replaced with a new fenestration product, including sash and glazing, the replacement fenestration unit shall meet the applicable requirements for *U*-factor and SHGC as provided in Table R402.1.4.

**R503.1.2 Heating and cooling systems. [Not Discussed by WG]** New heating, cooling and duct systems that are part of the alteration shall comply with Sections R403.1, R403.2, R403.3 and R403.6.

**Exception:** Where ducts from an existing heating and cooling system are extended, duct systems with less than 40 linear feet (12.19 m) in unconditioned spaces shall not be required to be tested in accordance with Section R403.3.3.

**R503.1.3 Service hot water systems. [Not Discussed by WG]** New service hot water systems that are part of the alteration shall comply with Section R403.4.

**R503.1.4 Lighting. [Not Discussed by WG]** New lighting systems that are part of the alteration shall comply with Section 404.1.

**Exception:** Alterations that replace less than 50 percent of the luminaires in a space, provided that such alterations do not increase the installed interior lighting power.

**R503.2 Change in space conditioning. [Not Discussed by WG]** Any nonconditioned or low-energy space that is altered to become *conditioned space* shall be required to be brought into full compliance with this code.

**Exception:** Where the simulated performance option in Section R405 is used to comply with this section, the annual energy cost of the proposed design is permitted to be 110 percent of the annual energy cost otherwise allowed by Section R405.3.

## SECTION R504
## REPAIRS

**R504.1 General. [Not Discussed by WG]** Buildings, structures and parts thereof shall be repaired in compliance with Section R501.3 and this section. Work on nondamaged components necessary for the required *repair* of damaged components shall be considered part of the *repair* and shall not be subject to the requirements for *alterations* in this chapter. Routine maintenance required by Section R501.3, ordinary repairs exempt from *permit*, and abatement of wear due to normal service conditions shall not be subject to the requirements for *repairs* in this section.

**R504.2 Application. [Not Discussed by WG]** For the purposes of this code, the following shall be considered repairs:

1. Glass-only replacements in an existing sash and frame.
2. Roof repairs.
3. Repairs where only the bulb and/or ballast within the existing luminaires in a space are replaced provided that the replacement does not increase the installed interior lighting power.

## SECTION R505
## CHANGE OF OCCUPANCY OR USE

**R505.1 General. [Not Discussed by WG]** Spaces undergoing a change in occupancy that would result in an increase in demand for either fossil fuel or electrical energy shall comply with this code.

**R505.2 General. [Not Discussed by WG]** Any space that is converted to a dwelling unit or portion thereof from another use or occupancy shall comply with this code.

**Exception:** Where the simulated performance option in Section R405 is used to comply with this section, the annual energy cost of the proposed design is permitted to be 110 percent of the annual energy cost otherwise allowed by Section R405.3.

# CHAPTER 6
# REFERENCED STANDARDS
## [Not Discussed by WG]

This chapter lists the standards that are referenced in various sections of this document. The standards are listed herein by the promulgating agency of the standard, the standard identification, the effective date and title, and the section or sections of this document that reference the standard. The application of the referenced standards shall be as specified in Section 106.

## AAMA

American Architectural Manufacturers Association
1827 Walden Office Square
Suite 550
Schaumburg, IL 60173-4268

| Standard reference number | Title | Referenced in code section number |
|---|---|---|
| AAMA/WDMA/CSA 101/I.S.2/A C440—11 | North American Fenestration Standard/Specifications for Windows, Doors, and Unit Skylights | R402.4.3 |

## ACCA

Air Conditioning Contractors of America
2800 Shirlington Road, Suite 300
Arlington, VA 22206

| Standard reference number | Title | Referenced in code section number |
|---|---|---|
| Manual J—2011 | Residential Load Calculation Eighth Edition | R403.7 |
| Manual S—13 | Residential Equipment Selection | R403.7 |

## APSP

The Association of Pool and Spa Professionals
2111 Eisenhower Avenue
Alexandria, VA 22314

| Standard reference number | Title | Referenced in code section number |
|---|---|---|
| APSP 14—11 | American National Standard for Portable Electric Spa Energy Efficiency | R403.10.1,403.11 |
| APSP 15a—2013 | American National Standard for Residential Swimming Pool and Spa Energy Efficiency | R403.12 |

## ASHRAE

American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc.
1791 Tullie Circle, NE
Atlanta, GA 30329-2305

| Standard reference number | Title | Referenced in code section number |
|---|---|---|
| ASHRAE—2013 | ASHRAE Handbook of Fundamentals | R402.1.5, Table R405.5.2(1) |
| ASHRAE 193—2010 | Method of Test for Determining the Airtightness of HVAC Equipment | R403.3.2.1 |

# ASTM

ASTM International
100 Barr Harbor Drive
West Conshohocken, PA 19428-2859

| Standard reference number | Title | Referenced in code section number |
|---|---|---|
| C 1363—11 | Standard Test Method for Thermal Performance of Building Materials and Envelope Assemblies by Means of a Hot Box Apparatus | R303.1.4.1 |
| E 283—04 | Test Method for Determining the Rate of Air Leakage Through Exterior Windows, Curtain Walls and Doors Under Specified Pressure Differences Across the Specimen | R402.4.4 |
| E 779—10 | Standard Test Method for Determining Air Leakage Rate by Fan Pressurization | R402.4.1.2 |
| E 1827—11 | Standard Test Methods for Determining Airtightness of Building Using an Orifice Blower Door | R402.4.1.2 |

# CSA

CSA Group
8501 East Pleasant Valley
Cleveland, OH 44131-5575

| Standard reference number | Title | Referenced in code section number |
|---|---|---|
| AAMA/WDMA/CSA 101/I.S.2/A440—11 | North American Fenestration Standard/Specification for Windows, Doors and Unit Skylights | R402.4.3 |
| CSA 55.1—2012 | Test Method for measuring efficiency and pressure loss of drain water heat recovery units | R403.5.4 |
| CSA 55.2—2012 | Drain water heat recover units | R403.5.4 |

# DASMA

Door and Access Systems Manufacturers Association
1300 Sumner Avenue
Cleveland, OH 44115-2851

| Standard reference number | Title | Referenced in code section number |
|---|---|---|
| 105—92(R2004)—13 | Test Method for Thermal Transmittance and Air Infiltration of Garage Doors | R303.1.3 |

## ICC

International Code Council, Inc.
500 New Jersey Avenue, NW
6th Floor
Washington, DC 20001

| Standard reference number | Title | Referenced in code section number |
|---|---|---|
| IBC—15 | International Building Code® | R201.3, R303.2, R402.1.1, R501.4 |
| ICC 400—12 | Standard on the Design and Construction of Log Structures | Table R402.5.1.1 |
| IECC—15 | International Energy Conservation Code® | R101.4.1, 403.8 |
| IECC—09 | 2009 International Energy Conservation Code® | R406.2 |
| ECC—06 | 2006 International Energy Conservation Code® | R202, R406.3.1 |
| IFC—15 | International Fire Code® | R201.3, R501.4 |
| IFGC—15 | International Fuel Gas Code® | R201.3, R501.4 |
| IMC—15 | International Mechanical Code® | R201.3, R403.3.2, R403.6, R501.4 |
| IPC—15 | International Plumbing Code® | R201.3, R501.4 |
| IPSDC—15 | International Private Sewage Disposal Code® | R501.4 |
| IPMC—15 | International Property Maintenance Code® | R501.4 |
| IRC—15 | International Residential Code® | R201.3, R303.2, R402.1.1, R402.2.11, R403.3.2, R403.6, R501.4 |

## IEEE

The Institute of Electrical and Electronic Engineers, Inc.
3 Park Avenue
New York, NY 1016-5997

| Standard reference number | Title | Referenced in code section number |
|---|---|---|
| 515.1—2012 | IEEE Standard for the Testing, Design, Installation, and Maintenance of Electrical Resistance Trace Heating for Commercial Applications | R403.5.1.2 |

## NFPA

National Fire Protection Association
1 Battermarch Park
Quincy, MA 02169-7471

| Standard reference number | Title | Referenced in code section number |
|---|---|---|
| 70—14 | National Electrical Code | R501.4 |

## NFRC

National Fenestration Rating Council, Inc.
6305 Ivy Lane, Suite 140
Greenbelt, MD 20770

| Standard reference number | Title | Referenced in code section number |
|---|---|---|
| 100—2009 | Procedure for Determining Fenestration Products *U*-factors—Second Edition | R303.1.3 |
| 200—2009 | Procedure for Determining Fenestration Product Solar Heat Gain Coefficients and Visible Transmittance at Normal Incidence—Second Edition | R303.1.3 |
| 400—2009 | Procedure for Determining Fenestration Product Air Leakage—Second Edition | R402.4.3 |

## UL

UL LLC
333 Pfingsten Road
Northbrook, IL 60062

| Standard reference number | Title | Referenced in code section number |
|---|---|---|
| 127—11 | Standard for Factory Built Fireplaces | R402.4.2 |
| 515—11 | Electrical Resistance Heat Tracing for Commercial and Industrial Applications including revisions through November 30, 2011 | R403.5.1.2 |

## US-FTC

United States-Federal Trade Commission
600 Pennsylvania Avenue NW
Washington, DC 20580

| Standard reference number | Title | Referenced in code section number |
|---|---|---|
| CFR Title 16 (May 31, 2005) | R-value Rule | R303.1.4 |

## WDMA

Window and Door Manufacturers Association
2025 M street, NW Suite 800
Washington, DC 20036-3309

| Standard reference number | Title | Referenced in code section number |
|---|---|---|
| AAMA/WDMA/CSA 101/I.S.2/A440—11 | North American Fenestration Standard/Specification for Windows, Doors and Unit Skylights | R402.4.3 |

# Technical Support Document
# for the U.S. Department of Energy's
# Notice of Proposed Rulemaking
# Establishing Energy Conservation Standards
# for Manufactured Housing

## Abstract

The Energy Independence and Security Act of 2007 (EISA, Pub. L. No. 110-140) directs the U.S. Department of Energy (DOE) to establish energy conservation standards for manufactured housing. EISA requires the standards to "be based on the most recent version of the International Energy Conservation Code [(IECC)] …, except in cases in which [DOE] finds that the [IECC] is not cost effective, or a more stringent standard would be more cost effective, based on the impact of the [IECC] on the purchase price of manufactured housing and on total life-cycle construction and operating costs." 42 U.S.C. 17071(b)(1).

This technical support document sets forth the energy and economic analyses underlying DOE's proposed energy conservation standards for manufactured housing. DOE used a life-cycle cost analysis from the homeowner's perspective to determine the cost effectiveness of the requirements in the proposed rule compared to the baseline of existing federal requirements for manufactured homes contained in 24 CFR Part 3280, Manufactured Home Construction and Safety Standards, promulgated by the U.S. Department of Housing and Urban Development. DOE documented the projected economic, financial, and energy-efficiency measures for the life-cycle cost analysis. DOE also quantified the costs, benefits, and net value to the consumer of the proposed rule.

## Summary

The Energy Independence and Security Act of 2007 (EISA, Pub. L. No. 110-140) was signed into law on December 19, 2007. EISA requires the U.S. Department of Energy (DOE) to develop energy conservation standards for manufactured housing. This technical support document sets forth the energy and economic analyses underlying DOE's proposed energy conservation standards for manufactured housing.

EISA requires the standards to "be based on the most recent version of the International Energy Conservation Code [(IECC)] …, except in cases in which [DOE] finds that the [IECC] is not cost-effective, or a more stringent standard would be more cost-effective, based on the impact of the [IECC] on the purchase price of manufactured housing and on total life-cycle construction and operating costs." 42 U.S.C. 17071(b)(1). The IECC is a nationally recognized model code developed by the International Code Council, which many state and local governments have adopted in establishing minimum design and construction requirements for the energy efficiency of residential and commercial buildings. The IECC contains requirements related to energy efficiency for space heating, space cooling (air conditioning), water heating, and lighting.

DOE proposes to establish energy conservation standards for manufactured housing based on the negotiated consensus recommendation of the manufactured housing working group (MH working group) approved by the Appliance Standards and Rulemaking Federal Advisory Committee (ASRAC) in accordance with the Federal Advisory Committee Act and the Negotiated Rulemaking Act. The MH working group recommendation is based on the 2015 edition of the IECC, while taking into consideration the costs and benefits of the proposed standards, factory design and construction techniques unique to manufactured housing, and the current construction and safety standards set forth by U.S. Department of Housing and Urban Development (HUD).

This technical support document contains both energy and economic analyses underlying the proposed rule, as recommended by the MH working group. These analyses address the potential impacts on the purchase price and total life-cycle construction and operating costs of manufactured housing under the proposed rule. DOE analyzed the life-cycle cost (LCC) of manufactured homes from a consumer's perspective that balanced the costs of energy-efficiency measures (EEMs) applied to manufactured homes built in accordance with the minimum standards of the HUD Manufactured Home Construction and Safety Standards (the HUD Code) with benefits of energy savings.

Specifically, this technical support document contains an LCC analysis that compares the total long-run (present value) costs of the proposed rule to the HUD code. For purposes of this LCC analysis, DOE considered the economic benefit as the energy savings from the EEMs over the baseline manufactured home constructed in accordance with the minimum requirements of the HUD Code; the major cost was the EEM cost, including the associated mortgages, fees, and payments. All calculations used in performing the LCC analysis required definition of various financial, economic, and fuel price parameters. The technical support document also contains an

analysis on the impact on the purchase price of manufactured homes based on analyses of the proposed rule, using the purchase price of manufactured homes built in compliance with the HUD code as a basis for comparison. DOE conducted all energy simulation analyses contained in this technical support document using EnergyPlus software.

DOE examined several financial, economic, and fuel price parameters in developing the LCC analysis. Because most homes are purchased with financing, the development of the proposed requirements accounts for two types of loans that are common for manufactured housing: personal property loans and real estate loans. Personal property loans have higher interest rates and shorter loan terms than conventional real estate loans. For purposes of DOE's LCC analysis, personal property loans were assumed to have a 9 percent interest rate over 15 years, with a down payment of 20 percent. Real estate loans were assumed to have a 5 percent interest rate over a 30-year term, with a 20 percent down payment. The nominal discount rate was set to equal the loan interest rates. The analysis period was 30 years. National average residential fuel prices and escalation rates were obtained from the DOE Energy Information Administration for electricity, fuel oil, natural gas, and liquid petroleum gas (LPG).

DOE performed LCC calculations for single-section (924 square feet) and double-section (1,568 square feet) manufactured homes with five different equipment/fuel types.[a] The five equipment/fuel types were:

- Natural gas with a forced-air furnace
- LPG (propane) with a forced-air furnace
- Oil with a forced-air furnace
- Electric resistance with a forced-air furnace
- Electric heat pump with forced-air distribution.

EISA also directs DOE to consider basing its energy conservation standards "on the climate zones established by HUD rather than the climate zones under the [IECC]." 42 U.S.C. 171071(b)(2)(B). Consistent with the recommendations of the MH working group, DOE proposes four climate zones (see Figure S.1) combining the benefits of both the HUD code climate zones and the IECC climate zones.

[a] In all cases an electric central air conditioning system was included for purposes of DOE's analysis.

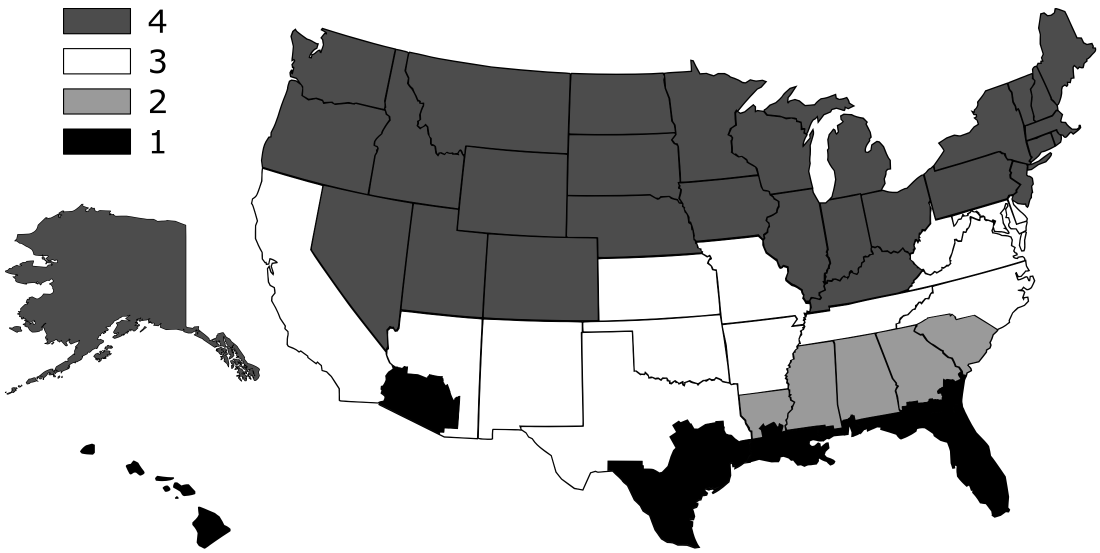



**Figure S.1 Proposed Climate Zones**

As discussed in detail in chapter 8 of this technical support document, the national average life-cycle cost savings from the proposed standards would be $4,625 for multi-section manufactured homes and $3,211 for single-section manufactured homes. DOE estimates that the proposed rule would result in an increased purchase price of manufactured homes, ranging from $1,348 to $3,829 for multi-section manufactured homes with a weighted national average of $3,109, and ranging from $1,219 to $2,443 for single-section manufactured homes with a weighted national average of $2,226. However, DOE also estimates, based on national averages, the proposed rule would save approximately $490 per year in energy costs over the HUD code for a typical multi-section manufactured home and approximately $345 per year for a typical single-section manufactured home. The national average simple payback (purchase price increase divided by the annual energy savings) would be 6.9 years for multi-section manufactured homes, and 7.1 years for single-section manufactured homes.

## Abbreviations and Acronyms

| | |
|---|---|
| ACH | air changes per hour |
| ASHRAE | American Society of Heating, Refrigerating, and Air-Conditioning Engineers Inc. |
| Btu | British thermal unit |
| CFR | Code of Federal Regulations |
| $CH_4$ | methane |
| $CO_2$ | carbon dioxide |
| DOE | U.S. Department of Energy |
| EEM | energy-efficiency measure |
| EISA | Energy Independence and Security Act of 2007 |
| EPA | U.S. Environmental Protection Agency |
| Hg | mercury |
| HUD | U.S. Department of Housing and Urban Development |
| IECC | International Energy Conservation Code |
| LCC | life-cycle cost |
| LPG | liquid petroleum gas |
| $N_2O$ | nitrous oxide |
| NIA | national impact analysis |
| NOx | nitrogen oxide |
| OMB | Office of Management and Budget |
| SHGC | solar heat gain coefficient |
| $SO_2$ | sulfur dioxide |
| TSD | technical support document |
| U.S.C. | United States Code |

## Contents

## Tables

## Figures

# CHAPTER 1. INTRODUCTION

The Energy Independence and Security Act of 2007 (EISA, Pub. L. No. 110-140) was signed into law on December 19, 2007. EISA directed the U.S. Department of Energy (DOE) to develop energy conservation standards for manufactured housing. This technical support document (TSD) sets forth the energy and economic analyses underlying DOE's proposed energy conservation standards for manufactured housing.

EISA requires the standards to "be based on the most recent version of the International Energy Conservation Code [(IECC)] …, except in cases in which [DOE] finds that the [IECC] is not cost-effective, or a more stringent standard would be more cost-effective, based on the impact of the [IECC] on the purchase price of manufactured housing and on total life-cycle construction and operating costs" 42 U.S.C. 17071(b)(1)). The IECC is a nationally recognized model code developed by the International Code Council, which many state and local governments have adopted in establishing minimum design and construction requirements for the energy efficiency of residential and commercial buildings.

The IECC contains requirements related to energy efficiency for space heating, space cooling (air conditioning), water heating, and lighting. In developing the proposed energy conservation requirements, DOE conducted both energy and economic analyses of the impact of the proposed rule on the purchase price and total life-cycle construction and operating costs of manufactured housing. DOE also performed similar analyses for the impacts on manufactured homes from the 2015 edition of the IECC. DOE also accounted for unique aspects of manufactured housing in assessing whether the requirements of the IECC were appropriate for manufactured housing.

The proposed energy conservation standards for manufactured housing are based on the negotiated consensus recommendation of the manufactured home (MH) working group approved by the Appliance Standards and Rulemaking Federal Advisory Committee (ASRAC) in accordance with the Federal Advisory Committee Act and the Negotiated Rulemaking Act. The MH working group recommendation is based on the 2015 edition of the IECC, while taking into consideration the costs and benefits of the proposed standards, factory design and construction techniques unique to manufactured housing, and the current construction and safety standards set forth by U.S. Department of Housing and Urban Development (the HUD Code).

Chapters of this TSD are organized as follows. Chapter 2 presents an overview of the energy conservation requirements set forth in the HUD code. Chapter 3 summarizes the relevant requirements contained in the 2015 edition of the IECC. Chapter 4 discusses DOE's selection of climate zones, which differentiate geographical areas that have different requirements for manufactured homes. Chapter 5 describes energy efficiency measures used in the analysis and their incremental costs. Chapter 6 discusses the analysis of energy efficiency levels relative to the HUD code and the 2015 IECC, which produced the proposed requirements for manufactured housing. Chapter 7 discusses the building simulation analysis that calculates the energy use for the proposed standards. 8 details the life-cycle cost (LCC) analysis for manufactured homes under the proposed rule. Chapter 9 details the LCC analysis for a particular subgroup, namely low-income buyers. Chapter 10 describes the analysis and projects shipments of manufactured homes. Chapter 11 describes the energy savings and economic impact of the proposed rule for the nation as a whole. Chapter 12 discusses the impact of the proposed rule on manufacturers. Chapter 13 contains analysis of emissions reductions as a result of the proposed rule, and chapter 14 covers the monetization of these emission reductions. Finally, chapter 15 contains analysis of regulatory alternatives to the proposed rule.

# CHAPTER 2. ENERGY EFFICIENCY REQUIREMENTS IN THE HUD CODE

The HUD code includes requirements related to the energy efficiency of manufactured homes. Specifically, subpart F of the HUD code, Thermal Protection, establishes thermal transmittance requirements for the entire building thermal envelope ($U_o$ requirements) of manufactured homes for three climate zones within the United States (see Figure 2.1). $U_o$ is a measure of the heat loss/gain rate through the building thermal envelope of the manufactured home; therefore, a lower $U_o$ corresponds with a more tightly insulated building thermal envelope. The HUD code contains $U_o$ requirements for the combined thermal transmittance value of walls, ceilings, floors, fenestration, and external ducts within the building thermal envelope for manufactured homes installed in different climate zones. The HUD code also specifies adjustments to $U_o$ requirements corresponding with installation of high-efficiency heating and cooling equipment in the manufactured home. Moreover, subpart F of the HUD code establishes requirements for air leakage control through the building thermal envelope.


**Figure 2.1 HUD Code Thermal Envelope Heat Loss/Gain ($U_o$) Requirements**

Subpart H of HUD code, Heating, Cooling and Fuel Burning Systems, establishes requirements for sealing air supply ducts and for insulating both air supply and return ducts. Specifically, HUD requires ducts to be insulated to *R*-4 (24 CFR Part 3280.715).[b] *R*-value is the measure of a building component's ability to resist heat flow (thermal resistance). A higher *R*-value represents a greater ability to resist heat flow. Therefore, a higher *R*-value of insulation often corresponds with a more tightly insulated building thermal envelope.

[b] A Rule issued by HUD on December 09, 2013 (78 FR 73966), would increase the crossover duct R-value to R-8.

The HUD code contains no requirements for fenestration solar heat gain coefficient (SHGC), mechanical system piping insulation, or installation of insulation.

## CHAPTER 3. INTERNATIONAL ENERGY CONSERVATION CODE

As stated in chapter 1 of this TSD, EISA requires DOE's energy conservation standards for manufactured housing to "be based on the most recent version of the [IECC] …, except in cases in which [DOE] finds that the [IECC] is not cost-effective, or a more stringent standard would be more cost-effective, based on the impact of the [IECC] on the purchase price of manufactured housing and on total life-cycle construction and operating costs" 42 U.S.C. 17071(b)(1). The IECC sets voluntary industry standards for the "effective use of energy" in all existing buildings. The IECC also applies to new buildings and to remodels, renovations, and additions to existing buildings. An updated version of the IECC generally is published every three years.

DOE notes that the 2015 IECC contains separate requirements for two categories of buildings: residential and commercial. The only chapters of the IECC with specific requirements for residential buildings are chapter 4 and, to a lesser extent, chapters 1 and 3. Specifically, chapter 1 primarily addresses the scope of the IECC and provides instruction on confirming compliance with the IECC. Chapter 2 provides definitions of terms used in the 2015 IECC. DOE reviewed many of the definitions set forth in this chapter in developing its proposed manufactured housing standards. Chapter 3 provides the climate zones used in determining compliance with the standards set forth in the 2015 IECC. DOE notes that the 2015 IECC divides the United States into eight primary climate zones based on county boundaries (see Figure 3.1). Chapter 3 also specifies information required at the building site to verify insulation level and identifies National Fenestration Rating Council (NFRC) standards for rating fenestration performance. Chapter 4 sets forth residential energy efficiency requirements. DOE's proposed manufactured housing standards are based only on the provisions in the 2015 IECC that apply to residential buildings. Table 3.1 provides the table of contents of the residential provisions in the 2015 IECC.

**Table 3.1 2015 IECC Table of Contents**

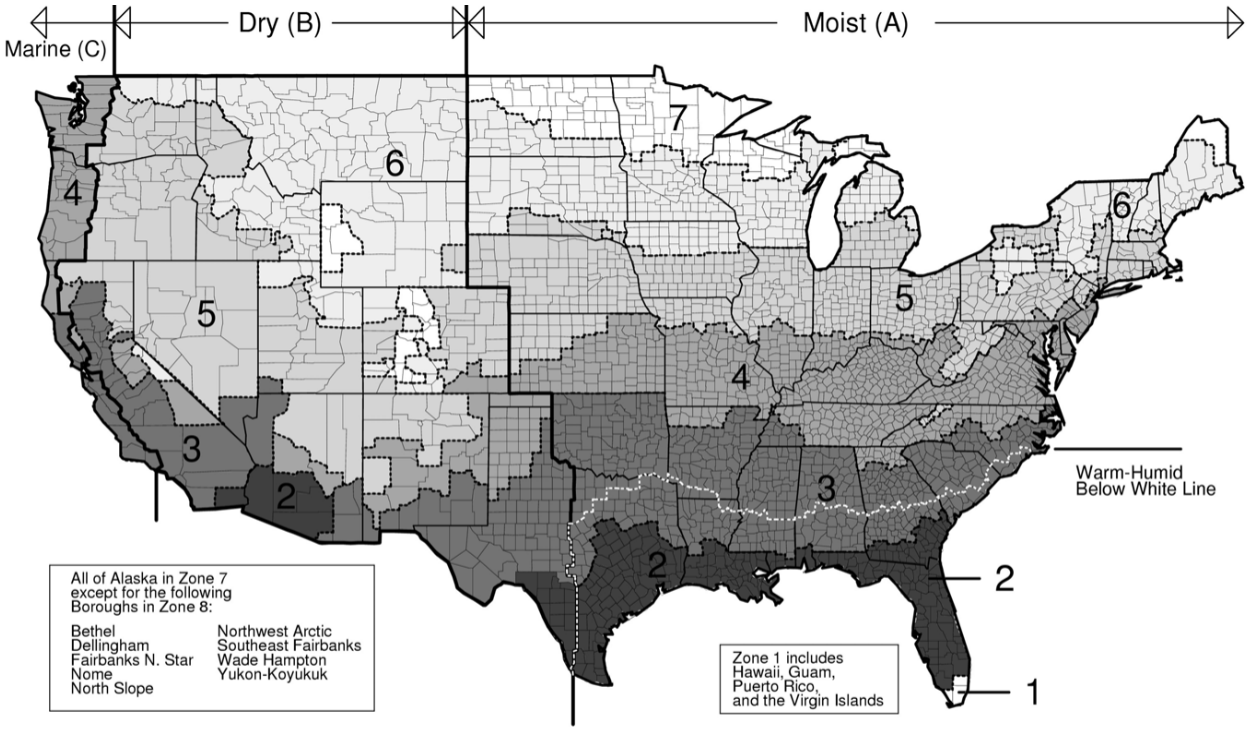



**Figure 3.1 2015 IECC Climate Zones**

## 3.1 RESIDENTIAL BUILDING REQUIREMENTS – CHAPTER 4 OF THE IECC

The 2015 IECC sets forth construction standards related to energy efficiency for five building elements: 1) the building thermal envelope, 2) space heating, 3) space cooling (air conditioning), 4) water heating, and 5) lighting.

The 2015 IECC contains three pathways for complying with the building thermal envelope energy efficiency requirements:

- Prescriptive measures. The 2015 IECC sets forth specific standards for insulation R-values, fenestration U-factors, and SHGC. These requirements do not vary by building size, shape, window area, or other features. The 2015 IECC also sets forth specific U-factor requirements that permit compliance using less common component types (*e.g.*, structural insulated panels).
- Total building envelope UA (U-factor multiplied by area). This option in the 2015 IECC also allows for tradeoffs, where some energy efficiency measures can fall below code requirements if balanced by other measures that exceed code requirements. For example, if wall insulation exceeds the specific R-value requirement, then ceiling insulation may not need to meet the specific R-value requirement so long as the total building envelope UA meets minimum requirements. This path is similar to the maximum coefficient of heat transfer that established the thermal envelope requirements in 24 CFR Part 3280.506.
- Simulated performance (requires building energy simulation software). This path allows compliance if the home has calculated annual energy consumption equal to or less than that of a standard reference design that meets the minimum requirements contained

in the 2015 IECC prescriptive pathway. This option allows for crediting energy efficiency measures, such as renewable energy measures, that are not accounted for under the prescriptive option or total building envelope UA option. The 2015 IECC performance path allows no tradeoff credit for the use of high-efficiency space heating, space cooling, or water heating equipment.

Each of the three pathways for complying with the building thermal envelope requirements in the 2015 IECC generally result in buildings having the same overall level of energy efficiency, even though a building may comply under one option but not under another option. DOE has incorporated elements of the prescriptive measures option and total building envelope option into its proposed thermal envelope requirements.

DOE carefully reviewed the standards set forth in section 402 of the 2015 IECC in developing its proposed standards, as this section contains standards applicable to the building thermal envelope (*e.g.*, ceilings, walls, windows, floors, and foundations). Although manufactured homes can be placed on basement or slab foundations, these foundations are not part of the factory assembly but rather are constructed at the home installation site (and covered by the local construction code).

The 2015 IECC also contains a number of important requirements that apply across all climate zones. For example, there are requirements for duct system testing and maximum duct air leakage. The 2015 IECC does not require duct testing if all ducts are located inside the building thermal envelope, although there is a requirement for the ducts to be sealed.

The 2015 IECC also requires air leakage testing, where the building envelope is sealed and the building is pressurized at a test pressure of 50 pascals. The air leakage must not exceed three or five air changes per hour, depending on the climate zone in which the home is placed.

The 2015 IECC further requires that ducts located in attics that supply conditioned air be insulated to minimum of *R*-8, while ducts located in unconditioned spaces are required to be insulated to a minimum of *R*-6. The 2015 IECC does not require ducts located inside the conditioned space to be insulated.

The 2015 IECC also requires that a minimum of 75 percent of the lamps or lighting fixtures within a home are high-efficacy lamps (such as a compact fluorescent bulb). DOE notes that EISA section 321 requires mandatory performance standards for light bulbs, and DOE is considering revised lighting conservation standards in a separate regulatory action (see public docket EERE-2013-BT-STD-0051). Accordingly, DOE has not proposed lighting efficiency standards in the proposed rule.

The 2015 IECC requires that a permanent certificate be installed in the home that lists the predominant *R*-values of insulation, *U*-factors of fenestration, and the type and efficiency of heating, cooling, and service water heating equipment. Finally, the 2015 IECC requires *R*-3 insulation on water heating pipes with certain characteristics.

## CHAPTER 4. CLIMATE ZONES

The HUD code, 2015 IECC, and the proposed rule set forth varying requirements based on where a manufactured home is sited geographically within the country. The differences in requirements account for the impact of climate on the energy conservation of a manufactured home. For example, the appropriate level of insulation of a roof/ceiling for a home in southern Florida would not necessarily be appropriate for installation in a home in New Hampshire. Regions within the United States and U.S. territories with distinct requirements based on their climate are referred to as climate zones.

As shown in Figure 4.1, the HUD code divides the United States into three distinct climate zones, the boundaries of which are separated along state lines. The HUD code climate zones were developed to be sensitive to the manner in which the industry constructs and places manufactured homes into the market. In contrast, the 2015 IECC climate zones are separated along county lines to facilitate state and local enforcement of the IECC for site-built and modular construction. Section R301 (and its subsections) of the 2015 IECC divides the country into eight basic climate zones, the boundaries of which are separated along county lines; the 2015 IECC also provides requirements for three possible variants (dry, moist, and marine) within some climate zones, as indicated in

Figure 4.2.

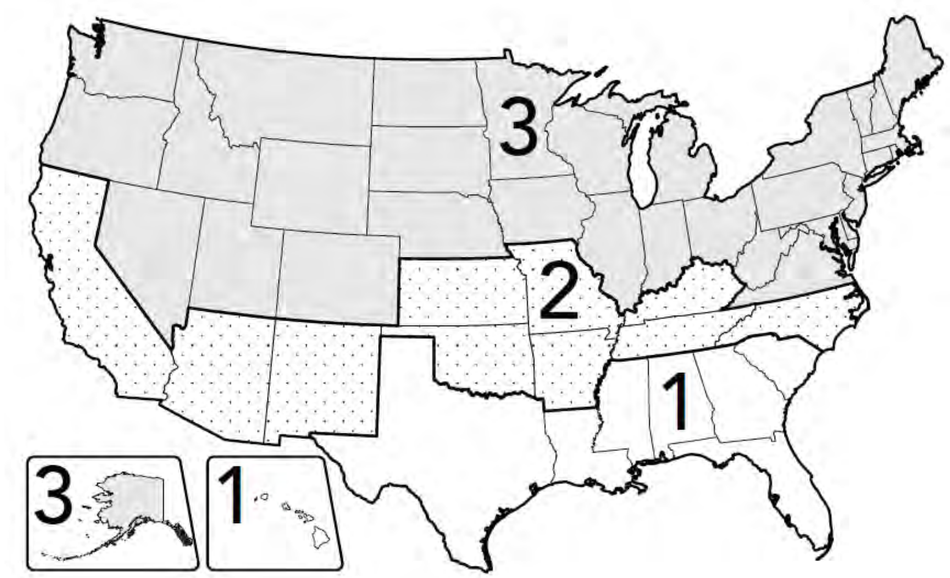



**Figure 4.1 Climate Zones in the HUD Code**

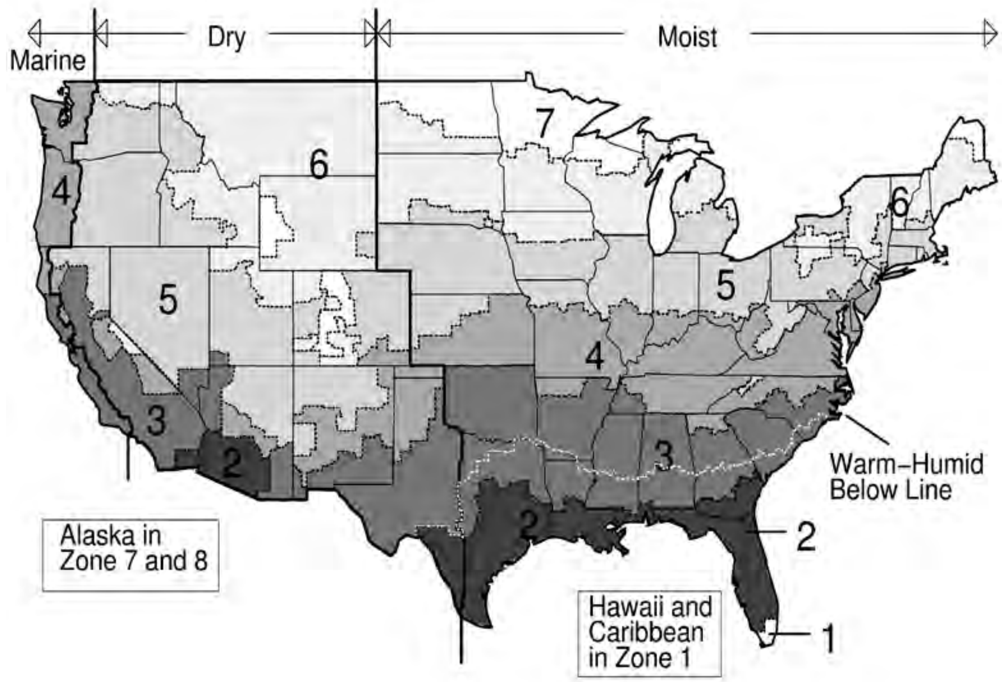



**Figure 4.2. Climate Zones in the 2015 IECC**

If DOE's proposed energy conservation standards used the eight climate zones established in the IECC, forty states would be divided into two or more climate zones. Although the IECC climate zones more accurately account for U.S. climatic conditions that affect energy use, any loss of accuracy in addressing climatic differences would be offset by the impracticality to the manufactured housing industry of developing homes for eight zones, with multiple zones existing within the same state. A large number of zones, particularly within a state, complicates the manufactured housing industry because the eventual destination of the home is not always known when the home is manufactured. Though some homes are custom orders, other homes are stocked as inventory with manufactured housing dealers. In particular, manufactured housing dealers and installers in states with multiple climate zones would encounter increased complexities associated with ordering, stocking, selling, installing, and servicing manufactured homes.

Pursuant to EISA, DOE may consider basing its energy conservation standards on the climate zones established by HUD rather than on the climate zones contained in the IECC. *See* 42 U.S.C. 17071(b)(2)(B). To establish climate zones, the MH working group used the results of the life-cycle cost (LCC) analysis to determine the most cost-effective energy conservation requirements for the 19 cities in the analysis (see chapter 8 of this TSD for more details on the LCC analysis). The MH working group then established climate zone boundaries by grouping cities whose most cost-effective energy conservation requirements were the same. For example, Miami, Houston, and Phoenix most cost-effective energy conservation requirements were the same, so these cities were placed in the same climate zone (proposed climate zone 1).

Generally, the MH working group avoided bifurcation of a state for simplification of requirements within a state. The MH working group selected climate zone boundaries along state lines to be consistent with the HUD code in most cases, with the exception of placing Virginia, West Virginia, Maryland, and Delaware in the same zone as North Carolina, and placing Kentucky in the same zone as Illinois, Indiana, and Ohio. The climate and cost-effectiveness calculations indicated these four states should have the same energy conservation standards as other states placed in proposed climate zone 3. However, due to significant climate variation, the working group recommended bifurcations to Arizona, Texas, Louisiana, Mississippi, Alabama, and Georgia along the northern border of IECC climate zone 2.

Shown in Figure 4.3, the climate zone arrangement in the proposed rule synthesizes the advantages of both the HUD code and 2015 IECC climate zones. These four climate zones more accurately reflect regions with similar climates than the HUD code does, and simultaneously minimize the extensive subdivisions of states as prescribed by the 2015 IECC. The proposed climate zones are consistent with the recommendations of the MH working group. *See* EERE 2009 BT BC 0021 0107 2, Recommendations 3.1 and 3.2 (hereinafter referred to as Term Sheet)). The MH working group recommended these climate zones based on analysis of energy conservation in 19 geographically diverse cities, as discussed in chapter 6 of this TSD. The working group originally recommended climate zone designation of 1A, 1B, 2, and 3; for simplicity, the climate zones referred to by these working group designations have been renamed in the proposed rule as climate zones 1, 2, 3, and 4 respectively.

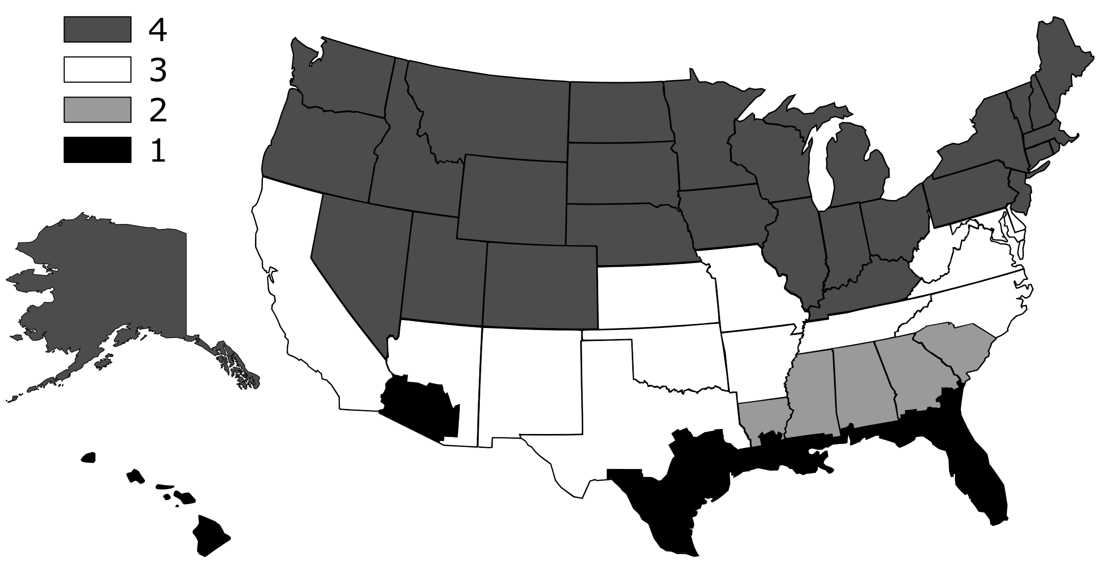



**Figure 4.3 DOE Proposed Climate Zones**

While DOE generally favored establishment of a single climate zone per state, in some cases, the size or varied climate of a state necessitated two zones. DOE’s proposed climate zones bifurcate Arizona, Texas, Louisiana, Alabama, Mississippi, and Georgia. The inland climate of Texas, Louisiana, Alabama, Mississippi, and Georgia is much different than the coastal climate where these states border the Gulf of Mexico. Similarly, southwestern Arizona exhibits different weather patterns than the rest of the state.

# CHAPTER 5. ENERGY EFFICIENCY MEASURES AND INCREMENTAL COSTS

Energy efficiency measures (EEMs) are elements of a manufactured home affecting energy conservation that are considered in this analysis. This chapter discusses EEM options and their incremental costs, which were used in the life-cycle cost analysis. Section 5.1 discusses the prototype manufactured homes selected for the analysis. Section 5.2 summarizes the EEMs examined in this analysis. Section 5.3 presents the analysis of EEM costs and characteristics data, including selection of EEMs and determination of costs for insulation in ceilings, walls, and floors; window costs; and duct and envelope sealing costs.

## 5.1 MANUFACTURED HOME PROTOTYPE

The analyses in this TSD were based on prototypical single- and double-section manufactured homes as discussed by the MH working group (see Term Sheet at 2). Manufactured homes also can consist of three or more units in width; however, the 2013 American Housing Survey indicates that triple-section manufactured homes account for only 1.5 percent of all manufactured homes.[1] Therefore, DOE only analyzed double-section homes to represent multi-section homes in the analyses. Based on discussions of the MH working group, DOE assumed in its analyses a single-section manufactured home to be 14 feet wide by 66 feet long, with a floor area of 924 square feet. DOE assumed in its analysis a double-section manufactured home to be 28 feet wide by 56 feet long with a floor area of 1,568 square feet. Chapter 7 of this TSD describes in greater detail the specific geometries assumed for conducting the analysis.

## 5.2 ENERGY EFFICIENCY MEASURE RANGES

Energy efficiency measure options, performance characteristics, and costs must be determined for all manufactured home components affected by the proposed rule for calculation of energy and cost savings. These components include ceilings, walls, floors, windows, ducts, and the building envelope. For each component, DOE produced a list of EEM options and associated cost. Table 5.1 provides the range of energy efficiency levels examined for this analysis. The least energy efficient levels are consistent with minimum levels that would comply with the HUD code for a typical home.

**Table 5.1 Range of Energy Efficiency Options Included in the Analysis**

| Building Component | Range of Options |
|---|---|
| Ceiling (hr-ft$^2$-°F/Btu) | *R*-22 to *R*-38 |
| Wall (hr-ft$^2$-°F/Btu) | *R*-11 to *R*-21 |
| Floor (hr-ft$^2$-°F/Btu) | *R*-11 to *R*-30 |
| Window *U*-Factor (Btu/hr-ft$^2$-°F) | *U*-1.08 to *U*-0.30 |
| Window SHGC | 0.7 to 0.25 |
| Duct Sealing (cfm25/100 ft$^2$ CFA)* | 12 to 4 |
| Envelope Sealing (ACH) | 8 to 5 |
| *CFA = conditioned floor area | |

## 5.3 ENERGY EFFICIENCY MEASURES AND COSTS

DOE based energy efficiency measure cost estimates on cost data provided by the MH working group. *See* EERE-2009-BT-BC-0021-0091. All costs reported are incremental costs for each EEM option relative to the lowest performing level presented in the relevant table. All costs reported here are relative to the purchase prices made available to the home buyer, which includes all markups for manufacturer overhead and profits, but does not include sales tax. To calculate the incremental cost between a minimally HUD compliant home and a home compliant with DOE's proposed rule, the incremental cost of the HUD compliant energy efficiency measure is subtracted from the incremental cost of the DOE compliant energy efficiency measure.

### 5.3.1 Ceilings

Energy efficiency measures for ceilings involve increasing its thermal resistance, or R-value, by increasing the level of insulation. Factors such as thickness, material properties, and structural features (such as air pockets) affect the ability of insulation to resist heat transfer. Types of insulation used for ceilings include: blanket insulation, typically made of fiberglass or other plastic or natural fibers; foam board or rigid foam insulation, such as extruded polystyrene foam; loose-fill or blown-in insulation, where pieces of cellulose or fiberglass are blown to fill in the space being insulated; and spray foam insulation, where a foam such as polyisocyanurate is sprayed to fill in the space being insulated.

Table 5.2 shows the incremental cost increases provided by the MH working group for ceiling insulation relative to an *R*-22 reference point. Data for *R*-34 was not provided and was determined via linear interpolation between *R*-30 and *R*-38 insulation. Extruded polystyrene foam (XPS) associated with a roof *R*-value contemplates additional costs associated with using XPS insulation in walls, which results in different dimensions for manufactured home construction. XPS does not refer to the choice of insulation for the roof or ceiling itself.

**Table 5.2 Ceiling Insulation Incremental Upgrade Costs from *R*-22**

| R-Value *hr-ft2-°F/Btu* | Single Section Cost *$* | Multi Section Cost *$* |
|---|---|---|
| 22 | -- | -- |
| 30 | 409.3 | 646.14 |
| 34 | 595.24 | 904.62 |
| 38 | 781.17 | 1163.1 |
| 38XPS* | 908.05 | 1,345.84 |
| * XPS refers to additional cost involved when using extruded polystyrene insulation in ceilings. | | |

### 5.3.2 Walls

Energy efficiency measures for walls involve increasing their thermal resistance by increasing insulation. The types of insulation used for walls in manufactured homes include those used for ceilings. In addition, exterior walls may also utilize insulated siding as an efficiency measure. Insulated siding consists of a layer of rigid foam insulation that is fused to the exterior surface.

Table 5.3 lists the cost increases provided by the MH working group for wall insulation relative to an *R*-11 reference point.

**Table 5.3 Wall Insulation Incremental Upgrade Costs from *R*-11**

| *R*-Value (hr-ft$^2$-°F/Btu) | Single-Section Cost *$* | Multi-Section Cost *$* |
|---|---|---|
| 11 | -- | -- |
| 13 | 61.86 | 60.86 |
| 15 | 610.79 | 600.93 |
| 19 | 610.79 | 600.93 |
| 20 | 737.92 | 726.01 |
| 21 | 737.92 | 726.01 |
| 21+5* | 2,199.75 | 2,176.76 |
| * Refers to a combination of *R*-21 batt insulation and *R*-5 insulated siding. | | |

### 5.3.3 Floors

Energy efficiency measures for floors involve increasing thermal resistance through increasing insulation. The types of insulation typically used in floors include blanket and batt insulation. Table 5.4 lists the incremental costs provided by the MH working group for floor insulation upgrades, relative to and *R*-11 reference point. XPS associated with a floor *R*-value indicates additional floor costs accompanying the use of XPS sheathing in walls, which results in different dimensions for manufactured home construction. XPS does not refer to the type of insulation for the floor itself.

**Table 5.4 Floor Insulation Incremental Upgrade Costs from *R*-11**

| *R*-Value (hr-ft$^2$-°F/Btu) | Single-Section Cost $ | Multi-Section Cost $ |
|---|---|---|
| 11 | -- | -- |
| 13 | 41.86 | 71.04 |
| 19 | 116.11 | 197.03 |
| 22 | 239.73 | 406.83 |
| 30 | 608.06 | 1005.26 |
| 38XPS* | 911.78 | 1426.22 |
| * XPS refers to additional cost involved when using polystyrene extruded polystyrene insulation in floors. | | |

### 5.3.4 Windows

DOE considered several energy efficiency measures for windows to improve thermal performance, which affect the *U*-factor and SHGC for a given window. The EEMs include several types of glazing, including: clear single or dual glazing; enhanced dual glazing; low-emissivity (low-E) dual glazing; and enhanced low-emissivity dual glazing. These EEMs also include: selection of frame material, namely aluminum or vinyl framing; adding a storm window; adding argon gas fill; and adding enhanced glass spacers.

The glazed portion of a window can vary by the number of panes or coating used on the glass surface. Single or dual glazing refers to the number of panes of glass used in the window assembly. A single glazed window uses one pane of glass, while a dual glazed window uses two panes of glass separated by a fixed distance. The space between the panes is sealed and filled with air or other gases, functioning as insulation. Clear or low-emissivity glazing refers to coatings that may be added to the glass surface. Clear glazing is uncoated, while low-E and enhanced low-E glass is designed to reflect and minimize UV and infrared light passing through its body. As a result, low-emissivity glass reduces radiative heat transfer through the window. Consequently, low-E coatings decrease both the U-factor and SHGC of a window, thereby increasing its insulating capabilities. Enhanced low-E glass refers to additional coating material relative to normal low-E glass, which offers a lower U-factor and SHGC. Finally, storm windows are secondary windows that can be installed inside or outside existing windows. Typically, storm windows are used as retrofits to improve the thermal performance of existing windows. Storm windows can be made using same types of glazing as normal windows, and therefore can add significant thermal performance benefits.

The material used to construct the window frame can vary from window to window. Aluminum window frames are strong and light, but have high thermal conductivity, which is a source of heat loss. Conversely, vinyl frames have far lower thermal conductivity and therefore higher thermal resistance. Furthermore, due to their hollow construction, vinyl window frames can be filled with insulation to further improve their thermal resistance.

The space between the panes in a dual glazed window can be modified to enhance energy efficiency. Argon gas fill refers to replacing the air in the space in between panes in a multi-pane window to lower its U-factor. Argon gas molecules have a lower specific heat capacity and diffusivity than air molecules, which leads to lower thermal conductivity. Moreover, due to higher molecular mass, argon gas molecules move more slowly relative to air molecules, which reduce convective heat transfer. Glass spacers are bars that are used to maintain a fixed separation between panes in a multi-pane window. Traditionally, these bars are hollow aluminum, which leads to high thermal conductivity through the edge regions of the glass. Enhanced glass spacers involve utilizing technology to reduce this heat transfer. In addition, these spacers reduce the exfiltration of any special gas fill in the window, such as argon, as well as the infiltration of air and moisture. Materials used for this purpose include foams, plastics, and combinations of plastic and metal.

*U*-factors and SHGCs for different types of windows are provided in Table 5.5. Table 5.5 also provides incremental costs based on data provided by the MH working group for windows relative to an aluminum framed window with clear single glazing reference point.

**Table 5.5 Window Costs and Characteristics**

| Window/Frame Type | *U*-factor (Btu/hr-ft$^2$-°F) | SHGC | Single-Section Cost $ | Multi-Section Cost $ |
|---|---|---|---|---|
| Aluminum Frame with Clear Single Glazing | 1.08<br>0.75<br>0.65 | 0.7 | -- | -- |
| Aluminum Frame with Clear Single Glazing + Storm | 0.5 | 0.6 | 1608.90 | 949.93 |
| Vinyl Frame with Clear Dual Glazing | 0.49<br>0.4 | 0.71 | 1761.93 | 1040.29 |
| Vinyl Frame with Low-E Dual Glazing | 0.35 | 0.33 | 2295.48 | 1355.31 |
| Vinyl Frame with Low-E Dual Glazing + Argon | 0.32 | 0.33 | 2427.83 | 1433.45 |
| Vinyl Frame with Enhanced Low-E Dual Glazing | 0.35 | 0.25 | 2448.51 | 1445.66 |
| Vinyl Frame with Enhanced Low-E Dual Glazing + Argon | 0.31 | 0.25 | 2572.59 | 1518.92 |
| Vinyl Frame with Low-E Dual Glazing + Argon + Enhanced Glass Spacer | 0.31 | 0.31 | 3172.31 | 1873.01 |
| Vinyl Frame with Enhanced Low-E Dual Glazing + Argon + Enhanced Glass Spacer | 0.3 | 0.25 | 3296.39 | 1946.27 |
| Combination of Vinyl Frame with Low-E Dual Glazing and Vinyl Frame with Enhanced Low-E Dual Glazing* | 0.35 | 0.3 | 2352.87 | 1389.19 |

| |
|---|
| * Corresponds to a home with windows installed of varying performance. The cost was computed by linear interpolation. |

### 5.3.5 Doors

For purposes of analysis, DOE assumed all manufactured homes are constructed with two doors with a total area of 36 square feet and a *U*-factor of 0.40. Because DOE assumed that doors would be identical in construction under both the DOE proposed rule and the HUD code, DOE did not provide incremental costs for doors in this analysis.

### 5.3.6 Envelope Air Sealing

Infiltration is unintentional air leakage through cracks, seams, and penetrations through the exterior envelope of the home, which represents a source of heat loss. Both the HUD code and the proposed rule require these sources of leakage to be sealed, so that the air leakage rate of the building is a given number of air changes per hour when a manufactured home is depressurized to 50 pascals using air tightness testing equipment. An air change per hour represents the complete volume of air inside the building envelope of the home being replaced by air leaking in from outside the building each hour. DOE has assumed a baseline air leakage rate of eight air changes per hour (ACH) for the typical manufactured home built to the HUD code. The proposed standards would require manufacturers to follow prescriptive envelope sealing factors, which can be visually inspected. DOE expects that following these prescriptive factors would result in a maximum of five ACH air leakage at the 50 pascal test pressure. These factors are described in chapter 6 of the TSD. Table 5.6 provides the total incremental costs per manufactured home for the increased sealing requirements of the proposed rule; these were presented to the MH working group and used as a basis for their recommendations.

**Table 5.6 Improved Envelope Air Sealing Costs**

| Air Leakage Level *ACH* | Single-Section Cost *$* | Multi- Section Cost *$* |
|---|---|---|
| 8 | -- | - |
| 5 | 230 | 390 |

### 5.3.7 Duct Sealing

Duct sealing keeps conditioned air from escaping into unconditioned spaces. Sealing joints with a product such as mastic can reduce duct leakage effectively. MH working group manufacturers expressed an expectation that testing the duct leakage rate would be required in every manufactured home to ensure compliant duct sealing has been achieved, which would contribute to increased cost. *See* 9/22/2014 WG Transcript, EERE-2009-BT-BC-0021-0102 at p. 319. Table 5.7 lists the costs to reduce duct leakage to the proposed limit for multi- and single-section homes. These costs were presented to the MH working group and served as the basis for their recommendations.

**Table 5.7 Improved Duct Leakage Limit Costs**

| Duct Leakage Limit *cfm25/100 ft² CFA* | Single-Section Cost *$* | Multi- Section Cost *$* |
|---|---|---|
| 12 | -- | -- |
| 4 | 330 | 390 |

### 5.3.8 Insulation of Hot Water Pipes

The MH working group considered insulating hot water piping located outside conditioned space. As a conservative estimate, the MH working group agreed to assume the retail cost to the consumer would be about $50 per manufactured home (regardless of size). This cost was included in the cost-benefit analysis completed during the negotiated consensus process of the MH working group.

### 5.3.9 Energy Efficiency Measure Lifetime

Insulation and windows were presumed to last the 30-year lifetime assumed in the analysis, so there was no replacement cost, and DOE assumed that the energy savings from improved levels would remain for the length of the 30-year analysis period. This assumption was included in the cost-benefit analysis completed during the negotiated consensus process of the MH working group.

# CHAPTER 6. ENERGY EFFICIENCY LEVELS ANALYSIS

The MH working group sought to find a cost-effective set of EEM requirements that saves energy relative to the HUD code. This chapter discusses the methodology and analysis used during the MH working group's negotiated consensus process.

## 6.1 GENERAL METHODOLOGY

The MH working group recommended two paths to compliance regarding the building thermal envelope. The first was a prescriptive path which would provide the exact EEMs (either via *R*-value, *U*-factor, or SHGC) to be implemented in the manufactured home to achieve compliance, providing a straightforward option for construction. In contrast, the whole-home, performance-based overall thermal transmittance ($U_o$) requirements for the entire building thermal envelope would allow a manufactured home to be constructed using a variety of different components with varying thermal properties as long as the building thermal envelope meets an overall thermal performance requirement.

The MH working group began its analysis by establishing the prescriptive path. Then, to establish the performance path, the MH working group calculated the $U_o$ of a manufactured home that uses the EEMs dictated by the prescriptive path.

The MH working group began by selecting cities from a wide cross section of the United States for analysis of the impact of different efficiency standards. Next, the MH working group completed sensitivity analyses studying the relative cost-effectiveness of changing individual EEM requirements. Finally, after finding the most cost-effective set of requirements for each city, DOE grouped cities with the same EEM requirements, forming the proposed climate zones. Each of these steps is discussed in more detail in sections 6.1.1 through 6.1.3.

### 6.1.1 City Selection

The MH working group began its process by selecting nineteen cities located throughout each of the eight 2015 IECC climate zones. This was consistent with 42 U.S.C. 17071(b), which requires that DOE's regulations be based on the most recent version of the IECC. This city placement gave the MH working group the opportunity to analyze the cost effectiveness of changes to the requirements specified in the 2015 IECC. The MH working group chose four cities in the southern states of Mississippi, Alabama, Georgia, and South Carolina for additional sensitivity analysis regarding the impacts on these states with large manufactured home shipment volumes. DOE calculated energy use and cost-effectiveness for the cities listed in Table 6.1.

**Table 6.1 Cities Analyzed**

| | |
|---|---|
| Miami, FL | Baltimore, MD |
| Houston, TX | Albuquerque, NM |
| Phoenix, AZ | Salem, OR |
| Atlanta, GA | Chicago, IL |
| Charleston, SC | Boise, ID |
| Jackson, MS | Burlington, VT |
| Birmingham, AL | Helena, MT |
| Memphis, TN | Duluth, MN |
| El Paso, TX | Fairbanks, AK |
| San Francisco, CA | |

### 6.1.2 EEM Sensitivity Analysis

Once the cities were selected, the MH working group started its analysis with the 2015 IECC. The MH working group calculated the cost-effectiveness of a manufactured home built to the minimum specifications of the 2015 IECC relative to a manufactured home constructed in accordance with the minimum requirements of the HUD code to establish an initial reference point for all sensitivity analysis. The MH working group then conducted sensitivity analyses on each EEM to identify potential revisions to the 2015 IECC that increase cost-effectiveness for manufactured housing. The MH working group recommended DOE propose the most cost-effective EEM, based on LCC analysis (see chapter 8 of this TSD for an explanation of the LCC analysis).

#### 6.1.2.1 Envelope Air Sealing

The 2015 IECC requires envelope air sealing of five ACH in IECC climate zones 1A and 2A, and envelope air sealing of three ACH in all other IECC climate zones. Further, section R402.4 of the 2015 IECC requires testing to confirm that the specified level of air sealing has been reached. The MH working group discussed the benefits and burdens of the IECC requirements.

The MH working group concluded that the testing requirements of the 2015 IECC were overly costly and impractical for manufactured housing. In the case of multi-section manufactured housing, the manufacturer would need to join the sections in the factory to complete an envelope air- sealing test. The multi-section home would then be separated for transport and sale. To alleviate concerns with these burdensome requirements, the MH working group recommended an alternative requirement based on visual inspection.

The 2006 IECC, 2009 IECC, and the HUD code all allow confirmation of envelope air sealing by visual inspection of the code enforcement official. The MH working group recommended returning to a similar system for this proposed rule to avoid excessive testing costs and business risk associated with constructing a non-compliant manufactured home. Based on experience testing and designing manufactured homes, the MH working group recommended prescriptive factors, which could be visually inspected. DOE expects that the proposed standards that would allow for visual inspection in lieu of air leakage testing would achieve a whole-home air exchange rate of five ACH.

#### 6.1.2.2 Wall Insulation

The MH working group completed sensitivity analyses for the wall insulation requirements in the 2015 IECC to determine if cost-effective revisions were possible. The 2015 IECC has different requirements for each IECC climate zone, and the MH working group analyzed several alternative wall insulation options in each zone. Table 6.2 lists the wall insulation options analyzed by the MH working group for each of the 19 cities. Table 6.2 also lists the proposed wall insulation requirement for each city. The most cost-effective requirement is included in the proposed requirement.

Based on its ranking of the cost-effectiveness of each EEM, the MH working group expected some EEM requirements in the 2015 IECC could be revised to increase cost-effectiveness. For Atlanta, Charleston, Jackson, and Birmingham, the MH working group analyzed a less stringent wall insulation level based on an expectation that for these cities in the southeast, the reduced heating load would yield an optimal wall insulation level at a lower *R*-value.

The MH working group also tested the relative cost-effectiveness of removing insulated siding in the northern cities of Burlington, Helena, Duluth, and Fairbanks. Insulated siding is an expensive EEM (see chapter 5 of the TSD), and the MH working group expected it would not be cost effective compared to not using the insulated siding in these northern cities. The MH working group found that *R*-5 insulated siding was cost-effective for the cities of Fairbanks and Duluth, but did not want to recommend a separate wall insulation requirement for only those two cities. Because very few manufactured homes are shipped to the regions represented by Duluth and Fairbanks, the MH working group assigned the most cost-effective wall insulation requirement (*R*-21 without insulated siding) corresponding to Burlington and Helena to Duluth and Fairbanks.

**Table 6.2 Wall Insulation Options Analyzed**

| **City** | **2015 IECC Requirement** ***R-Value*** | **Sensitivity Analysis Options** ***R-Value*** | **Proposed Requirement** ***R-Value*** |
|---|---|---|---|
| Miami | 13 | None | 13 |
| Houston | 13 | None | 13 |
| Phoenix | 13 | None | 13 |
| Atlanta | 21 | 13 | 13 |
| Charleston | 21 | 13 | 13 |
| Jackson, MS | 21 | 13 | 13 |
| Birmingham | 21 | 13 | 13 |

| | | | |
|---|---|---|---|
| Memphis | 21 | None | 21 |
| El Paso | 21 | None | 21 |
| San Francisco | 21 | None | 21 |
| Baltimore | 21 | None | 21 |
| Albuquerque | 21 | None | 21 |
| Salem | 21 | None | 21 |
| Chicago | 21 | None | 21 |
| Boise | 21 | None | 21 |
| Burlington | 21 + 5* | 21 | 21 |
| Helena | 21 + 5* | 21 | 21 |
| Duluth | 21 + 5* | 21 | 21** |
| Fairbanks | 21 + 5* | 21 | 21** |

* R-21 + R-5 refer to a combination of R-21 batt insulation and R-5 insulated siding.
** R-21 was not the most cost effective, but was selected for consistency with Burlington and Helena.

#### 6.1.2.3 Ceiling Insulation

The MH working group completed sensitivity analyses for ceiling insulation requirements in the 2015 IECC to determine if cost-effective revisions were possible. The 2015 IECC has different requirements for each IECC climate zone, and the MH working group analyzed several alternative ceiling insulation options in each zone. Table 6.3 lists the ceiling insulation options analyzed by the MH working group for each of the 19 cities. Table 6.3 also lists the proposed ceiling insulation requirement for each city. The most cost-effective requirement is included in the proposed requirement.

The MH working group considered alternative ceiling insulation levels for most cities in the analysis. In the case of Miami, the MH working group did not pursue less stringent options, based on the results of the Houston sensitivity analysis of *R*-22 ceilings indicating *R*-22 was less cost-effective than *R*-30. Similarly, for Chicago, Burlington, Helena, Duluth, and Fairbanks, DOE did not analyze less stringent options based on the sensitivity analysis for Salem and Boise indicating *R*-30 was less cost effective than *R*-38.

**Table 6.3 Ceiling Insulation Options Analyzed**

| City | 2015 IECC Requirement *R-Value* | Sensitivity Analysis Options *R-Value* | Proposed Requirement *R-Value* |
|---|---|---|---|
| Miami | 30 | None | 30 |
| Houston | 38 | 22, 30, 34 | 30 |
| Phoenix | 38 | 30, 34 | 30 |
| Atlanta | 38 | 22, 30 | 30 |

| | | | |
|---|---|---|---|
| Charleston | 38 | 22, 30 | 30 |
| Jackson | 38 | 22, 30 | 30 |
| Birmingham | 38 | 22, 30 | 30 |
| Memphis | 38 | 30, 34 | 30 |
| El Paso | 38 | 30, 34 | 30 |
| San Francisco | 38 | 30, 34 | 30 |
| Baltimore | 38 | 30 | 30 |
| Albuquerque | 38 | 30 | 30 |
| Salem | 38 | 30 | 38 |
| Chicago | 38 | None | 38 |
| Boise | 38 | 30 | 38 |
| Burlington | 38 | None | 38 |
| Helena | 38 | None | 38 |
| Duluth | 38 | None | 38 |
| Fairbanks | 38 | None | 38 |

#### 6.1.2.4 Floor Insulation

The MH working group completed sensitivity analysis for the floor insulation requirements in the 2015 IECC to determine if cost-effective revisions were possible. The 2015 IECC has different requirements for each IECC climate zone, and the MH working group analyzed several alternative floor insulation options in each zone. Table 6.4 lists the floor insulation options analyzed by the MH working group for each of the 19 cities. Table 6.4 also lists the proposed floor insulation requirement for each city. The most cost-effective requirement is included in the proposed requirement.

The MH working group considered alternative floor insulation levels for most cities in the analysis. For Miami, Houston, and Phoenix, the MH working group did not pursue more stringent options, based on the results of the Atlanta, Charleston, Jackson, and Birmingham sensitivity analyses of *R*-22 and *R*-19 floor insulation (which indicated *R*-22 and *R*-19 were less cost effective than *R*-13). For Memphis, El Paso, San Francisco, Baltimore, and Albuquerque, the MH working group did not pursue less stringent options, finding that the 2015 IECC requirements were reasonable.

The MH working group found that floor insulation for Duluth and Fairbanks was most cost effective at *R*-38. However, the MH working group reassigned the floor insulation level for those cities so that Duluth and Fairbanks could be placed in the same climate zone as Salem, Chicago, Boise, Burlington, and Helena. Because very few manufactured homes are shipped to the regions represented by Duluth and Fairbanks, the MH working group assigned the most cost-effective floor insulation requirement (*R*-30) corresponding to Salem, Chicago, Boise, Burlington, and Helena to Duluth and Fairbanks.

**Table 6.4 Floor Insulation Options Analyzed**

| City | 2015 IECC Requirement *R-Value* | Sensitivity Analysis Options *R-Value* | Proposed Requirement *R-Value* |
|---|---|---|---|
| Miami | 13 | None | 13 |
| Houston | 13 | None | 13 |
| Phoenix | 13 | None | 13 |
| Atlanta | 19 | 13; 22 | 13 |
| Charleston | 19 | 13; 22 | 13 |
| Jackson | 19 | 13; 22 | 13 |
| Birmingham | 19 | 13; 22 | 13 |
| Memphis | 19 | None | 19 |
| El Paso | 19 | None | 19 |
| San Francisco | 19 | None | 19 |
| Baltimore | 19 | None | 19 |
| Albuquerque | 19 | None | 19 |
| Salem | 30 | None | 30 |
| Chicago | 30 | None | 30 |
| Boise | 30 | None | 30 |
| Burlington | 30 | None | 30 |
| Helena | 30 | None | 30 |
| Duluth | 38 | 30 | 30* |
| Fairbanks | 38 | 30 | 30* |

#### 6.1.2.5 Glazed Fenestration *U*-Factor

The MH working group completed sensitivity analysis for the glazed fenestration *U*-factor requirements in the 2015 IECC to determine if cost-effective revisions were possible. The 2015 IECC has different requirements for each IECC climate zone, and the MH working group analyzed several alternative *U*-factor options in each zone. Table 6.5 lists the glazed fenestration *U*-factor options analyzed by the MH working group for each of the 19 cities. Table 6.5 also lists the proposed *U*-factor requirement for each city. The most cost-effective requirement is included in the proposed requirement.

As discussed in chapter 5 of the TSD, glazed fenestration is available in a variety of *U*-factors, corresponding to varying design options. These design options include frame material (aluminum or vinyl), single- or dual-glazed glass (multiple panes), gas fill between the glazing (normal air or gases such as argon), and low-heat-loss glass spacers.

The MH working group agreed that aluminum framing should be eliminated from further analysis, and that low-E dual glazing was an appropriate minimum requirement. This led the group to primarily consider *U*-factors of 0.35 and lower. After finding that 0.35 *U*-factor windows were more cost effective than 0.31 *U*-factor windows in the cities of Atlanta, Charleston, Jackson, and Birmingham, the MH working group did not perform additional sensitivity analysis on *U*-factors more stringent than the 2015 IECC for cities in northern climate zones.

**Table 6.5 Glazed Fenestration *U*-Factor Options Analyzed**

| City | 2015 IECC Requirement *U-Factor* | Sensitivity Analysis Options *U-Factor* | Proposed Requirement *U-Factor* |
|---|---|---|---|
| Miami | NR | 0.35 | 0.35 |
| Houston | 0.4 | 0.35 | 0.35 |
| Phoenix | 0.4 | 0.35 | 0.35 |
| Atlanta | 0.35 | 0.31; 0.35 | 0.35 |
| Charleston | 0.35 | 0.31; 0.35 | 0.35 |
| Jackson | 0.35 | 0.31; 0.35 | 0.35 |
| Birmingham | 0.35 | 0.31; 0.35 | 0.35 |
| Memphis | 0.35 | None | 0.35 |
| El Paso | 0.35 | None | 0.35 |
| San Francisco | 0.35 | None | 0.35 |
| Baltimore | 0.35 | None | 0.35 |
| Albuquerque | 0.35 | None | 0.35 |
| Salem | 0.32 | None | 0.32 |
| Chicago | 0.32 | None | 0.32 |
| Boise | 0.32 | None | 0.32 |
| Burlington | 0.32 | None | 0.32` |
| Helena | 0.32 | None | 0.32 |
| Duluth | 0.32 | None | 0.32 |
| Fairbanks | 0.32 | None | 0.32 |

#### 6.1.2.6 Glazed Fenestration SHGC

The MH working group completed sensitivity analysis for the glazed fenestration SHGC requirements in the 2015 IECC to determine if cost-effective revisions were possible. The 2015

IECC has different requirements for each IECC climate zone, and the MH working group analyzed several alternative SHGC options in each zone. Table 6.6 lists the glazed fenestration SHGC options analyzed by the MH working group for each of the 19 cities. Table 6.6 also lists the proposed SHGC requirement for each city. The most cost-effective requirement is included in the proposed requirement.

The MH working group did not run sensitivity analyses for different SHGC options for cities found in the northern climate zones (Salem, Chicago, Boise, Burlington, Helena, Duluth, and Fairbanks). SHGC tends to have a smaller impact on energy use in regions dominated by heating rather than cooling loads. In these locations, more stringent SHGC can lead to increased energy consumption by blocking the solar heating effects of sunlight. For these reasons, the MH working group recommended not modifying the 2015 IECC specification of no requirement.

The MH working group recommended that DOE perform a sensitivity analysis of the total cost of ownership to determine the most cost-effective SHGC for climate zones 1B and 2, which includes Atlanta, Charleston, Jackson, Birmingham, Memphis, El Paso, San Francisco, Baltimore, and Albuquerque. *See* Term Sheet at 3, Recommendation 5. This sensitivity analysis placed all windows on one side of the manufactured home, with the windows facing west. This window orientation gives SHGC the greatest impact on energy use. As described in a request for information (hereafter the 2015 RFI) published on February 11, 2015, DOE conducted this sensitivity analysis and found an SHGC of 0.30 was most cost-effective based on a 10-year cost of ownership savings calculation. *See* 80 FR 7550.

Based on comments received in response to the 2015 RFI, DOE determined that the window orientation assumption in the 2015 RFI was inconsistent with all other analytical assumptions, which are detailed in chapter 7 of this TSD. A more representative energy use analysis of SHGC places windows uniformly on all sides of the home, to represent the average window orientation experienced in aggregate across sited manufactured homes. While the assumption of all windows facing west represents the highest energy use window orientation, manufactured homes with other window orientations would not experience as large an economic benefit.

DOE repeated its SHGC sensitivity analysis of climate zones 1B and 2 using a uniform window orientation to study the economic impacts of an SHGC of 0.25, 0.30, and 0.33. This analysis indicated SHGC of 0.33 had the largest total cost of ownership savings, and therefore, DOE proposes requiring SHGC of 0.33 in climate zones 1B and 2, as is indicated in Table 6.6.

**Table 6.6 SHGC Options Analyzed**

| City | 2015 IECC Requirement | Sensitivity Analysis Options | Proposed Requirement |
|---|---|---|---|
| Miami | 0.25 | 0.33 | 0.25 |
| Houston | 0.25 | 0.33; 0.4 | 0.25 |
| Phoenix | 0.25 | 0.33 | 0.25 |

| | | | |
|---|---|---|---|
| Atlanta | 0.25 | 0.25; 0.30; 0.33; 0.4 | 0.33 |
| Charleston | 0.25 | 0.25; 0.30; 0.33 | 0.33 |
| Jackson | 0.25 | 0.25; 0.30; 0.33 | 0.33 |
| Birmingham | 0.25 | 0.25; 0.30; 0.33; 0.4 | 0.33 |
| Memphis | 0.25 | 0.25; 0.30; 0.33 | 0.33 |
| El Paso | 0.25 | 0.25; 0.30; 0.33 | 0.33 |
| San Francisco | 0.25 | 0.25; 0.30; 0.33 | 0.33 |
| Baltimore | NR | 0.25; 0.30; 0.33; 0.4 | 0.33 |
| Albuquerque | NR | 0.25; 0.30; 0.33; 0.4 | 0.33 |
| Salem | NR | None | None |
| Chicago | NR | None | None |
| Boise | NR | None | None |
| Burlington | NR | None | None |
| Helena | NR | None | None |
| Duluth | NR | None | None |
| Fairbanks | NR | None | None |

#### 6.1.2.7 Hot Water Pipe Insulation

The 2015 IECC requires that hot water pipes be insulated to *R*-3. The MH working group agreed to recommend DOE retain the *R*-3 insulation requirement, but revise the categories of hot water pipe that must be insulated. The categories of pipes that must be insulated include, regardless of size, those that are outside conditioned space, and those connecting a service water heating system to a distribution manifold. DOE excluded the following categories: piping serving more than one dwelling unit; piping under a floor slab; buried-in piping; and supply and return piping in recirculation systems other than demand recirculation systems. These excluded categories were considered not applicable to manufactured homes. The MH working group did not carry out sensitivity analyses for alternative levels of pipe insulation.

#### 6.1.2.8 Duct Sealing

The 2015 IECC requires that duct leakage must be no greater than four cubic feet per minute (cfm) per 100 square feet of floor area at a 25 pascal test pressure, when measured post-construction. The 2015 IECC also has duct leakage requirements based on rough-in testing, where the maximum duct leakage required must be four cfm/100 $ft^2$ with the air handler installed, and three cfm/100f $t^2$ without the air handler installed. The MH working group considered only the post-construction test to be consistent with MH industry practice. *See* 9/10/2014 Working Group Transcript, EERE-2009-BT-BC-0021-0133 at p. 227. The MH working group agreed to recommend retaining the four cfm duct leakage requirement and did not carry out sensitivity analyses for alternative levels of duct leakage.

### 6.1.3 Climate Zones

Having assessed the EEM options for each component in each city, the MH working group then grouped cities whose most cost-effective EEM options were the same. In doing so, the MH working group proposed the creation of a new set of climate zones, based on geographic areas best served by the same energy conservation standards. See chapter 4 of the TSD for additional discussion of the climate zones.

## 6.2 BUILDING THERMAL ENVELOPE PRESCRIPTIVE PATH REQUIREMENTS

Based on calculations of the most cost-effective EEMs and selection of four climate zones, the MH working group recommended the prescriptive path requirements in listed in Table 6.7. For comparison, Table 6.7 also lists the EEM components the MH working group assigned to represent a HUD code-compliant manufactured home.

**Table 6.7 Comparison of Component Requirements with HUD Code Baseline**

| Climate Zone | | | Location | Building Component | Efficiency Level | |
|---|---|---|---|---|---|---|
| HUD Code | IECC | Proposed Rule | | | HUD Code | Proposed Rule |
| 1 | 1A | 1 | Miami | Wall Insulation *R*-value | 11 | 13 |
| | | | | Ceiling Insulation *R*-value | 22 | 30 |
| | | | | Floor Insulation *R*-value | 22 | 13 |
| | | | | Window *U*-factor | 1.08 | 0.35 |
| | | | | Window SHGC | 0.70 | 0.25 |
| | | | | Envelope Leakage Limit | NR (8)* | 5 |
| | | | | Duct Leakage Limit | NR (12)** | 4 |
| | | | | Domestic Hot Water Pipe Insulation | NR | *R*-3 |
| 1 | 2A | 1 | Houston | Wall Insulation *R*-value | 11 | 13 |
| | | | | Ceiling Insulation *R*-value | 22 | 30 |
| | | | | Floor Insulation *R*-value | 22 | 13 |
| | | | | Window *U*-factor | 1.08 | 0.35 |
| | | | | Window SHGC | 0.70 | 0.25 |
| | | | | Envelope Leakage Limit | NR (8)* | 5 |
| | | | | Duct Leakage Limit | NR (12)** | 4 |
| | | | | Domestic Hot Water Pipe Insulation | NR | *R*-3 |
| 2 | 2B | 1 | Phoenix | Wall Insulation *R*-value | 11 | 13 |
| | | | | Ceiling Insulation *R*-value | 22 | 30 |
| | | | | Floor Insulation *R*-value | 19 | 13 |
| | | | | Window *U*-factor | 0.50 | 0.35 |
| | | | | Window SHGC | 0.60 | 0.25 |
| | | | | Envelope Leakage Limit | NR (8)* | 5 |
| | | | | Duct Leakage Limit | NR (12)** | 4 |
| | | | | Domestic Hot Water Pipe Insulation | NR | *R*-3 |
| 1 | 3A | 2 | Atlanta | Wall Insulation *R*-value | 11 | 13 |

| Climate Zone | | | Location | Building Component | Efficiency Level | |
|---|---|---|---|---|---|---|
| **HUD Code** | **IECC** | **Proposed Rule** | | | **HUD Code** | **Proposed Rule** |
| | | | | Ceiling Insulation *R*-value | 22 | 30 |
| | | | | Floor Insulation *R*-value | 22 | 13 |
| | | | | Window *U*-factor | 1.08 | 0.35 |
| | | | | Window SHGC | 0.70 | 0.33 |
| | | | | Envelope Leakage Limit | NR (8)[a] | 5 |
| | | | | Duct Leakage Limit | NR (12)[b] | 4 |
| | | | | Domestic Hot Water Pipe Insulation | NR | *R*-3 |
| 1 | 3A | 2 | Charleston | Wall Insulation *R*-value | 11 | 13 |
| | | | | Ceiling Insulation *R*-value | 22 | 30 |
| | | | | Floor Insulation *R*-value | 22 | 13 |
| | | | | Window *U*-factor | 1.08 | 0.35 |
| | | | | Window SHGC | 0.70 | 0.33 |
| | | | | Envelope Leakage Limit | NR (8)* | 5 |
| | | | | Duct Leakage Limit | NR (12)** | 4 |
| | | | | Domestic Hot Water Pipe Insulation | NR | *R*-3 |
| 1 | 3A | 2 | Jackson | Wall Insulation *R*-value | 11 | 13 |
| | | | | Ceiling Insulation *R*-value | 22 | 30 |
| | | | | Floor Insulation *R*-value | 22 | 13 |
| | | | | Window *U*-factor | 1.08 | 0.35 |
| | | | | Window SHGC | 0.70 | 0.33 |
| | | | | Envelope Leakage Limit | NR (8)* | 5 |
| | | | | Duct Leakage Limit | NR (12)** | 4 |
| | | | | Domestic Hot Water Pipe Insulation | NR | *R*-3 |
| 1 | 3A | 2 | Birmingham | Wall Insulation *R*-value | 11 | 13 |
| | | | | Ceiling Insulation *R*-value | 22 | 30 |
| | | | | Floor Insulation *R*-value | 22 | 13 |
| | | | | Window *U*-factor | 1.08 | 0.35 |
| | | | | Window SHGC | 0.70 | 0.33 |
| | | | | Envelope Leakage Limit | NR (8)* | 5 |
| | | | | Duct Leakage Limit | NR (12)** | 4 |
| | | | | Domestic Hot Water Pipe Insulation | NR | *R*-3 |
| 2 | 3A | 3 | Memphis | Wall Insulation *R*-value | 11 | 21 |
| | | | | Ceiling Insulation *R*-value | 22 | 30 |
| | | | | Floor Insulation *R*-value | 19 | 19 |
| | | | | Window *U*-factor | 0.50 | 0.35 |
| | | | | Window SHGC | 0.60 | 0.33 |
| | | | | Envelope Leakage Limit | NR (8)* | 5 |
| | | | | Duct Leakage Limit | NR (12)** | 4 |
| | | | | Domestic Hot Water Pipe Insulation | NR | *R*-3 |
| 2 | 3B | 3 | El Paso | Wall Insulation *R*-value | 11 | 21 |

| Climate Zone | | | Location | Building Component | Efficiency Level | |
|---|---|---|---|---|---|---|
| **HUD Code** | **IECC** | **Proposed Rule** | | | **HUD Code** | **Proposed Rule** |
| | | | | Ceiling Insulation *R*-value | 22 | 30 |
| | | | | Floor Insulation *R*-value | 19 | 19 |
| | | | | Window *U*-factor | 0.50 | 0.35 |
| | | | | Window SHGC | 0.60 | 0.33 |
| | | | | Envelope Leakage Limit | NR (8)* | 5 |
| | | | | Duct Leakage Limit | NR (12)** | 4 |
| | | | | Domestic Hot Water Pipe Insulation | NR | *R*-3 |
| 2 | 3C | 3 | San Francisco | Wall Insulation *R*-value | 11 | 21 |
| | | | | Ceiling Insulation *R*-value | 22 | 30 |
| | | | | Floor Insulation *R*-value | 19 | 19 |
| | | | | Window *U*-factor | 0.50 | 0.35 |
| | | | | Window SHGC | 0.60 | 0.33 |
| | | | | Envelope Leakage Limit | NR (8)* | 5 |
| | | | | Duct Leakage Limit | NR (12)** | 4 |
| | | | | Domestic Hot Water Pipe Insulation | NR | *R*-3 |
| 3 | 4A | 3 | Baltimore | Wall Insulation *R*-value | 13 | 21 |
| | | | | Ceiling Insulation *R*-value | 30 | 30 |
| | | | | Floor Insulation *R*-value | 22 | 19 |
| | | | | Window *U*-factor | 0.35 | 0.35 |
| | | | | Window SHGC | 0.33 | 0.33 |
| | | | | Envelope Leakage Limit | NR (8)* | 5 |
| | | | | Duct Leakage Limit | NR (12)** | 4 |
| | | | | Domestic Hot Water Pipe Insulation | NR | *R*-3 |
| 2 | 4B | 3 | Albuquerque | Wall Insulation *R*-value | 11 | 21 |
| | | | | Ceiling Insulation *R*-value | 22 | 30 |
| | | | | Floor Insulation *R*-value | 19 | 19 |
| | | | | Window *U*-factor | 0.50 | 0.35 |
| | | | | Window SHGC | 0.60 | 0.33 |
| | | | | Envelope Leakage Limit | NR (8)* | 5 |
| | | | | Duct Leakage Limit | NR (12)** | 4 |
| | | | | Domestic Hot Water Pipe Insulation | NR | *R*-3 |
| 3 | 4C | 4 | Salem | Wall Insulation *R*-value | 13 | 21 |
| | | | | Ceiling Insulation *R*-value | 30 | 38 |
| | | | | Floor Insulation *R*-value | 22 | 30†† |
| | | | | Window *U*-factor | 0.35 | 0.32 |
| | | | | Window SHGC | 0.33 | NR (0.33)[c] |
| | | | | Envelope Leakage Limit | NR (8)* | 5 |
| | | | | Duct Leakage Limit | NR (12)** | 4 |
| | | | | Domestic Hot Water Pipe Insulation | NR | *R*-3 |
| 3 | 5A | 4 | Chicago | Wall Insulation *R*-value | 13 | 21 |

| Climate Zone | | | Location | Building Component | Efficiency Level | |
|---|---|---|---|---|---|---|
| **HUD Code** | **IECC** | **Proposed Rule** | | | **HUD Code** | **Proposed Rule** |
| | | | | Ceiling Insulation *R*-value | 30 | 38 |
| | | | | Floor Insulation *R*-value | 22 | 30[††] |
| | | | | Window *U*-factor | 0.35 | 0.32 |
| | | | | Window SHGC | 0.33 | NR (0.33)[°] |
| | | | | Envelope Leakage Limit | NR (8)[*] | 5 |
| | | | | Duct Leakage Limit | NR (12)[**] | 4 |
| | | | | Domestic Hot Water Pipe Insulation | NR | *R*-3 |
| 3 | 5B | 4 | Boise | Wall Insulation *R*-value | 13 | 21 |
| | | | | Ceiling Insulation *R*-value | 30 | 38 |
| | | | | Floor Insulation *R*-value | 22 | 30[††] |
| | | | | Window *U*-factor | 0.35 | 0.32 |
| | | | | Window SHGC | 0.33 | NR (0.33) [°] |
| | | | | Envelope Leakage Limit | NR (8)[*] | 5 |
| | | | | Duct Leakage Limit | NR (12)[**] | 4 |
| | | | | Domestic Hot Water Pipe Insulation | NR | *R*-3 |
| 3 | 6A | 4 | Burlington | Wall Insulation *R*-value | 13 | 21 |
| | | | | Ceiling Insulation *R*-value | 30 | 38 |
| | | | | Floor Insulation *R*-value | 22 | 30[††] |
| | | | | Window *U*-factor | 0.35 | 0.32 |
| | | | | Window SHGC | 0.33 | NR (0.33) [°] |
| | | | | Envelope Leakage Limit | NR (8)[*] | 5 |
| | | | | Duct Leakage Limit | NR (12)[**] | 4 |
| | | | | Domestic Hot Water Pipe Insulation | NR | *R*-3 |
| 3 | 6B | 4 | Helena | Wall Insulation *R*-value | 13 | 21 |
| | | | | Ceiling Insulation *R*-value | 30 | 38 |
| | | | | Floor Insulation *R*-value | 22 | 30[††] |
| | | | | Window *U*-factor | 0.35 | 0.32 |
| | | | | Window SHGC | 0.33 | NR (0.33) [°] |
| | | | | Envelope Leakage Limit | NR (8)[*] | 5 |
| | | | | Duct Leakage Limit | NR (12)[**] | 4 |
| | | | | Domestic Hot Water Pipe Insulation | NR | *R*-3 |
| 3 | 7 | 4 | Duluth | Wall Insulation *R*-value | 13 | 21 |
| | | | | Ceiling Insulation *R*-value | 30 | 38 |
| | | | | Floor Insulation *R*-value | 22 | 30[††] |
| | | | | Window *U*-factor | 0.35 | 0.32 |
| | | | | Window SHGC | 0.33 | NR (0.33) [°] |
| | | | | Envelope Leakage Limit | NR (8)[*] | 5 |
| | | | | Duct Leakage Limit | NR (12)[**] | 4 |
| | | | | Domestic Hot Water Pipe Insulation | NR | *R*-3 |
| 3 | 8 | 4 | Fairbanks | Wall Insulation *R*-value | 13 | 21 |

| Climate Zone | | | Location | Building Component | Efficiency Level | |
|---|---|---|---|---|---|---|
| HUD Code | IECC | Proposed Rule | | | HUD Code | Proposed Rule |
| | | | | Ceiling Insulation *R*-value | 30 | 38 |
| | | | | Floor Insulation *R*-value | 22 | 30†† |
| | | | | Window *U*-factor | 0.35 | 0.32 |
| | | | | Window SHGC | 0.33 | NR (0.33) ▫ |
| | | | | Envelope Leakage Limit | NR (8)* | 5 |
| | | | | Duct Leakage Limit | NR (12)** | 4 |
| | | | | Domestic Hot Water Pipe Insulation | NR | *R*-3 |

* In the absence of explicit requirements for envelope leakage limit in the HUD code, the baseline leakage rate was set based on common industry practice in discussion with the MH working group.
** In the absence of HUD code requirements for duct leakage limit, the baseline leakage rate was set based on common industry practice in discussion of the MH working group.
†† Per the MH working group term sheet (see Term Sheet at p. 3, Recommendation 5.1), the floor R-value assumes R-21 batt+R-14 blanket to account for compression areas in the floor in climate zone 4.
▫ In the absence of an SHGC requirement, the SHGC corresponding to the window meeting the U-factor requirement based on ASRAC Cost Analysis (see EERE-2009-BT-BC-0021-0091) was selected for use in simulations.
NR: No requirement
Units:
Wall Insulation R-value: (hr-ft2-°F/Btu)
Ceiling Insulation R-value: (hr-ft2-°F/Btu)
Floor Insulation R-value: (hr-ft2-°F/Btu)
Window U-factor: (Btu/hr-ft2-°F)
Envelope Leakage Limit: (ACH)
Duct Leakage Limit: (cfm25/100 ft2 CFA)

## 6.3 PERFORMANCE PATH REQUIREMENTS

As an alternative to the prescriptive building thermal envelope requirements, the MH working group recommended manufacturers may instead achieve compliance by meeting performance-based $U_o$ requirements. The purpose of this performance path alternative is to allow manufacturers more design flexibility (which could reduce construction cost) than the prescriptive requirements, while achieving equivalent thermal performance. Table 6.8 lists the required $U_o$ for each climate zone and manufactured home size. DOE computed each of these $U_o$ values from the prescriptive requirements of the proposed rule listed in Table 6.7 using the Battelle method.[2] Chapter 7 of this TSD describes the MH building construction assumptions (framing factors, floor area, etc.) used in this $U_o$ calculation.

Unlike the prescriptive path, the MH working group recommended that DOE propose separate performance path requirements for homes of different size. A single-section and multi-section manufactured home using the same EEMs will result in a different $U_o$ based on differences in ratios of floor area to ceiling area and ductwork placement. In general, larger manufactured homes (multi-section) achieve a smaller $U_o$ with all EEM selections held constant. This outcome is reflected in Table 6.8 with single-section homes having larger $U_o$ requirements.

**Table 6.8 Overall Thermal Transmittance Factors for Performance Option**

| **Climate Zone** | **Single-Section *U*o** | **Multi-Section *U*o** |
|---|---|---|
| 1 | 0.087 | 0.084 |
| 2 | 0.087 | 0.084 |
| 3 | 0.070 | 0.068 |
| 4 | 0.059 | 0.056 |

# CHAPTER 7. ENERGY SIMULATION ANALYSIS

This chapter describes the energy modeling software, climate locations, and details of the overall modeling methodology used in the analysis.

## 7.1 SIMULATION TOOL

The simulation software used by DOE for this energy analysis is EnergyPlus version 8.0 (DOE 2013).[3] EnergyPlus is a whole-building energy simulation program capable of simulating detailed hourly and sub-hourly heating, cooling, and ventilation loads in a building. Since being first introduced in 1996, EnergyPlus has been under continuous development by DOE. It has its roots in the popular energy modeling software DOE-2 and the detailed Heating, Ventilation and Air-Conditioning (HVAC) system modeling software Blast (Building Loads Analysis and System Thermodynamics); EnergyPlus inherits the features of DOE-2 and Blast and combines them with additional features of its own.[3]

## 7.2 CLIMATE LOCATIONS

The energy analysis is conducted in all standardized climate zones and moisture regimes occurring in the United States, as defined by the International Codes Council (ICC) and the American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE). As Figure 7.1 shows, the ICC and ASHRAE incorporate 15 standardized climate zones, and the HUD code for manufactured homes incorporates three zones. The energy analysis is conducted in a total of 19 climate locations to provide adequate coverage between the ICC and HUD climate zones and to provide adequate consideration to states in southeastern United States (Mississippi, Alabama, Georgia, and South Carolina), which account for a large portion of manufactured home sales.

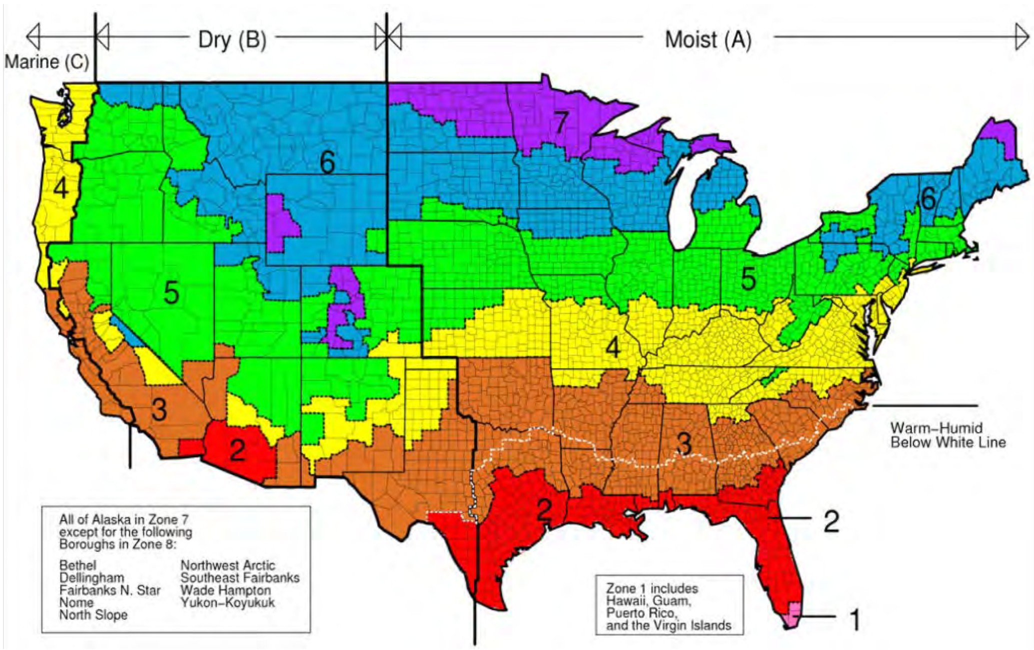



**Figure 7.1 IECC Climate Zone Map**

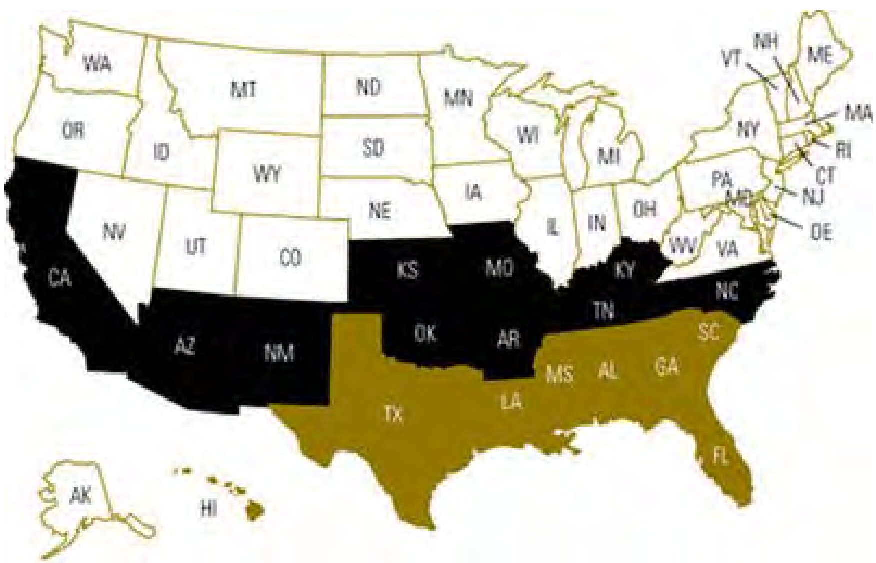



**Figure 7.2 HUD Climate Zone Map**

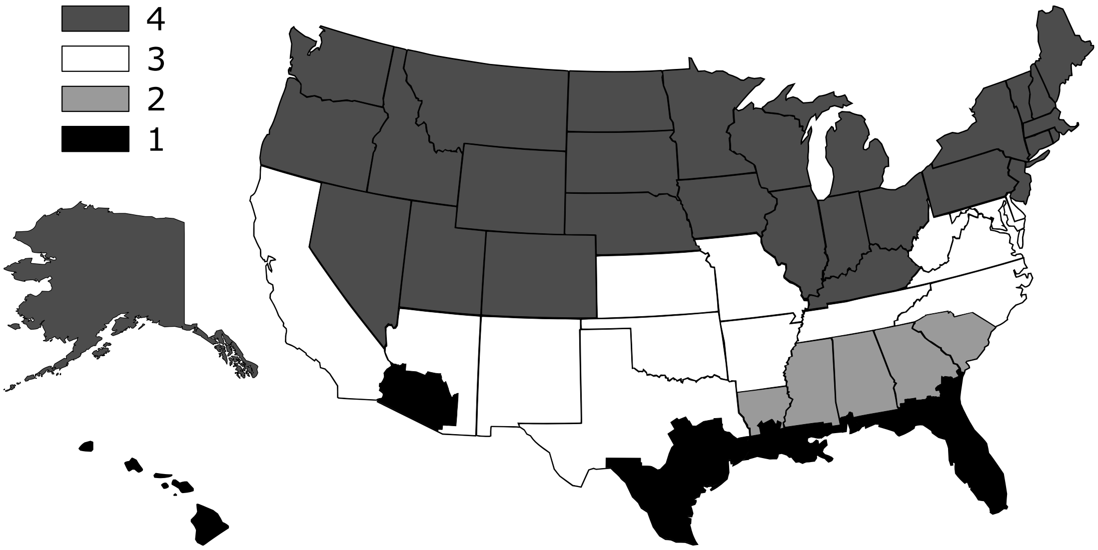



**Figure 7.3 Proposed Climate Zone Map**

Table 7.1 lists the climate locations used in the simulation analysis along with their respective HUD, IECC, and proposed climate-zone designation, as well as the Typical Meteorological Year (TMY) 3 weather file[c] used in simulations.

**Table 7.1 Climate Locations Used in Energy Analysis**

| HUD Code Zone | IECC Climate Zone | Climate Zone in Proposed Rule | Location | TMY3 Weather File Used in Simulation |
|---|---|---|---|---|
| 1 | 1A | 1 | Miami, FL | USA_FL_Miami.Intl.AP.722020_TMY3.epw |
| 1 | 2A | 1 | Houston, TX | USA_TX_Houston-Bush.Intercontinental.AP.722430_TMY3.epw |
| 2 | 2B | 1 | Phoenix, AZ | USA_AZ_Phoenix-Sky.Harbor.Intl.AP.722780_TMY3.epw |
| 1 | 3A | 2 | Atlanta, GA | USA_GA_Atlanta-Hartsfield-Jackson.Intl.AP.722190_TMY3.epw |
| 1 | 3A | 2 | Charleston, SC | USA_SC_Charleston.Intl.AP.722080_TMY3.epw |
| 1 | 3A | 2 | Jackson, MS | USA_MS_Jackson.Intl.AP.722350_TMY3.epw |
| 1 | 3A | 2 | Birmingham, AL | USA_AL_Birmingham.Muni.AP.722280_TMY3.epw |
| 1 | 3A | 2 | Memphis, TN | USA_TN_Memphis.Intl.AP.723340_TMY3.epw |
| 2 | 3B | 3 | El Paso, TX | USA_TX_El.Paso.Intl.AP.722700_TMY3.epw |
| 2 | 3C | 4 | San Francisco, CA | USA_CA_San.Francisco.Intl.AP.724940_TMY3.epw |

[c] Typical Meteorological Year 3 weather files are datasets of hourly solar radiation and meteorological elements for a period of 1 year. TMY3 files for more than 1,020 locations in the United States can be downloaded from http://apps1.eere.energy.gov/buildings/energyplus/weatherdata_about.cfm.

| | | | | |
|---|---|---|---|---|
| 3 | 4A | 3 | Baltimore, MD | USA_MD_Baltimore-Washington.Intl.AP.724060_TMY3.epw |
| 3 | 4B | 3 | Albuquerque, NM | USA_NM_Albuquerque.Intl.AP.723650_TMY3.epw |
| 3 | 4C | 4 | Salem, OR | USA_OR_Salem-McNary.Field.726940_TMY3.epw |
| 3 | 5A | 4 | Chicago, IL | USA_IL_Chicago-OHare.Intl.AP.725300_TMY3.epw |
| 3 | 5B | 4 | Boise, ID | USA_ID_Boise.Air.Terminal.726810_TMY3.epw |
| 3 | 6A | 4 | Burlington, VT | USA_VT_Burlington.Intl.AP.726170_TMY3.epw |
| 3 | 6B | 4 | Helena, MA | USA_MT_Helena.Rgnl.AP.727720_TMY3.epw |
| 3 | 7 | 4 | Duluth, MN | USA_MN_Duluth.Intl.AP.727450_TMY3.epw |
| 3 | 8 | 4 | Fairbanks, AK | USA_AK_Fairbanks.Intl.AP.702610_TMY3.epw |

## 7.3 BUILDING GEOMETRY

For the purpose of the energy analysis, the dimensions of the single-section manufactured homes are set to 14 feet by 66 feet, thus yielding a floor area of 924 square feet. The dimensions of the double-section manufactured homes are set to 28 feet by 54 feet, thus yielding a floor area of 1,568 square feet. As discussed in chapter 5 of this TSD, the double-section home is deemed to represent all multi-section homes. The floor-to-ceiling height for both homes was set to 7.5 feet. The roof is assumed to be gabled with the roof ridge along the long dimension of the homes. The window-to-floor ratio is set to 12 percent, thus yielding a window area of 111 square feet for single-section homes, and 188 square feet for double-section homes.

The window area is assumed to be distributed equally on all four facades to yield a solar-neutral orientation. While equal window distribution is atypical in any individual manufactured home, the solar-neutral approach is designed to represent an average of all home orientations. For the purposes of energy modeling, the windows are modeled as a single large window on each side. However, this is not expected to affect the results, as solar and conduction gains and losses are evenly distributed in the entire living space thermal zone. These assumptions were discussed as part of the negotiated consensus reached by the MH working group. Figure 7.4 and Figure 7.5 illustrate the two manufactured home prototype building models. Additional details about building geometry are covered in section 7.4.

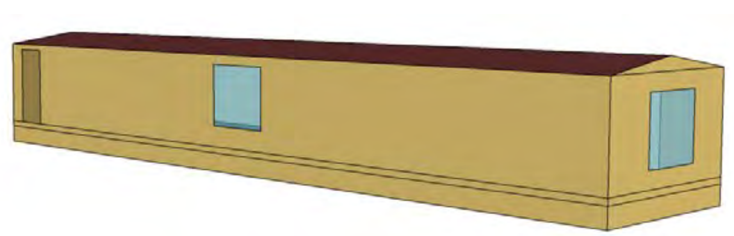


**Figure 7.4 Single-Section Manufactured Home Prototype**

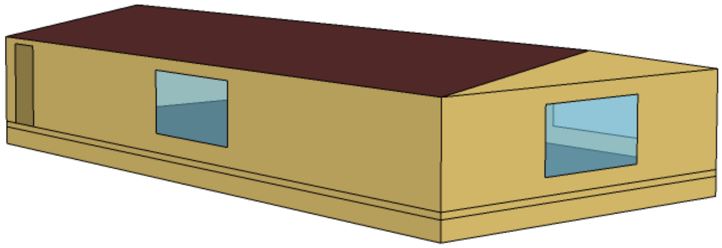


**Figure 7.5 Double-Section Manufactured Home Prototype**

The windows are assumed to have no overhangs to represent an average manufactured home. Both single-section and double-section homes are assumed to have two exterior doors with a total door area of 36 square feet. The manufactured homes are also assumed to have a vented attic and a vented crawlspace.

## 7.4 BUILDING THERMAL ENVELOPE

EnergyPlus is a detailed energy simulation program that requires detailed specification of building components for simulation. This section describes the building component assemblies and the derivation of the resulting component heat transfer coefficients (*U*-factors) for the various component efficiency levels considered in the energy analysis.

The building component assemblies typically found in manufactured homes differ from site-built homes due to the nature of construction and dimensional constraints of manufactured homes. The methodology used for calculating the *U*-factors for manufactured homes must adequately account for these constraints. The methodology published as part of an earlier analysis conducted by the Pacific Northwest National Laboratory (PNNL) by Conner and Taylor[2] has been widely accepted and used by the manufactured housing industry over the last two decades for calculating *U*-factors of various building components. This methodology is adapted to calculate the *U*-factors of building assemblies to match the component-level *U*-factors included in the cost data provided by the manufactured housing industry during the MH working group process (see EERE-2009-BT-BC-0021-091), consistent with the recommendation from the MH working group (see Term Sheet at 4-5, Recommendation 6.2). Note that for each component, the *U*-factors are representative of a particular construction technique used in the manufactured housing industry, and *U*-factors in actual homes will vary depending on the exact details of the construction.

This section describes the U-factor calculations for the ceilings, walls, and floors of a manufactured home. The heat-flow paths with and without insulation compression or reduction in thickness are computed separately for the ceilings, walls, and floors. The basic material properties used in calculations are summarized in Table 7.2, while the detailed ceiling, wall, and floor U-factor calculations are described in sections that follow.

**Table 7.2 Building Material Properties**

| Component | $R$-value (hr-ft$^2$-°F/Btu) | Material Description |
|---|---|---|
| Framing members** | 1.87 | 2” × 2” (1.5” × 1.5” actual) |
| | 4.38 | 2” × 4” (1.5” × 3.5” actual) |
| | 6.88 | 2” × 6” (1.5” × 5.5” actual) |
| | 9.74 | 2” × 8” (1.5” × 7.5” actual) |
| Air films | 0.25 | exterior air film (7.5 mph wind speed) |
| | 0.61 | horizontal air film, heat flow up |
| | 0.92 | horizontal air film, heat flow down |
| | 0.68 | vertical air film |
| Cladding and finishes | 0.45 | gypsum board, 1/2 inch |
| | 0.82 | particle board, 5/8 inch |
| | 0.00 | bottom board (thin material holding floor insulation in place) |
| | 1.00 | interior floor covering† |
| Ceiling insulation (per inch) | 2.5 to 3.7 | blown insulation†† |

* Except as noted, these data are from the 2013 *ASHRAE Fundamentals Handbook* (ASHRAE 2013, chapter 26).
** Wood framing members have a range of $R$-values. The commonly used $R$-value for wood is 1.25 per inch, which is used here. This value is also used in *2013 ASHRAE Fundamentals Handbook*; example 3, page 27.3.
† ASHRAE provides the $R$-value of linoleum as 0.51 and rugs as 1.59 (rug with rubber pad). An $R$-value of 1 is an intermediate value between these two.
†† Source: U.S. Department of Energy. *Buildings Energy Data Book*. Table 5.1.3. http://buildingsdatabook.eren.doe.gov/TableView.aspx?table=5.1.3.

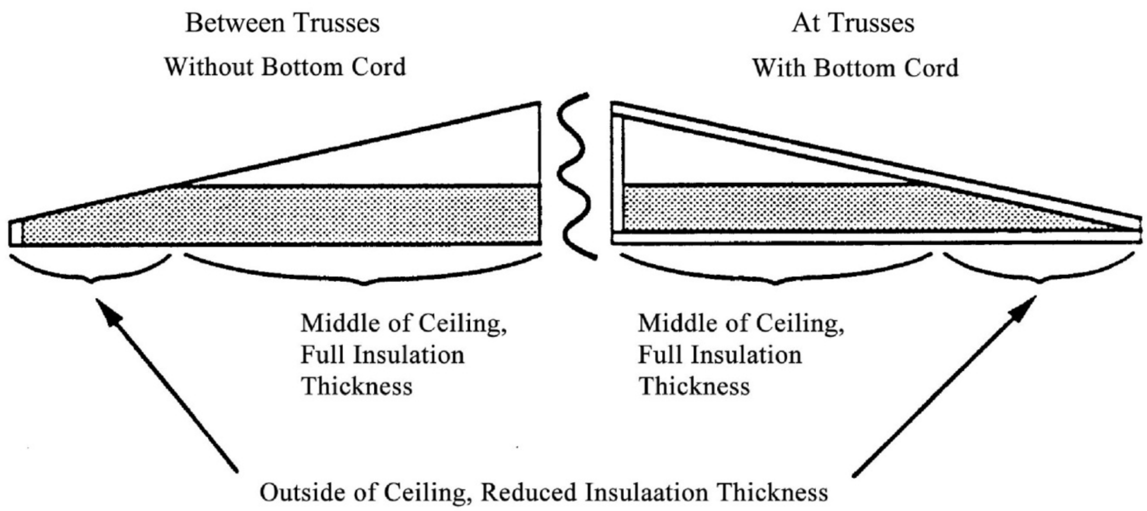
### 7.4.1 Ceiling *U*-Factors

The methodology described by Conner and Taylor[2] is applied to the current calculation of ceiling U-factors with the following assumptions: Roof trusses are 16 inches on center, accounting for 10 percent of the ceiling area framing; the truss bottom chord is 2 inches by 2 inches; the truss height is 30 inches for double-section manufactured homes and 18 inches for single-section manufactured homes; the attic cavity is ventilated with a 1-inch vented space maintained between the roof sheathing and the insulation; the heel height of the truss (from the top of the wall plate to the underside of the roof sheathing) is 2.5 inches where less than or equal to R-22 insulation is used, 5.5 inches for insulation between R-22 and R-30, and 7.5 inches where over R-38 insulation is used; the ceiling gypsum board fastened to the bottom chord of the truss is half-inch thick; blown fiberglass insulation with R-3.1 per inch is used, and 60 percent of the bottom chord is covered with insulation.[2]

As shown in Figure 7.6, the ceilings are divided into five areas for calculation purposes:

- The area in the middle portion of the roof, between the bottom chords of the trusses, with insulation at the full rated thickness
- The area in the outer portion of the roof, between the bottom chords of the truss, with insulation of reduced thickness
- The area in the middle portion of the roof, at the trusses where the bottom chord of the truss is covered by insulation up to the full height of the insulation (minus the height of the bottom chord)

- The area in the outer portion of the roof, at the trusses where the bottom chord of the truss is covered by insulation of reduced thickness where the top chord of the truss approaches the bottom chord (not shown in Figure 7.6)
- The area at the trusses where the bottom chord of the truss is uncovered by insulation due to the intersection of the bottom chord with the diagonal members of the truss or top chord of the truss, which is presumed to occur randomly over the length of the bottom chord.
-




Reproduced from Conner and Taylor.

**Figure 7.6 Ceiling Insulation**

The first step in calculating each ceiling R-value is to calculate the R-value of the ceiling excluding the insulation itself. This value does not change with insulation level. For the non-framing area between the bottom chords of the truss that R-value is:

| | |
|---|---|
| 0.61 | exterior air film (heat flow up) |
| 0.45 | ½-inch drywall |
| 0.61 | interior air film (heat flow up) |
| 1.67 | sum of above *R*-values for path without insulation |

In the area with the bottom chords and framing, the *R*-value of the bottom chord must be added:

| | |
|---|---|
| 0.61 | exterior air film (heat flow up) |
| 1.88 | 2”×2” bottom chord |
| 0.45 | ½-inch drywall |
| 0.61 | interior air film (heat flow up) |
| 3.55 | sum of above *R*-values for path without insulation |

In order to compute the ceiling insulation R-value over the area of reduced insulation thickness, the insulation thickness at the edge of the roof must be known. This thickness varies with heel height and the slope of the roof deck, and depends on the presence or absence of the bottom chord of the truss. These values are summarized in Table 7.3.

**Table 7.3 Insulation R-Value at the Roof Edge**

| Description | Roof Edge | | |
|---|---|---|---|
| Heel height (inches) | 2.5 | 5.5 | 7.5 |
| Insulation on bottom chord | *R*-0.00 | *R*-9.30 | *R*-15.50 |
| Insulation between bottom chords | *R*-4.65 | *R*-13.95 | *R*-20.15 |

The calculations for each ceiling insulation *R*-value for single- and double-section manufactured homes are detailed in Table 7.4 to Table 7.6, and Table 7.7 to Table 7.9, respectively. Table 7.10 provides a summary of ceiling *U*-factors.

**Table 7.4 Ceiling *U*-Factor for Single-Section Manufactured Homes with R-22 Ceiling Insulation**

| Description | At Trusses (Bottom Chord) | | | Between Trusses | |
|---|---|---|---|---|---|
| Insulation | None | Full | Partial | Full | Partial |
| Fraction of ceiling | 4.00% | 4.47% | 1.5% | 67.10% | 22.9% |
| *R*-value of non-insulation materials | 3.55 | 3.55 | 3.55 | 1.67 | 1.67 |
| Insulation *R*-value | 0 | 17.35 | Variable | 22 | Variable |
| Total path *R*-value | 3.55 | 20.9 | 9.79 | 23.67 | 13.14 |
| Path *U*-factor | 0.282 | 0.048 | 0.102 | 0.042 | 0.076 |
| **Overall *U*-factor = 0.0607** | | | | | |
| Insulation thickness = 7.1 inches<br>Fraction of ceiling with reduced insulation thickness = 25.44% (Ridge height = 23.5”; Heel height =2.5”) | | | | | |

**Table 7.5 Ceiling *U*-Factor for Single-Section Manufactured Homes with R-30 Ceiling Insulation**

| Description | At Trusses (Bottom Chord) | | | Between Trusses | |
|---|---|---|---|---|---|
| Insulation | None | Full | Partial | Full | Partial |
| Fraction of ceiling | 4.00% | 4.59% | 1.4% | 68.82% | 21.2% |
| *R*-value of non-insulation materials | 3.55 | 3.55 | 3.55 | 1.67 | 1.67 |
| Insulation *R*-value | 0 | 25.35 | Variable | 30 | Variable |
| Total path *R*-value | 3.55 | 28.9 | 19.80 | 31.67 | 22.71 |
| Path *U*-factor | 0.282 | 0.035 | 0.050 | 0.032 | 0.044 |
| **Overall *U*-factor = 0.0446** | | | | | |
| Insulation thickness = 9.7 inches<br>Fraction of ceiling with reduced insulation thickness = 23.53% (Ridge height = 26.5”; Heel height =5.5”) | | | | | |

**Table 7.6 Ceiling *U*-Factor for Single-Section Manufactured Homes with *R*-38 Ceiling Insulation**

| Description | At Trusses (Bottom Chord) | | | Between Trusses | |
|---|---|---|---|---|---|
| Insulation | None | Full | Partial | Full | Partial |
| Fraction of ceiling | 4.00% | 4.43% | 1.6% | 66.44% | 23.6% |
| *R*-value of non-insulation materials | 3.55 | 3.55 | 3.55 | 1.67 | 1.67 |

| | | | | | |
|---|---|---|---|---|---|
| Insulation *R*-value | 0 | 33.35 | Variable | 38 | Variable |
| Total path *R*-value | 3.55 | 36.9 | 27.00 | 39.67 | 29.86 |
| Path *U*-factor | 0.282 | 0.027 | 0.037 | 0.025 | 0.033 |
| **Overall *U*-factor = 0.0377** | | | | | |
| Insulation thickness = 12.3 inches<br>Fraction of ceiling with reduced insulation thickness = 26.17% (Ridge height = 28.5"; Heel height =7.5") | | | | | |

### Table 7.7 Ceiling *U*-Factor for Double-Section Manufactured Homes with *R*-22 Ceiling Insulation

| Description | At Trusses (Bottom Chord) | | | Between Trusses | |
|---|---|---|---|---|---|
| Insulation | None | Full | Partial | Full | Partial |
| Fraction of ceiling | 4.00% | 5.22% | 0.8% | 78.29% | 11.7% |
| *R*-value of non-insulation materials | 3.55 | 3.55 | 3.55 | 1.67 | 1.67 |
| Insulation *R*-value | 0 | 17.35 | Variable | 22 | Variable |
| Total path *R*-value | 3.55 | 20.9 | 9.79 | 23.67 | 13.14 |
| Path *U*-factor | 0.282 | 0.048 | 0.102 | 0.042 | 0.076 |
| **Overall *U*-factor = 0.0566** | | | | | |
| Insulation thickness = 7.1 inches<br>Fraction of ceiling with reduced insulation thickness = 13.02% (Ridge height = 44.5"; Heel height =2.5") | | | | | |

### Table 7.8 Ceiling *U*-Factor for Double-Section Manufactured Homes with *R*-30 Ceiling Insulation

| Description | At Trusses (Bottom Chord) | | | Between Trusses | |
|---|---|---|---|---|---|
| Insulation | None | Full | Partial | Full | Partial |
| Fraction of ceiling | 4.00% | 5.28% | 0.7% | 79.16% | 10.8% |
| *R*-value of non-insulation materials | 3.55 | 3.55 | 3.55 | 1.67 | 1.67 |
| Insulation *R*-value | 0 | 25.35 | Variable | 30 | Variable |
| Total path *R*-value | 3.55 | 28.9 | 19.80 | 31.67 | 22.71 |
| Path *U*-factor | 0.282 | 0.035 | 0.050 | 0.032 | 0.044 |
| **Overall *U*-factor = 0.0432** | | | | | |
| Insulation thickness = 9.7 inches<br>Fraction of ceiling with reduced insulation thickness = 12.04% (Ridge height = 47.5"; Heel height =5.5") | | | | | |

### Table 7.9 Ceiling *U*-Factor for Double-Section Manufactured Homes with *R*-38 Ceiling Insulation

| Description | At Trusses (Bottom Chord) | | | Between Trusses | |
|---|---|---|---|---|---|
| Insulation | None | Full | Partial | Full | Partial |
| Fraction of ceiling | 4.00% | 5.20% | 0.8% | 77.95% | 12.1% |
| *R*-value of non-insulation materials | 3.55 | 3.55 | 3.55 | 1.67 | 1.49 |
| Insulation *R*-value | 0 | 33.35 | Variable | 38 | Variable |
| Total path *R*-value | 3.55 | 36.9 | 27.00 | 39.67 | 29.86 |
| Path *U*-factor | 0.282 | 0.027 | 0.037 | 0.025 | 0.033 |
| **Overall *U*-factor = 0.0367** | | | | | |
| Insulation thickness = 12.3 inches<br>Fraction of ceiling with reduced insulation thickness = 13.39% (Ridge height = 49.5"; Heel height =7.5") | | | | | |

### Table 7.10 Ceiling *U*-Factors

| Insulation | *R*-22 | *R*-30 | *R*-38 |
|---|---|---|---|

| | | | |
|---|---|---|---|
| Double-section | *U*-0.0566 | *U*-0.0432 | *U*-0.0367 |
| Single-section | *U*-0.0607 | *U*-0.0446 | *U*-0.0377 |

### 7.4.2 Wall *U*-Factors

The methodology described by Conner and Taylor[2] is applied to the current calculation of exterior wall U-factors with the following assumptions: studs are 2 inches by 4 inches, except at R-19 and above where 2-inch by 6-inch studs are assumed; interior is 1/2-inch gypsum board and walls are vented to the exterior air; all wall studs are conservatively assumed to be 16 inches on center in the energy analysis, and therefore 25 percent[d] of the wall area is made up of the heat-flow path including the joist.

For calculation purposes, the walls were divided into two areas: the area at wall framing and the area between wall framing, with insulation.

The first step in calculating each wall U-factor is to determine the constant non-insulation portion. This value does not change with the addition of insulation. For the non-stud heat-flow path, this R-value is:

0.370 exterior air film and exterior materials
0.455 gypsum board, 1/2-inch
<u>0.680</u> interior air film (horizontal heat flow)
1.505 Sum of above *R*-value of non-stud path

In the area with the stud, the *R*-value of the stud must be added:

1.505 non-stud constant *R*-value
<u>4.375</u> 2” × 4” stud
5.880 Sum of above *R*-value for framing path

Or with the 2” × 6” stud at *R*-19 and above:

1.505 non-stud constant *R*-value
<u>6.875</u> 2” × 6” stud
8.380 Sum of above *R*-value for framing path

The wall *U*-factor calculations are provided in Table 7.11 through Table 7.15. Table 7.16 provides a summary of wall *U*-factors.

**Table 7.11 Wall *U*-Factor for Homes with *R*-11 Wall Insulation**

| Description | Frame | Insulation |
|---|---|---|
| Fraction | 25% | 75% |
| Constant *R*-value | 1.505 | 1.505 |

[d] From 2013 ASHRAE *Fundamentals Handbook*, page 27.3. The reference states that this includes an allowance for multiple studs, plates, sills, and extra framing around windows and doors.

| | | |
|---|---|---|
| Wood Stud | 4.375 | |
| Insulation *R*-value | 0 | 11 |
| Path *R*-value | 5.88 | 12.505 |
| Path *U*-value | 0.17 | 0.08 |
| **Overall *U*-factor = 0.1025** | | |

**Table 7.12 Wall *U*-factor for Homes with *R*-13 Wall Insulation**

| Description | Frame | Insulation |
|---|---|---|
| Fraction | 25% | 75% |
| Constant *R*-value | 1.505 | 1.505 |
| Wood Stud | 4.375 | |
| Insulation *R*-value | 0 | 13 |
| Path *R*-value | 5.88 | 14.505 |
| Path *U*-value | 0.17 | 0.069 |
| **Overall *U*-factor = 0.0943** | | |

**Table 7.13 Wall *U*-Factor for Homes with *R*-19 Wall Insulation**

| Description | Frame | Insulation |
|---|---|---|
| Fraction | 25% | 75% |
| Constant *R*-value | 1.505 | 1.505 |
| Wood Stud | 6.875 | |
| Insulation *R*-value | 0 | 18.24 |
| Path *R*-value | 8.38 | 19.745 |
| Path *U*-value | 0.119 | 0.051 |
| **Overall *U*-factor = 0.0680** | | |

**Table 7.14 Wall *U*-Factor for Homes with *R*-21 Wall Insulation**

| Description | Frame | Insulation |
|---|---|---|
| Fraction | 25% | 75% |
| Constant *R*-value | 1.505 | 1.505 |
| Wood Stud | 6.875 | |
| Insulation *R*-value | 0 | 21 |
| Path *R*-value | 8.38 | 22.505 |
| Path *U*-value | 0.119 | 0.044 |
| **Overall *U*-factor = 0.0628** | | |

**Table 7.15 Wall *U*-Factor for Homes with *R*-21+5 Wall Insulation**

| Description | Frame | Insulation |
|---|---|---|
| Fraction | 25% | 75% |
| Constant *R*-value | 1.505 | 1.505 |
| Wood Stud | 6.875 | |
| Insulation *R*-value | 0 | 21 |
| *R*-5 XPS | 5 | 5 |
| Path *R*-value | 13.38 | 27.505 |
| Path *U*-value | 0.075 | 0.036 |
| **Overall *U*-factor = 0.0458** | | |

**Table 7.16 Wall *U*-Factors**

| Insulation | *R*-11 | *R*-13 | *R*-19 | *R*-21 | *R*-21+5 |
|---|---|---|---|---|---|
| *U*-factor | 0.1025 | 0.0943 | 0.0680 | 0.0628 | 0.0458 |

### 7.4.3 Floor *U*-Factors

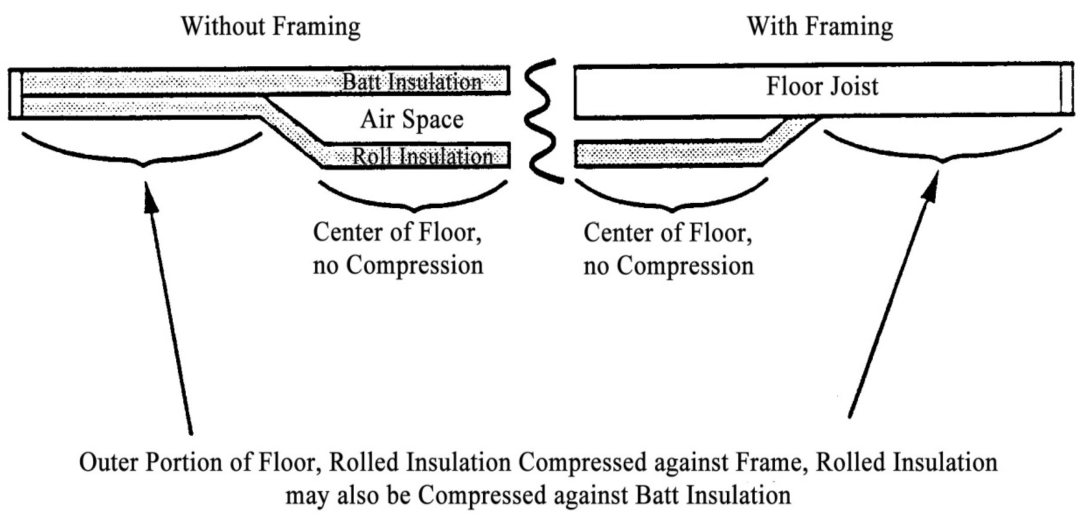
The methodology described by Conner and Taylor[2] is applied to the current calculation of floor U-factors with the following assumptions: Floor joists are 2 inches by 6 inches and spaced 16 inches on center up to and including R-22, and 2 inches by 8 inches and spaced 16 inches on center for insulation levels R-30 and above. Therefore, 10 percent of the floor area is made up of the heat-flow path, including the joists and rim joists. Where floors are insulated up to and including R-22, roll insulation is used. Where floors are insulated to R-30 and above, a combination of roll and batt insulation is used. The floor area is divided equally between the outer area and the middle area. In the outer area, there are no main ducts, and the roll insulation is held against the joists by the underbelly. In the middle area, the main ducts are against the underside of the floor framing and above the roll insulation. Also, the roll insulation does not touch the joists in the middle area. Joist insulation is held between the joists so that the bottom of the batt aligns with the bottom of the joists. The subfloor is 5/8-inch particle board, and the interior floor covering has an R-value of 1, which corresponds to a manufactured home that is largely covered with carpet but has areas of vinyl/linoleum.

Generally, in constructing an insulated floor, rolled insulation is placed under the floor and pressed up against the framing. The extent of the compression of the insulation against the framing varies with the home. For this calculation, it is assumed that the insulation would lose 12.5 percent of its R-value between the floor joists and 75 percent of its R-value where it touches the floor joists.[2] The "bottom board" in the middle portion of the subfloor containing the duct was assumed to extend below the rest of the roll insulation so that it would accommodate the duct without significant insulation compression.

For calculation purposes, the floors are divided into four areas as shown in Figure 7.7:

- The framing area in the center of the home where the roll insulation does not get compressed by the frame (note that, for "heated" floors, the floor joists have no insulating value and this area is treated as an extension of the non-framing area in the center of the home);

- The framing area on the outside portions of the home where the rolled insulation is pressed against the frame;
- The non-framing area in the center of the home where the insulation is not compressed; and
- The non-framing area on the outer portions of the home where the rolled insulation is slightly compressed by the adjacent framing members.




Source: Conner and Taylor

**Figure 7.7 Floor Insulation**

The first step in calculating each floor U-factor was to calculate the non-insulation, non-joist portion of the R-value. This value did not change with the addition of insulation or at the framing members. This was calculated separately for the "heated" and "unheated" subfloors. Heated subfloors are those portions of the floor under which HVAC ducts run, and unheated subfloors are the portion of the floors under which no ducts run.

Constant $R$-value portion of all heat-flow paths for the heated subfloor:

| | |
|---|---|
| 0.00 | crawl space |
| 0.92 | exterior air film[e] |
| 0.00 | bottom board (vinyl or kraft) |
| 0.00 | 5/8-inch particle board |
| 0.00 | floor covering (mostly rug, some vinyl) |
| <u>0.92</u> | interior air film |

[e] If the manufactured home includes skirting, the air speed under the home will be very slow. Even manufactured homes without skirting may be surrounded by other homes, trees, or other obstructions to the wind. The ground, the obstructions to the wind, and the restricted space under the home would greatly slow wind speeds under the home. Therefore, the exterior air film is probably best approximated by the air film for still air.

1.84 Sum of above *R*-values

Constant *R*-value portion of all heat-flow paths for the unheated subfloor:

0.00 crawl space
0.92 exterior air film
0.00 bottom board (vinyl or kraft)
0.82 5/8-inch particle board
1.00 floor covering (mostly rug, some vinyl)
0.92 interior air film
3.66 Sum of above *R*-values

The detailed calculations for the floor *U*-factors are provided in Table 7.17 through Table 7.22, and the overall floor *U*-factors are summarized in Table 7.23.

**Table 7.17 Floor U-Factor for Manufactured Homes with *R*-11 Floor Insulation**

| | Frame Insulation | | Non-Frame Insulation | |
|---|---|---|---|---|
| | Full | Partial | Full | Partial |
| Fraction of floor area | 0.00% | 5.00% | 50.00% | 45.00% |
| Constant *R*-value | | 1.84 | 1.84 | 1.84 |
| Roll insulation | | 2.75 | 11 | 9.625 |
| Floor joists (2" × 6") | | 0 | 0 | 0 |
| Total path *R*-value | | 4.59 | 12.84 | 11.465 |
| Path *U*-factor | | 0.2179 | 0.0779 | 0.0872 |
| **Floor *U*-factor = 0.0891** | | | | |

**Table 7.18 Floor *U*-Factor for Manufactured Homes with R-13 Floor Insulation**

| | Frame Insulation | | Non-Frame Insulation | |
|---|---|---|---|---|
| | Full | Partial | Full | Partial |
| Fraction of floor area | 0.00% | 5.00% | 50.00% | 45.00% |
| Constant *R*-value | | 1.84 | 1.84 | 1.84 |
| Roll insulation | | 3.25 | 13 | 11.375 |
| Floor joists (2" × 6") | | 0 | 0 | 0 |
| Total path *R*-value | | 5.09 | 14.84 | 13.215 |
| Path *U*-factor | | 0.1965 | 0.0674 | 0.0757 |
| **Floor *U*-factor = 0.0776** | | | | |

**Table 7.19 Floor *U*-Factor for Manufactured Homes with R-19 Floor Insulation**

| | Frame | | Non-Frame | |
|---|---|---|---|---|
| | Insulation | | Insulation | |
| | Full | Partial | Full | Partial |
| Fraction of floor area | 0.00% | 5.00% | 50.00% | 45.00% |
| Constant *R*-value | | 1.84 | 1.84 | 1.84 |
| Roll insulation | | 4.75 | 19 | 16.625 |
| Floor joists (2” × 6”) | | 0 | 0 | 0 |
| Total path *R*-value | | 6.59 | 20.84 | 18.465 |
| Path *U*-factor | | 0.1517 | 0.048 | 0.0542 |
| **Overall *U*-factor = 0.0560** | | | | |

**Table 7.20 Floor *U*-Factor for Manufactured Homes with R-22 Floor Insulation**

| | Frame | | Non-Frame | |
|---|---|---|---|---|
| | Insulation | | Insulation | |
| | Full | Partial | Full | Partial |
| Fraction of floor area | 0.00% | 5.00% | 50.00% | 45.00% |
| Constant *R*-value | | 1.84 | 1.84 | 1.84 |
| Roll insulation | | 5.5 | 22 | 19.25 |
| Floor joists (2” × 6”) | | 0 | 0 | 0 |
| Total path *R*-value | | 7.34 | 23.84 | 21.09 |
| Path *U*-factor | | 0.1362 | 0.0419 | 0.0474 |
| **Overall *U*-factor = 0.0491** | | | | |

**Table 7.21 Floor *U*-Factor for Manufactured Homes with R-30 Floor Insulation (R-11 roll, R-19 batt)**

| | Frame | | Non-Frame | |
|---|---|---|---|---|
| | Insulation | | Insulation | |
| | Full | Partial | Full | Partial |
| Fraction of floor area | 5.00% | 5.00% | 45.00% | 45.00% |
| Constant *R*-value | 3.66 | 3.66 | 3.66 | 3.66 |
| Roll insulation | 11 | 2.75 | 11 | 9.625 |
| Floor joists (2” × 8”) | 9.375 | 9.375 | 0 | 0 |
| Air space above roll insulation | 1.14 | 0 | 1.14 | 0 |
| Batt insulation | 0 | 0 | 19 | 17.57(* |
| Air space above batt | 0 | 0 | 1.14 | |
| Total path *R*-value | 25.175 | 15.785 | 35.94 | 30.85 |
| Path *U*-factor | 0.0397 | 0.0634 | 0.0278 | 0.0324 |
| **Overall *U*-factor = 0.0322** | | | | |
| *The R-11 roll insulation is 3.5 inches thick; and 75% (2.6 inches) of it is estimated to extend up between the floor joists. The R-19 batt insulation is 6 inches, which would leave 8.6 inches (2.6 + 6) of insulation in a 7.5-inch space between the joists. This is approximated by a compression of 12.7%, which is estimated to cause a reduction of the batt insulation R-value by 7.5%. | | | | |

**Table 7.22 Floor *U*-Factor for Manufactured Homes with *R*-38 Floor Insulation (*R*-19 roll, *R*-19 batt)**

| | Frame | | Non-Frame | |
|---|---|---|---|---|
| | Insulation | | Insulation | |
| | Full | Partial | Full | Partial |
| Fraction of floor area | 5.00% | 5.00% | 45.00% | 45.00% |
| Constant *R*-value | 3.66 | 3.66 | 3.66 | 3.66 |
| Roll insulation | 19 | 4.75 | 19 | 16.625 |
| Floor joists (2" × 8") | 9.375 | 9.375 | 0 | 0 |
| Air space above roll insulation | 1.14 | 0 | 1.14 | 0 |
| Batt insulation | 0 | 0 | 19 | 15.80* |
| Air space above batt | 0 | 0 | 1.14 | |
| Total path *R*-value | 33.175 | 17.785 | 43.94 | 36.09 |
| Path *U*-factor | 0.0301 | 0.0562 | 0.0228 | 0.0277 |
| **Overall *U*-factor = 0.0270** | | | | |

*The *R*-19 roll insulation is 6 inches thick; and 75% (4.5 inches) of it is estimated to extend up between the floor joists. The *R*-19 batt insulation is 6 inches, which would leave 10.5 inches (4.5 + 6) of insulation in a 7.5-inch space between the joists. This is approximated by a compression of 28.6%, which is estimated to cause a reduction of the batt insulation *R*-value by 16.8%.

**Table 7.23 Floor *U*-Factors**

| Insulation | *R*-11 | *R*-13 | *R*-19 | *R*-22 | *R*-30 | *R*-38 |
|---|---|---|---|---|---|---|
| *U*-factor | 0.0891 | 0.0776 | 0.0560 | 0.0491 | 0.0322 | 0.0270 |

## 7.5 LIGHTING

Lighting is modeled as hardwired, plug-in, and exterior based on the Building America Simulation Protocols.[4] DOE is not regulating lighting performance in the proposed rule, but lighting contributes to overall energy use in the energy simulation analysis. The corresponding lighting energy use for the baseline is calculated using Building America's equations shown in Table 7.24 based on conditioned floor area.

**Table 7.24 Baseline Lighting Energy Use for HUD Code**

| Type | | Energy Use |
|---|---|---|
| Interior Hardwired | = | 0.8 × (CFA x 0.542 + 334) kWh/yr |
| Interior Plug-in Lighting | = | 0.2 × (CFA x 0.542 + 334) kWh/yr |
| Exterior Lighting | = | CFA × 0.145 kWh/yr |

Building America assumes that 66 percent of all lamps are incandescent, 21 percent are compact fluorescent (CFL), and the remaining 13 percent are T-8 linear fluorescent in the baseline (*i.e.*, when the energy code has no requirements for efficient lamps (CFL and fluorescent)). DOE applied this assumption to the HUD code and to the proposed rule.

**Table 7.25 Lighting Fixture Types for all Cases Considered in the Energy Analysis**

| | HUD Code % | Proposed Rule % |
|---|---|---|
| Incandescent | 66 | 66 |
| CFL | 21 | 21 |
| Linear Fluorescent | 13 | 13 |

## 7.6 INTERNAL LOADS

Internal loads include interior equipment loads such as TVs, computers, etc., people loads, and lighting loads. Internal loads are not regulated by this proposed rule, but are relevant because they affect heating and cooling loads. The total internal heat gain for the baseline HUD code and proposed rule is assumed to be 67.5 kBtu/day for double-section manufactured homes, and 48.1 kBtu/day for single-section manufactured homes, as calculated using the assumptions in section R405 of the 2015 IECC.

## 7.7 ENVELOPE LEAKAGE

In EnergyPlus, air leakage through the building envelope is specified using effective leakage area (ELA), which is a measure of the total area of all sources of leakage in the building envelope. The input to EnergyPlus is the ELA at a 4 pascal reference pressure differential. This value is converted to the required EnergyPlus input of ELA using the methodology described by Mendon et al.[5] Table 7.26 lists the specific ELA values used in this analysis as input to EnergyPlus to model the HUD code (8 ACH) and proposed rule (5 ACH) requirements.

**Table 7.26 Effective Leakage Area**

| Description | Effective Leakage Area ($in^2$) | |
|---|---|---|
| **Air Changes at 50 Pa** | **Double section** | **Single section** |
| 3 | 32.27 | 19.01 |
| | 53.79 | 31.70 |
| 8 | 86.06 | 50.72 |

## 7.8 MECHANICAL SYSTEMS

Heating, ventilation and air conditioning (HVAC) systems in new manufactured homes are commonly electric air conditioning units with heating provided by a natural gas, liquid petroleum gas (LPG) furnace or oil furnace, electric resistance heating, or electric heat pump heating. Hence, these five HVAC systems have been considered in this analysis. This section describes the details of the HVAC system. The proposed rule would require no changes (*i.e.*, upgrades) to the heating and cooling equipment.

### 7.8.1 Thermal Zoning and Thermostat Set-Points

The manufactured home model is divided into three thermal zones for simulation purposes: a conditioned living zone, an unconditioned attic, and an unconditioned crawl space. The attic is assumed to be ventilated through eave and ridge vents. The heating set-point is assumed to be 72 °F (22.22 °C), and the cooling set-point is assumed to be 75 °F (23.88 °C) per IECC 2015.

### 7.8.2 HVAC System Sizing

The size of the heating and cooling coils is obtained by running the EnergyPlus design day simulation for the purpose of this energy analysis. EnergyPlus allows users to specify a winter design day and a summer design day, which are used for determining the heating and cooling coil size. The winter and summer design days are selected based on the ASHRAE heating and cooling design day criteria.[6]

### 7.8.3 HVAC Equipment Efficiency

The equipment efficiencies of all the five systems analyzed in this energy analysis are summarized in Table 7.27. These efficiencies are established in existing federal appliance standards.

**Table 7.27 Equipment Efficiencies**

| System | Efficiency |
|---|---|
| Electric AC with natural gas or liquid petroleum gas furnace | Seasonal energy efficiency ratio (SEER) of 13; annual fuel utilization efficiency of 80% |
| Electric AC with electric resistance heating | SEER 13; 100% heating efficiency |
| Electric heat pump | SEER of 14; heating seasonal performance factor of 8.2 |
| Electric AC with oil furnace | SEER of 13; annual fuel utilization efficiency of 75% |

### 7.8.4 Duct Leakage

EnergyPlus has the capability to simulate detailed duct losses with the "AirflowNetwork" model, which has been used in the present analysis to quantify duct losses. The ducts are assumed to be located in the crawlspace. All ducts, except the crossover duct for double-section manufactured homes, are assumed to be placed above the belly insulation under the floor so that they are surrounded by the floor insulation. Hence, the ducts are approximated to be insulated to the level of the floor belly insulation. The crossover duct for a double-section home is assumed to be insulated by *R*-8 duct insulation in all cases. Duct leakage is modeled as leakage from the main supply duct into the crawl space.

The proposed rule follows IECC 2015, which specifies thresholds for duct leakage levels; the HUD code requires sealing but does not specify duct leakage thresholds. Thus, duct leakage rates for the HUD baseline are assumed based on research conducted by Lucas et al.[7] The duct leakage threshold for the proposed rule is set at 4 cfm per 100 square feet of floor area, consistent with the recommendations of the MH working group. *See* Term Sheet at 5, Recommendation 7.2. Table 7.28 summarizes the total duct leakage rates at a test pressure of 25 pascals used for each case used in the energy analysis.

**Table 7.28 Duct Leakage Assumptions**

| Code | Cfm 25 Per 100 ft$^2$ of Floor Area | Single-Section *cfm 25* | Double-Section *cfm 25* |
|---|---|---|---|
| HUD | 12 | 111 | 188 |
| Proposed Rule | 4 | 37 | 63 |

### 7.8.5 Domestic Hot Water System

The water heater in all cases is assumed to be a storage-type water heater with energy conservation levels established by federal appliance standards. 10 CFR 430.32(d) Consistent with the recommendation of the MH working group (*see* Term Sheet at 6, Recommendation 7.3), all hot water pipes outside the conditioned space are assumed to be insulated to *R*-3, in addition to all hot water pipes from a water heater to a distribution manifold, which are also assumed to be insulated to *R*-3.

# CHAPTER 8. LIFE-CYCLE COST ANALYSIS

## 8.1 INTRODUCTION

EISA directs DOE to consider purchase price and LCC impacts when developing its energy conservation standards for manufactured housing. *See* 42 U.S.C. 413(b)(1). The effect of amended standards on individual customers usually includes a reduction in operating cost and an increase in purchase cost. This chapter describes two metrics used in the analysis to determine the economic impact of standards on individual residential consumers.

- LCC is the total customer cost over the life of an appliance or product, including purchase costs and operating costs (which include maintenance, repair, and energy costs). Future operating costs are discounted to the time of purchase and summed over the lifetime of the appliance or product.
- Payback period (PBP) measures the amount of time it takes customers to recover the assumed higher purchase price of more energy-efficient products through reduced operating costs.

## 8.2 LIFE-CYCLE COST AND PAYBACK PERIOD ANALYSIS INPUTS

### 8.2.1 Manufactured Home Incremental Purchase Price

Table 8.1 presents the total incremental purchase price for single-section and multi-section homes associated with the proposed rule. These incremental costs over the minimum requirements of the HUD code baseline are associated with the different energy efficiency measures such as thicker insulation. Details of the incremental costs of the individual components can be found in chapter 5 of this TSD.

**Table 8.1 Total Incremental Purchase Price of Manufactured Homes Under the Proposed Standard Over the HUD Code**

| Climate Zone | City | Total Incremental Purchase Price *2015$* | |
|---|---|---|---|
| | | **Single-Section** | **Multi-Section** |
| 1 | Miami | 2,443.20 | 3,828.76 |
| | Houston | 2,443.20 | 3,828.76 |
| | Phoenix | 1,576.35 | 2,361.02 |
| 2 | Atlanta | 2,348.41 | 3,668.22 |
| | Charleston | 2,348.41 | 3,668.22 |
| | Jackson | 2,348.41 | 3,668.22 |
| | Birmingham | 2,348.41 | 3,668.22 |
| 3 | Memphis | 2,268.69 | 3,030.44 |
| | El Paso | 2,268.69 | 3,030.44 |
| | San Francisco | 2,268.69 | 3,030.44 |
| | Baltimore | 1,219.46 | 1,348.40 |
| | Albuquerque | 2,268.69 | 3,030.44 |
| 4 | Salem | 2,207.63 | 2,877.44 |
| | Chicago | 2,207.63 | 2,877.44 |

| | | | |
|---|---|---|---|
| | Boise | 2,207.63 | 2,877.44 |
| | Burlington | 2,207.63 | 2,877.44 |
| | Helena | 2,207.63 | 2,877.44 |
| | Duluth | 2,207.63 | 2,877.44 |
| | Fairbanks | 2,207.63 | 2,877.44 |
| | National Average* | 2,226.12 | 3,109.20 |

*National average represents a shipment-weighted average. A detailed description of the shipments model can be found in chapter 10 of this NOPR TSD.

### 8.2.2 Financial Parameters

The majority of manufactured homes purchased are financed. Based on data submitted during the MH working group negotiated consensus process, approximately 70 percent of manufactured homes are purchased using a loan, and 30 percent of manufactured homes are purchased outright. (MHI, EERE-2009-BT-BC-0021-0122 at p. 191) DOE used these figures for the LCC and PBP analyses. DOE also defined several financing parameters that affect the cost and duration of the loan, including the mortgage interest rate, loan term, down payment, points, loan fees, and private mortgage insurance.

#### 8.2.2.1 Mortgage Type and Interest Rate

The mortgage interest rate can vary greatly depending on whether the loan is a personal property loan (often referred to as a “chattel loan”) or a real estate loan. Real estate loans may be easier to obtain when the home buyer is purchasing land in addition to the manufactured home and/or where the manufactured home is located on a permanent foundation. Personal property loans are typically obtained when the land upon which the manufactured home is placed is leased.[8]

According to data submitted during the MH working group negotiated consensus process, 78 percent of manufactured homes that are purchased with financing use a personal property loan, and 22 percent of financed purchases use a real estate loan (Next Step Network, EERE-2009-BT-BC-0021-74 at p. 1) DOE used these values to account for the fraction of loans by loan type in the analysis.

According to data submitted during the MH working group negotiated consensus process, real estate loans typically have a mortgage interest rate ranging from 3.957 percent to 4.320 percent. DOE assumed a five percent mortgage interest rate for real estate loans as a conservative estimate. (Next Step Network, EERE-2009-BT-BC-0021-74 at p. 1) According to data submitted during the MH working group negotiated consensus process, personal property loans typically have a mortgage interest rate ranging from 6.3 percent to 9.5 percent. (Next Step Network, EERE-2009-BT-BC-0021-74 at p. 1) DOE assumed a nine percent interest rate for personal property loans as a conservative estimate.

#### 8.2.2.2 Loan Term

According to data submitted to the MH working group, personal property loan terms range from 12 to 20 years, and real estate loans range from 15 to 30 years. (Next Step Network, EERE-2009-

BT-BC-0021-74 at p. 1) DOE assumed a 15-year loan term for personal property loans and a 30-year loan term for real estate loans.

#### 8.2.2.3 Down Payment

According to the MH working group, personal property loans require a down payment of 12 to18 percent of the total value of the loan, and real estate loans require a down payment of 10 to 20 percent of the total value of the loan. (Next Step Network, EERE-2009-BT-BC-0021-74 at p. 1) DOE assumed that both types of loans would require a 20-percent down payment of the total value of the loan for this analysis.

#### 8.2.2.4 Points and Loan Fees

According to the MH working group, both personal property and real estate loans have points and loan fees of one to two percent of the total value of the loan. (Next Step Network, EERE-2009-BT-BC-0021-74 at p. 1) DOE assumed a loan fee of one percent for both personal property loans and real estate loans in its analysis.

#### 8.2.2.5 Private Mortgage Insurance

The 2013 American Housing Survey reports that only about 12 percent of manufactured home loans include private mortgage insurance in the mortgage payment.[1] Therefore, no private mortgage insurance was assumed in this analysis.

#### 8.2.2.6 Summary

The MH working group reviewed the financial assumptions used in the LCC analysis during the negotiated consensus process. The MH working group agreed with these assumptions and based its recommendations to DOE on the results of the LCC analysis.

### 8.2.3 Discount Rate (Alternative Investment Rate)

A LCC analysis must sum costs and benefits occurring in different years into a common valuation, known as the present value. To translate costs and benefits occurring in future years as a present value, a discount rate needs to be established.

One possibility is to set the discount rate to be equivalent to the mortgage interest rate. Mortgage prepayment is an "investment" available to consumers who purchase manufactured homes using financing. One argument for using a discount rate established by mortgage prepayment is that the homebuyer has borrowed money at that rate, demonstrating that his implicit discount rate must be at least that high. Further, paying off the mortgage early represents a reasonable and usually available alternative investment for the consumer. Mortgage prepayment was used to establish the discount rate for this analysis; therefore, nominal discount rates of nine percent for consumers using personal property loans and five percent for consumers using real estate loans were used in this analysis. For manufactured homes that are purchased outright (*i.e.*, cash purchase), DOE assumed a discount rate of five percent.

The MH working group reviewed the discount rates used in the LCC analysis during the negotiated consensus process. The MH working group agreed with these assumptions and based its recommendations to DOE on the results of the LCC analysis.

### 8.2.4 Analysis Period

DOE's economic analysis examines the costs affecting all consumers who live in manufactured homes. In performing this analysis, DOE analyzed the costs and benefits to consumers over a 10-year analysis period and a 30-year analysis period. The 10-year analysis period represents the cost of ownership over the tenure of the first homebuyer, and the 30-year analysis period reflects the total cost of ownership over the lifetime of the manufactured home. (National Resource Defense Council, EERE-2009-BT-BC-0021-0120 at p. 343) One study estimated the average useful life for new manufactured homes that are continuously occupied as 57.5 years.[9] However, energy efficiency measures may not last as long as the house does. A 30-year lifetime was selected for purposes of this analysis, as a typical length that energy efficiency measures last in the aggregate. The impact of the selection of a 30-year lifetime for the analysis on energy cost savings is reduced by the effect of the discount rate in reducing the value of costs and benefits far into the future when determining the present value (*i.e.*, the benefits accrued over a longer analysis period are heavily discounted, minimizing the impact).

The MH working group reviewed the analysis periods used in the LCC analysis during the negotiated consensus process. The MH working group agreed with these assumptions and based its recommendations to DOE on the results of the LCC analysis.

### 8.2.5 Residual Value of Energy Efficiency Measures

DOE assumed that the energy efficiency measures (*e.g.*, thicker insulation) had a lifetime of 30 years before requiring replacement. In addition, DOE assumed that the value of those energy efficiency measures depreciated linearly over time to having no value at the end of its lifetime. This residual value of the energy efficiency measures becomes significant for the 10-year analysis period. DOE assumed that at the end of the 10-year analysis period, the homebuyer is able to sell the manufactured home adjusting for the depreciated value of the energy efficiency measures. In the 30-year analysis period, the energy efficiency measures have depreciated to $0.00, so the homebuyer is not able to recoup any of their initial investment.

The MH working group reviewed the residual value assumption used in the LCC analysis during the negotiated consensus process. The MH working group agreed with this assumption and based its recommendations to DOE on the results of the LCC analysis.

### 8.2.6 Property Tax and Sales Tax Rate

Property taxes vary widely within and among states. The median property tax rate reported by the 2013 American Housing Survey for all manufactured homes is $10 per $1,000 in home value.[1] Therefore, for purposes of this analysis, DOE assumed a property tax rate of 1.0 percent.

Sales tax also varies by state. Sales taxes on manufactured home purchases often are lower than sales tax for the purchase of other consumer goods. This is because some states, including Texas, Minnesota, and Indiana, apply a 0.65 multiplier to reduce their sales tax to account for material costs and not labor costs. Texas has a sales tax of 3.25 percent on manufactured homes.[10] Mississippi has a sales tax of 3 percent for manufactured homes, compared to a sales tax of 7 percent for most other items.[11] For the purpose of this analysis, DOE has assumed a tax rate of 3 percent for all 50 states.

The MH working group reviewed the property tax and sales tax assumptions used in the LCC analysis during the negotiated consensus process. The MH working group agreed with these assumptions and based its recommendations to DOE on the results of the LCC analysis.

### 8.2.7 Income Tax Deduction

The marginal income tax rate paid by the homeowner determines the value of the mortgage tax deduction. However, DOE determined that most owners of manufactured homes do not itemize their income tax deduction. The 2013 American Housing Survey reports a median income of $30,407 for all manufactured home owners.[1] The Internal Revenue Service reports that of the tax filers who earned less than $50,000 per year in 2012, only 13 percent made itemized deductions.[12] Because only a small portion of manufactured home owners likely itemize their income tax deductions, DOE assumed no benefit to the homeowner for the mortgage tax deduction.

The MH working group reviewed the income tax deduction assumption used in the LCC analysis during the negotiated consensus process. The MH working group agreed with this assumption and based its recommendations to DOE on the results of the LCC analysis.

### 8.2.8 Fuel Price Parameters

Fuel prices are expected to rise over the length of the analysis period. To accurately calculate energy cost savings from improved energy efficiency, both current fuel prices and fuel price escalation rates were required.

#### 8.2.8.1 Current Fuel Prices

Table 8.2 provides the fuel costs assumed in this analysis. The natural gas, LPG, and distillate fuel oil prices are national average residential fuel prices from the 2015 *Annual Energy Outlook (AEO)*.[13] The electricity prices are national average residential prices from the DOE Energy Information Administration *Short-Term Energy Outlook*.[14] These electricity prices take into account summer (air conditioning) and winter (heating) variations in electricity rates. Specifically, DOE used electricity prices from 2014 quarter 2 and quarter 3 for summer electricity prices, and quarter 4 of 2014 and quarter 1 of 2015 for winter electricity prices.[14]

**Table 8.2 National Average Residential Fuel Costs for Winter 2014-2015 (Heating) and Summer 2014 (Air Conditioning)**

| | Energy Cost |
|---|---|

| | |
|---|---|
| Electricity | 12.3 cents/kwh (Winter)<br>12.9 cents/kWh (Summer) |
| Natural Gas | 10.67 $/MBtu |
| LPG<br>Distillate Fuel Oil | 24.18 $/MBtu<br>26.61 $/MBtu |

#### 8.2.8.2 Fuel Price Escalation Rates

Fuel price escalation rates were obtained from Table A.3 of the *AEO* 2015.[13] Table 8.3 shows the fuel price escalation rates used in the analysis.

**Table 8.3 Projected Nominal Fuel Price Escalation Rate**

| Electricity | Natural Gas | LPG | Fuel Oil |
|---|---|---|---|
| 2.5% | 3.5% | 2.3% | 2.5% |

### 8.2.9 Summary of Financial, Economic, and Fuel Price Assumptions

Table 8.4 summarizes DOE's assumptions regarding financial, economic, and fuel price.

**Table 8.4 Financial, Economic, and Fuel Price Assumptions**

| **Finance Parameters** | | |
|---|---|---|
| | **Personal Property (Chattel) Loans** | **Real Estate Loans** |
| Mortgage interest rates | 9% | 5% |
| Loan term | 15 years | 30 years |
| Down payment | 20% | 20% |
| Loan fees and points | 1% | 1% |
| **Other Rates and Times** | | |
| Discount rate (nominal) | 9% | 5% |
| Analysis Period | 30 years and 10 years | |
| Property tax rate | 0.9% | |
| **Fuel Prices and Escalation Rates** | | |
| | Price | Escalation Rate |
| Electricity<br>Summer<br>Winter | <br>12.9 cents/kWh<br>12.3 cents/kWh | 2.5% |
| Natural gas | $10.67/MBtu | 3.5% |
| Liquid petroleum gas<br>Oil | $24.18/MBtu<br>$26./MBtu | 2.3%<br>2.5% |

## 8.3 RESULTS

This section compares the costs and benefits of the proposed energy conservation standard associated with an individual consumer. As discussed in chapter 5 of this TSD, DOE's proposed standards would increase the purchase price of manufactured homes. The results described in section 8.3.1 show decreasing annual energy costs that would result from the proposed regulation. The results described in section 8.3.2 and 8.3.3 show the LCC benefits over 10-year and 30-year analysis periods, and the PBP from the consumer's perspective that would result from the adoption of the proposed standard.

### 8.3.1 Annual Energy Cost Savings

Table 8.5 shows the annual combined energy cost savings associated with the proposed rule compared to the HUD code, analyzed for single-section and multi-section manufactured homes. The energy cost savings presented in Table 8.5 represent a weighted average of the different heat types, described in chapter 10 of this TSD. Table 8.5 provides the cost savings for the first year of occupation based on the fuel costs provided in Section 8.2.8.1. The national average annual savings for homes built in compliance with the proposed rule compared to the HUD code is $344.67 for single-section manufactured homes and $489.94 for multi-section manufactured homes.

**Table 8.5 Annual Energy Cost Savings Associated with the Proposed Rule Over the HUD Code**

| Climate Zone | City | Annual Energy Cost Savings *2015$* | |
|---|---|---|---|
| | | Single-Section | Multi-Section |
| 1 | Miami | 257.58 | 426.89 |
| | Houston | 300.17 | 493.99 |
| | Phoenix | 250.51 | 408.02 |
| 2 | Atlanta | 349.08 | 575.50 |
| | Charleston | 307.26 | 504.38 |
| | Jackson | 335.36 | 549.30 |
| | Birmingham | 328.93 | 538.03 |
| 3 | Memphis | 339.42 | 489.35 |
| | El Paso | 322.62 | 463.51 |
| | San Francisco | 247.89 | 347.55 |
| | Baltimore | 309.07 | 431.79 |
| | Albuquerque | 330.29 | 471.64 |
| 4 | Salem | 279.47 | 376.55 |
| | Chicago | 407.22 | 567.89 |
| | Boise | 305.82 | 418.97 |
| | Burlington | 421.00 | 585.54 |
| | Helena | 394.38 | 542.16 |
| | Duluth | 545.72 | 759.02 |
| | Fairbanks | 753.33 | 1048.40 |
| | National Average* | 344.67 | 489.94 |

*National average represents a shipment-weighted average. A detailed description of the shipments model can be found in chapter 10 of this TSD.

Table 8.6 provides the percent savings of the space conditioning and water heating energy costs associated with the proposed rule over the HUD code for single-section and multi-section manufactured homes. These results are for the weighted average of the five heating system types discussed in chapter 10 of the TSD.

**Table 8.6 Annual Energy Cost Savings Associated with the Proposed Rule Compared to the HUD Code as a Percentage of HUD Code Energy Costs**

| Climate Zone | City | Annual Energy Cost Savings *% of HUD code* | |
|---|---|---|---|
| | | **Single-Section** | **Multi-Section** |
| 1 | Miami | 24.72 | 29.30 |
| | Houston | 25.53 | 30.60 |
| | Phoenix | 21.83 | 26.19 |
| 2 | Atlanta | 25.82 | 31.13 |
| | Charleston | 25.32 | 30.37 |
| | Jackson | 25.44 | 30.57 |
| | Birmingham | 25.28 | 30.41 |
| 3 | Memphis | 26.16 | 28.18 |
| | El Paso | 27.99 | 29.93 |
| | San Francisco | 31.83 | 34.09 |
| | Baltimore | 21.03 | 22.29 |
| | Albuquerque | 28.40 | 30.47 |
| 4 | Salem | 25.71 | 26.65 |
| | Chicago | 24.88 | 26.13 |
| | Boise | 24.87 | 26.10 |
| | Burlington | 25.35 | 26.59 |
| | Helena | 25.74 | 27.02 |
| | Duluth | 26.42 | 27.53 |
| | Fairbanks | 25.81 | 26.92 |
| | National Average* | 25.54 | 28.31 |

* National average represents a shipment-weighted average. A detailed description of the shipments model can be found in chapter 10 of this TSD.

### 8.3.2 Present Value of Life-Cycle Costs

Table 8.7 and Table 8.8 show the net LCC savings associated with the proposed rule compared to the HUD code for a 30-year and 10-year analysis period, respectively, for single-section and multi-section manufactured homes. The results account for the energy cost savings and mortgage payments over the entire analysis period discounted to a present value, using the discount rates discussed in section 8.2.3. The results in Table 8.7 and Table 8.8 represent a weighted average of the three different methods for purchasing the home discussed in section 8.2.2 and section 8.2.2.1: outright purchase with cash, financed with a personal property loan, and financed with a real estate loan. The results in Table 8.7 and Table 8.8 also represent the weighted average across all five heating system types discussed in chapter 10 of this TSD. There is net LCC savings for all cities in both single-section and multi-section homes for the 30-year analysis period and net savings for the total cost of ownership of the first homebuyer in the10-year analysis period.

### Table 8.7 30-Year Analysis Period LCC Savings of the Proposed Rule Compared to the HUD Code

| Climate Zone | City | LCC Savings *2015$* | |
|---|---|---|---|
| | | Single-Section | Multi-Section |
| 1 | Miami | 1,495.75 | 2,725.53 |
| | Houston | 2,197.30 | 3,830.68 |
| | Phoenix | 2,366.14 | 4,082.47 |
| 2 | Atlanta | 3,107.81 | 5,351.58 |
| | Charleston | 2,420.03 | 4,182.23 |
| | Jackson | 2,882.03 | 4,920.27 |
| | Birmingham | 2,776.66 | 4,735.39 |
| 3 | Memphis | 3,052.67 | 4,668.98 |
| | El Paso | 2,763.67 | 4,226.38 |
| | San Francisco | 1,595.12 | 2,400.40 |
| | Baltimore | 3,715.93 | 5,589.00 |
| | Albuquerque | 2,959.56 | 4,454.67 |
| 4 | Salem | 2,209.43 | 3,086.61 |
| | Chicago | 4,312.92 | 6,240.25 |
| | Boise | 2,649.55 | 3,795.72 |
| | Burlington | 4,610.86 | 6,629.43 |
| | Helena | 4,138.40 | 5,866.11 |
| | Duluth | 6,684.40 | 9,514.36 |
| | Fairbanks | 10,124.83 | 14,309.30 |
| | National Average* | 3,211.03 | 4,624.87 |

* National average represents a shipment-weighted average. A detailed description of the shipments model can be found in chapter 10 of this TSD.

### Table 8.8 10-Year Analysis Period Total Cost of Ownership Savings of the Proposed Rule Compared to the HUD Code

| Climate Zone | City | Total Cost of Ownership Savings *2015$* | |
|---|---|---|---|
| | | Single-Section | Multi-Section |
| 1 | Miami | 204.58 | 500.94 |
| | Houston | 534.81 | 1,021.34 |
| | Phoenix | 788.10 | 1,434.37 |
| 2 | Atlanta | 983.65 | 1,770.53 |
| | Charleston | 659.73 | 1,219.24 |
| | Jackson | 877.35 | 1,567.57 |
| | Birmingham | 827.81 | 1,480.22 |
| 3 | Memphis | 969.43 | 1,573.67 |
| | El Paso | 837.27 | 1,370.83 |
| | San Francisco | 267.33 | 484.67 |
| | Baltimore | 1,501.66 | 2,357.91 |
| | Albuquerque | 907.93 | 1,448.92 |
| 4 | Salem | 561.42 | 827.62 |
| | Chicago | 1,551.77 | 2,311.86 |
| | Boise | 766.85 | 1,158.27 |
| | Burlington | 1,669.98 | 2,463.74 |

| | | | |
|---|---|---|---|
| | Helena | 1,458.35 | 2,120.14 |
| | Duluth | 2,640.08 | 3,813.39 |
| | Fairbanks | 4,253.47 | 6,062.15 |
| | National Average* | 1,045.23 | 1,679.96 |
| * National average represents a shipment weighted average. A detailed description of the shipments model can be found in chapter 10 of this TSD. | | | |

### 8.3.3 Simple Payback

The simple payback is the purchase price increase, detailed in Table 8.1, divided by the first year energy cost savings, detailed in Table 8.5. Table 8.9 shows the simple payback for the proposed rule in the 19 cities analyzed for single-section and multi-section homes.

**Table 8.9 Simple Payback Period of the Proposed Rule**

| Climate Zone | City | Simple Payback Period *Years* | |
|---|---|---|---|
| | | Single-Section | Multi-Section |
| 1 | Miami | 9.5 | 9.0 |
| | Houston | 8.3 | 7.9 |
| | Phoenix | 6.3 | 5.8 |
| 2 | Atlanta | 7.0 | 6.7 |
| | Charleston | 7.9 | 7.5 |
| | Jackson | 7.2 | 6.9 |
| | Birmingham | 7.4 | 7.1 |
| 3 | Memphis | 7.1 | 6.5 |
| | El Paso | 7.3 | 6.8 |
| | San Francisco | 10.0 | 9.5 |
| | Baltimore | 4.3 | 3.4 |
| | Albuquerque | 7.4 | 6.8 |
| 4 | Salem | 9.1 | 8.8 |
| | Chicago | 6.2 | 5.8 |
| | Boise | 8.3 | 7.9 |
| | Burlington | 6.1 | 5.7 |
| | Helena | 6.6 | 6.2 |
| | Duluth | 4.7 | 4.4 |
| | Fairbanks | 3.5 | 3.3 |
| | National Average* | 7.1 | 6.9 |
| * National average represents a shipment-weighted average. A detailed description of the shipments model can be found in chapter 10 of this TSD. | | | |

# CHAPTER 9. LIFE-CYCLE COST SUBGROUP ANALYSIS

## 9.1 INTRODUCTION

The consumer subgroup analysis evaluates impacts on groups or customers who may be disproportionately affected by any national energy conservation standard. DOE evaluates impacts on particular subgroups of consumers by analyzing the LCC impacts for those consumers from the proposed standard. DOE determined the impact on low-income buyers using the LCC spreadsheet models for manufactured homes. Chapter 8 of the TSD explains in detail the inputs to the models used in determining LCC impacts. DOE evaluated impacts of the proposed rule on low-income buyers.

## 9.2 INPUTS

To evaluate the impacts of the proposed rule on low-income buyers, DOE evaluated the LCC savings assuming manufactured homes are purchased only with personal property loans. As described in chapter 8 of the TSD, personal property loans are typically given to lower income individuals because they do not require the homebuyer to own the land where they will place the house. Personal property loans tend to have higher interest rates to compensate for the added risk of default for a low-income consumer. Chapter 8 of the TSD presents the results as a weighted average of personal property loans, real estate loans, and outright (cash) purchases. With the exception of only analyzing the impacts on MH buyers with personal property loans, all other inputs and assumptions are consistent with chapter 8 of this TSD.

## 9.3 RESULTS

Table 9.1 and Table 9.2 show the LCC savings over a 30-year and 10-year analysis period, respectively, of the proposed rule compared to the HUD code for the purchase of a single-section and multi-section home using a personal property loan. In Miami and San Francisco, the total cost of ownership (10-year analysis period) savings are negative for single-section manufactured homes, meaning that the monetary value derived from energy savings would not be greater than the cost of the more efficient home, and consumers would incur a slight net cost. Shipments of single-section manufactured homes to Miami account for 18-percent of shipments to cities in climate zone 1, and shipments of single-section manufactured homes to San Francisco account for 3-percent of shipments to climate zone 3. This indicates that shipments to these cities do not represent the most significant share of the market in climate zones 1 and 3 respectively. Moreover, the shipment weighted average for the cities in climate zones 1 and 3 respectively would achieve net savings in the 10-year analysis period.[f] Over the entire life cycle of the manufactured home (30-year analysis period), all cities show a positive net savings. Therefore,

[f] The weighted average 10-year cost of ownership savings for single-section homes in climate zone 1 is $170.69. The weighted average 10-year cost of ownership savings for single-section homes in climate zone 3 is $671.25.

DOE considered the proposed rule to be financially beneficial, despite slight net costs in specific cities for single-section manufactured homes over a 10-year period.

**Table 9.1 30-Year Analysis Period LCC Savings of the Proposed Rule Compared to the HUD Code for Personal Property Loans**

| Climate Zone | City | LCC Savings *2015$* | |
|---|---|---|---|
| | | **Single-Section** | **Multi-Section** |
| 1 | Miami | 647.76 | 1,315.95 |
| | Houston | 1,201.02 | 2,187.69 |
| | Phoenix | 1,521.73 | 2,704.03 |
| 2 | Atlanta | 1,939.76 | 3,422.42 |
| | Charleston | 1,397.01 | 2,500.46 |
| | Jackson | 1,761.61 | 3,082.31 |
| | Birmingham | 1,678.31 | 2,936.48 |
| 3 | Memphis | 1,911.97 | 3,021.16 |
| | El Paso | 1,685.31 | 2,673.88 |
| | San Francisco | 757.39 | 1,225.36 |
| | Baltimore | 2,665.41 | 4,114.75 |
| | Albuquerque | 1,832.51 | 2,843.99 |
| 4 | Salem | 1,252.66 | 1,795.01 |
| | Chicago | 2,911.63 | 4,282.12 |
| | Boise | 1,599.10 | 2,353.43 |
| | Burlington | 3,138.87 | 4,578.47 |
| | Helena | 2,770.21 | 3,981.50 |
| | Duluth | 4,772.08 | 6,850.37 |
| | Fairbanks | 7,483.03 | 10,628.48 |
| | National Average* | 2,043.77 | 2,965.30 |

* National average represents a shipment-weighted average. A detailed description of the shipments model can be found in chapter 10 of this TSD.

**Table 9.2 10-Year Analysis Period Total Cost of Ownership Savings of the Proposed Rule Compared to the HUD Code for Personal Property Loans**

| Climate Zone | City | Total Cost of Ownership Savings *2015$* | |
|---|---|---|---|
| | | **Single-Section** | **Multi-Section** |
| 1 | Miami | (110.02)** | (7.68)** |
| | Houston | 191.46 | 466.73 |
| | Phoenix | 527.60 | 1,021.51 |
| 2 | Atlanta | 611.96 | 1,169.94 |
| | Charleston | 316.75 | 666.77 |
| | Jackson | 515.00 | 984.95 |
| | Birmingham | 469.88 | 905.00 |
| 3 | Memphis | 608.87 | 1,067.34 |
| | El Paso | 488.57 | 882.68 |
| | San Francisco | (31.85)** | 73.83 |

| | | | |
|---|---|---|---|
| | Baltimore | 1,221.95 | 1,986.95 |
| | Albuquerque | 552.57 | 953.46 |
| 4 | Salem | 243.81 | 404.84 |
| | Chicago | 1,147.13 | 1,759.05 |
| | Boise | 431.32 | 706.35 |
| | Burlington | 1,254.75 | 1,896.76 |
| | Helena | 1,061.75 | 1,583.92 |
| | Duluth | 2,139.39 | 3,127.52 |
| | Fairbanks | 3,610.95 | 5,178.40 |
| | National Average* | 683.11 | 1,150.00 |

* National average represents a shipment-weighted average. A detailed description of the shipments model can be found in chapter 10 of this TSD.
** Numbers in parentheses are negative values.

## CHAPTER 10. SHIPMENTS ANALYSIS

### 10.1 INTRODUCTION

DOE analyzes shipments of manufactured homes because shipments are a necessary input to calculating the national energy savings (NES) and the net present value (NPV), discussed further in chapter 11 of this TSD.

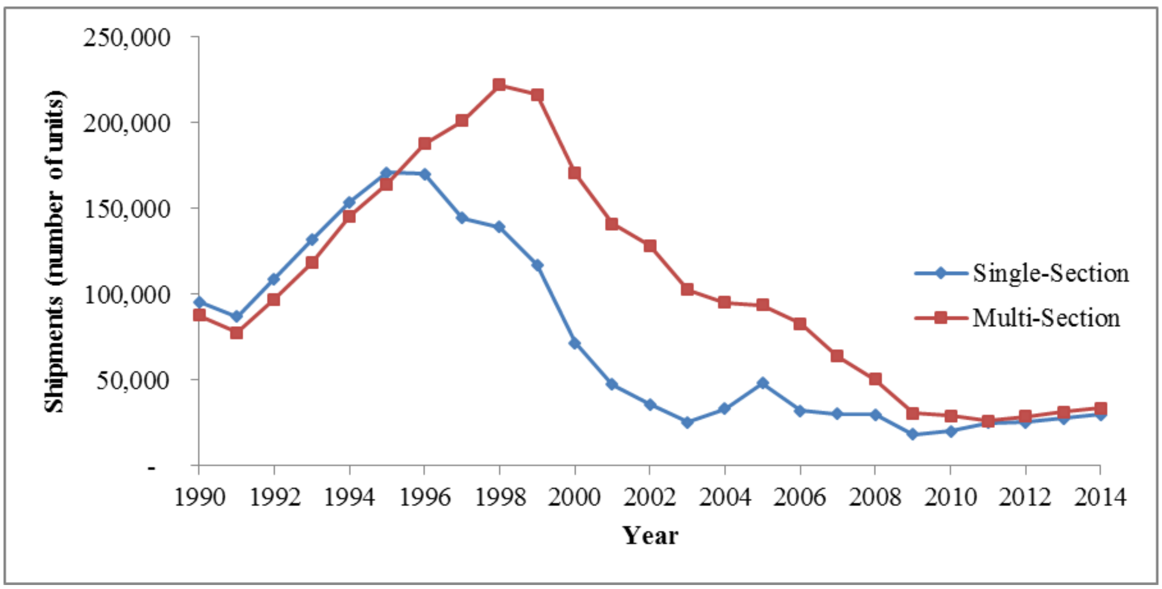
DOE developed a shipment model for manufactured housing using historical data from the Manufactured Housing Institute (MHI)[15] and using projections for growth in new housing starts from the *AEO* 2015 to forecast shipments into the future.[13]

### 10.2 BASE-CASE SHIPMENTS

The base-case shipments correspond to DOE's expectation of shipment levels during the analysis period if no energy conservation standards are adopted.

#### 10.2.1 Data Inputs

DOE used historical data from MHI to develop the base-case shipments model. MHI publishes an annual report of manufactured housing shipments categorized by state and by the number home sections (*i.e.*, single-section or multi-section). The latest report contains shipments categorized by state for single-section and multi-section manufactured homes from 1990 to 2014.[15]

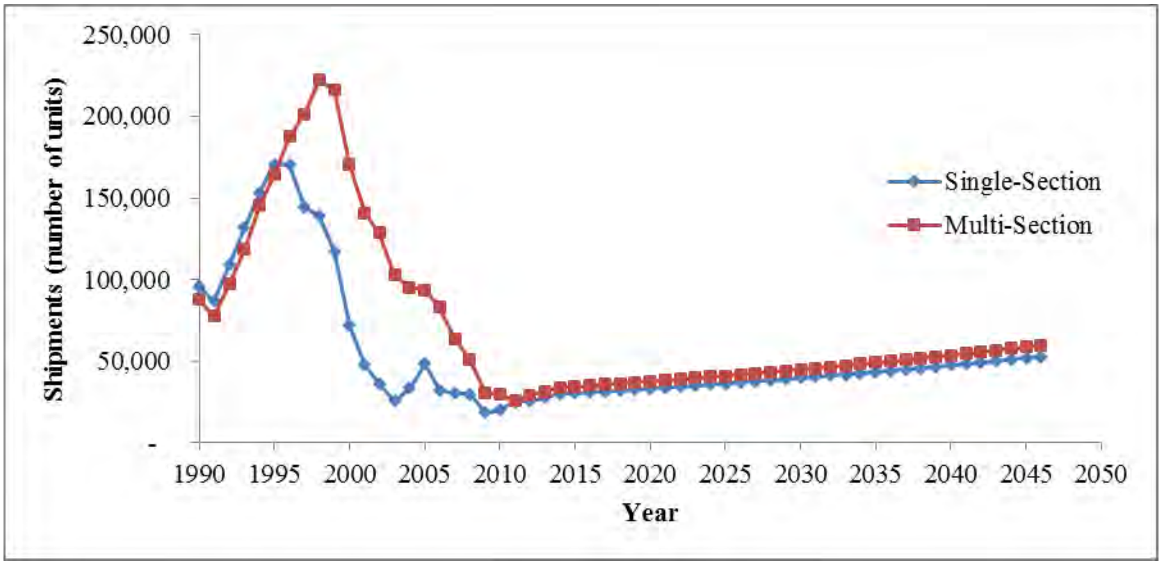



Source: Manufactured Housing Institute

**Figure 10.1 Historical Manufactured Home Shipments, 1990-2014**

Because the calculations of NES and NPV require DOE to consider 30 years of shipments from the compliance date of the proposed rule, it was necessary to forecast the shipments into the future. To estimate future shipments of manufactured homes, DOE assumed that manufactured housing shipments would grow at the same rate as the rest of the residential real estate sector.

DOE used the *AEO 2015* reference case growth rate in new residential housing starts to project shipments to 2046 for each state. Figure 10.2 shows the entire shipments model with both historical and projected shipments of single-section and multi-section manufactured homes for the entire nation.




Source: Manufactured Housing Institute

**Figure 10.2 Historical and Projected Manufactured Home Shipments, 1990-2046**

### 10.2.2 Shipment Aggregation by City

Because all energy use intensities and incremental home prices, discussed in chapter 7 and chapter 5 of this TSD, respectively, were analyzed for 19 different cities in the four proposed climate zones, it was necessary to aggregate the shipments originally categorized by state in the MHI report[15] into shipments for the 19 cities. DOE allocated shipments to the different cities according to their proximity to a state. In addition, DOE avoided allocating shipments from a state to a city in a different climate zone. For example, all manufactured housing shipments in Nevada were allocated to Boise rather than to San Francisco because both Boise and Nevada lie in proposed climate zone 4. Figure 10.3 shows how the different states were allocated to the different cities. The blue lines mark the boundary of a city's shipments. For example, all shipments in Washington and Oregon were allocated to Salem. Table 10.1 shows the fraction of the total national shipments allocated to each of the 19 cities for single- and multi-section shipments.


**Figure 10.3. Boundaries of Shipment Allocations to the 19 Cities**

**Table 10.1 Fraction of National Shipments Allocated to the 19 Cities for Single-Section and Multi-Section Manufactured Homes**

| City | Fraction of National Shipments % | |
|---|---|---|
| | Single-Section | Multi-Section |
| Miami | 4.2 | 8.6 |
| Houston | 19.2 | 12.1 |
| Phoenix | 0.6 | 1.2 |
| Atlanta | 1.2 | 2.4 |
| Charleston, SC | 2.7 | 3.7 |
| Jackson, MS | 7.7 | 5.3 |
| Birmingham | 3.6 | 4.0 |
| Memphis | 5.6 | 7.0 |
| El Paso | 16.7 | 11.6 |
| San Francisco | 0.9 | 6.8 |
| Baltimore | 7.1 | 8.1 |
| Albuquerque | 2.2 | 2.9 |
| Salem, OR | 0.9 | 3.9 |
| Chicago | 13.3 | 10.3 |
| Boise | 0.6 | 1.6 |
| Burlington | 5.9 | 6.5 |
| Helena | 3.0 | 1.6 |
| Duluth | 4.3 | 2.5 |

| | | |
|---|---|---|
| Fairbanks | 0.1 | 0.02 |

### 10.2.3 Shipment Distribution by Heating Type

As described in chapter 7 of this TSD, DOE analyzed energy use intensities of single-section and multi-section manufactured homes with five different types of heating systems: electric resistance heaters, air-source heat pumps, natural gas furnaces, LPG furnaces, and oil furnaces. As mentioned in chapter 8 and chapter 11 of this TSD, results for the LCC, NES, and NPV are presented as a weighted average of these five different heating systems. DOE used 2013 shipment data from MHI,[15] and regional data of heating type distributions submitted during the MH working group negotiated consensus process to estimate heating type distributions in each of the 19 cities.

DOE first assigned heating type distributions to the 50 states based on which of the four heating type regions that the state resided: Northeast, South, Midwest, and West. The categorization of the 50 states into the four heat type regions is detailed in Table 10.2. Next, DOE assigned heating type distributions to the 19 cities according to which states were assigned to that city, as shown in Figure 10.3. In cases where a city's borders encompassed states in different heating type distribution regions, shown in Figure 10.3, DOE calculated a shipment-weighted average to assign the heating type distribution in that city. For example, DOE calculated a shipment-weighted average fuel type distribution for El Paso. In the shipments model, El Paso shipments are aggregated from northern Texas, Oklahoma, and Kansas. Because northern Texas and Oklahoma are considered Southern states, and Kansas is considered a Midwestern state, DOE calculated a shipment-weighted average of the three states to assign the fuel type distribution in El Paso. Table 10.3 shows the heating type distribution in the four regions, and Table 10.4 shows the resulting heating type distribution in the 19 cities.

**Table 10.2 Allocation of U.S. States into Four Heating Type Regions**

| Heating Type Region | Applicable U.S. States |
|---|---|
| North | Connecticut, Maine, Massachusetts, New Hampshire, Rhode Island, Vermont, New Jersey, New York, Pennsylvania |
| South | Delaware, Florida, Georgia, Maryland, North Carolina, South Carolina, Virginia, West Virginia, Alabama, Kentucky, Mississippi, Tennessee, Arkansas, Louisiana, Oklahoma, Texas, Hawaii* |
| Midwest | Illinois, Indiana, Michigan, Ohio, Wisconsin, Iowa, Kansas, Minnesota, Missouri, Nebraska, North Dakota, South Dakota |
| West | Arizona, Colorado, Idaho, Montana, Nevada, New Mexico, Utah, Wyoming, Alaska, California, Oregon, Washington |
| *DOE assumed Hawaii had a fuel distribution of a southern state because its climate is similar to that of south Florida. | |

**Table 10.3 Distribution of Heating Types in Four U.S. Regions**

| Region | Heating System Type Distribution % | | | | |
|---|---|---|---|---|---|
| | Electric Resistance* | Electric Heat Pump* | Natural Gas Furnace** | LPG Furnace** | Distillate Oil Furnace |
| Northeast | 11 | 4 | 48 | 27 | 10 |
| South | 24 | 9 | 42 | 24 | 0 |
| Midwest | 69 | 26 | 3 | 2 | 0 |
| West | 26 | 10 | 41 | 23 | 0 |

*Assumed 27% of electric heating systems were heat pumps[67]

**Assumed 36% of gas heating systems used LPG
Source: U.S. Census Bureau. *American Housing Survey 2009--National Summary Tables.* (2010).

**Table 10.4 Distribution of Heating Types in the 19 Cities**

| City | Heating System Type Distribution % | | | | |
|---|---|---|---|---|---|
| | Electric Resistance | Electric Heat Pump | Natural Gas Furnace | LPG Furnace | Distillate Oil Furnace |
| Miami | 69 | 26 | 3 | 2 | 0 |
| Houston | 69 | 26 | 3 | 2 | 0 |
| Phoenix | 26 | 10 | 41 | 23 | 0 |
| Atlanta | 69 | 26 | 3 | 2 | 0 |
| Charleston | 69 | 26 | 3 | 2 | 0 |
| Jackson | 69 | 26 | 3 | 2 | 0 |
| Birmingham | 69 | 26 | 3 | 2 | 0 |
| Memphis | 59 | 22 | 12 | 7 | 0 |
| El Paso | 67 | 25 | 4 | 3 | 0 |
| San Francisco | 26 | 10 | 41 | 23 | 0 |
| Baltimore | 69 | 26 | 3 | 2 | 0 |
| Albuquerque | 26 | 10 | 41 | 23 | 0 |
| Salem | 26 | 10 | 41 | 23 | 0 |
| Chicago | 37 | 14 | 31 | 18 | 0 |
| Boise | 26 | 10 | 41 | 23 | 0 |
| Burlington | 11 | 4 | 48 | 27 | 10 |
| Helena | 26 | 10 | 41 | 23 | 0 |
| Duluth | 24 | 9 | 42 | 24 | 0 |
| Fairbanks | 30 | 11 | 38 | 22 | 0 |

The MH working group reviewed the final heating type distributions used in this analysis during the negotiated consensus process. The MH working group agreed with these distributions and based its recommendations to DOE on the results of this analysis.

## 10.3 STANDARDS-CASE SHIPMENTS

All standards-case shipments are assumed to just meet the proposed energy conservation standard. However, as customers shift from manufactured housing just compliant with the HUD code to manufactured housing compliant with the proposed energy conservation standard, the increase in upfront home price affects the shipment volume. This section reviews this change to shipment volume in the standards case.

Price elasticity of demand (price elasticity) is an economic concept that describes the change of the quantity demanded in response to a change in price. Price elasticity is typically represented as a ratio of the percentage change in quantity relative to a percentage change in price.

Several papers have been published describing price elasticity in the context of the manufactured housing market. Marshall and Marsh reviewed several historic studies and determined the short-term price elasticity is -0.48, meaning that a 10-percent price increase would translate to a 4.8-percent reduction in manufactured home placements.[17] This result is similar to a previous study by Kavanaugh et al. that also reviewed several historic studies. Kavanaugh estimated elasticity at -0.7.[18]

DOE found the Marshall and Marsh study to be the best basis for analysis based on its recent publication and focus on separating the short-term consumer impacts from any long-term investment decisions made by manufactured housing retailers.[17] Therefore, DOE used the elasticity value of -0.48 in its analysis of changes to future shipments in response to the proposed energy conservation standard.

To incorporate this price elasticity associated with the proposed rule into the shipments model, DOE first calculated the relative percentage increase in manufactured home purchase price under the proposed rule compared to the purchase price of homes constructed in accordance with the HUD code. DOE calculated this percentage by dividing the incremental costs described in chapter 5 this TSD by the 2014 average sales price of single-section and multi-section homes as reported by the U.S. Census Bureau (the average sales price is the assumed baseline home price).[19] Next, using these relative price increases expressed as a percentage increase in home purchase price, DOE multiplied by the elasticity value of -0.48 to get relative shipment reduction factors. DOE calculated these factors for single-section and multi-section homes in all 19 cities.

$$Standards\ Case\ Shipments = Base\ Case\ Shipments * \left(\frac{Incremental\ Cost\ Increase}{2013\ Average\ Sales\ Price} * (-0.48) + 1\right)$$

DOE applied these factors for each year of shipments in the analysis period to capture the impacts of the increased purchase price on manufactured home demand. As described in chapter 11 of this TSD, DOE did not assume that the incremental cost increase of manufactured homes would decrease over time (*i.e.,* no price learning), and therefore the shipment reduction factors do not change over time. Figure 10.4 and Figure 10.5 show the impact of price elasticity on the shipment model for single-section and multi-section manufactured homes, respectively, assuming compliance with the proposed rule in 2017.

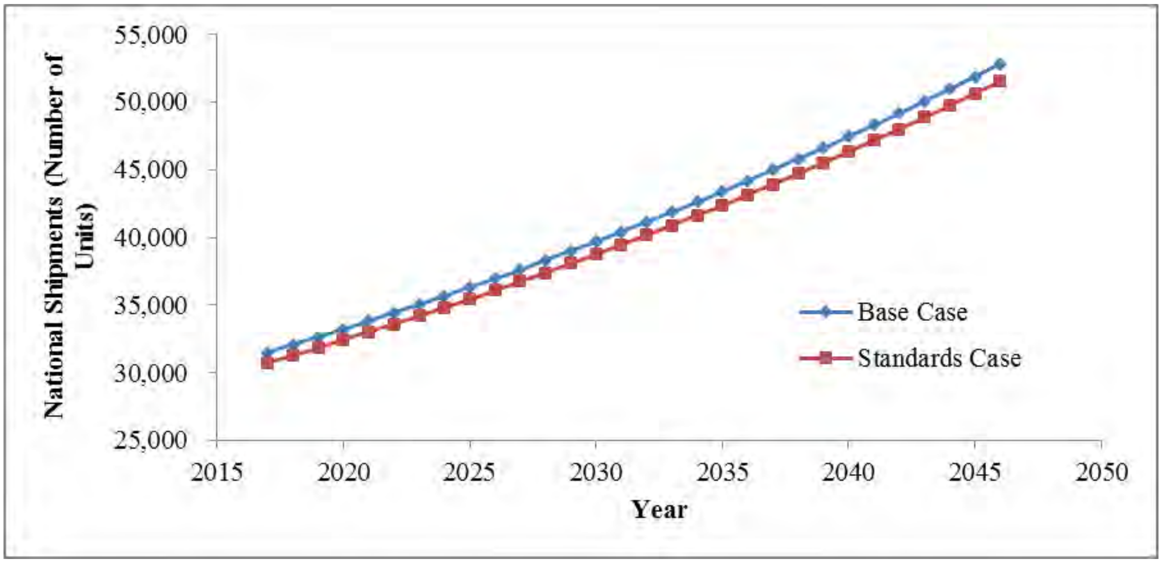



**Figure 10.4 Price Elasticity Impacts on Shipments of Single-Section Manufactured Homes, 2017-2046**

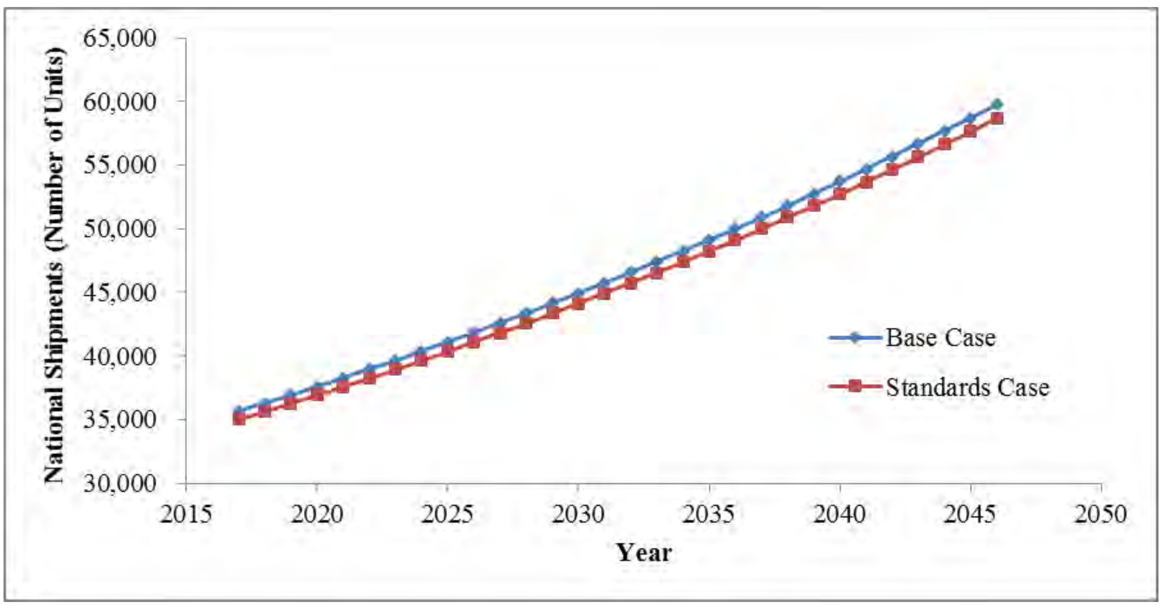



**Figure 10.5 Price Elasticity Impacts on Shipments of Multi-Section Manufactured Homes, 2017-2046**

## 10.4 SENSITIVITY ANALYSIS

To account for the range of estimates available for certain key shipment assumptions, DOE completed a sensitivity analysis. This analysis focuses on changes to two parameters: (1) a shipment growth rate of 6.5 percent instead of 1.8 percent, and (2) a price elasticity of demand of -2.40 instead of -0.48. As shown in Figure 11A.1, a 6.5% growth rate corresponds to about

300,000 more home shipments in 2046 relative to a 1.8% growth rate (about 450,000 shipments with a 6.5% growth rate versus about 100,000 shipments with a 1.8% growth rate in 2046). Based on an increased purchase price of five percent resulting from the proposed rule, this would result in an estimated loss in demand and availability of about 57,100 homes (12 percent shipment reduction) in 2046 based on -2.4 elasticity factor and 6.5 percent growth rate ~~and~~ compared to a 1.8 percent growth rate~~,~~ that would result in an estimated a loss of about 2,600 homes (2.4 percent shipment reduction) based on -0.48 elasticity factor.

To examine other impacts of the shipment sensitivities, DOE analyzed the National Energy Savings (NES) and the Net Present Value (NPV) for the proposed rule, the 2012 IECC, and 2009 IECC. The sensitivity analysis is discussed in detail in appendix 11A below.

# CHAPTER 11. NATIONAL IMPACT ANALYSIS

## 11.1 INTRODUCTION

This chapter examines selected national impacts attributable to the proposed rule for single-section and multi-section manufactured homes. The results presented here include NES; operating cost savings; increased total installed costs; and the NPV of the difference between the value of operating cost savings and increased total installed costs.

The national impact analysis (NIA) model incorporates the shipments model that DOE used to project future purchases of manufactured homes, discussed in chapter 10 of this TSD. DOE evaluates national impacts over the lifetime of all manufactured homes shipped over a 30-year analysis period from 2017 to 2046.

## 11.2 NATIONAL ENERGY SAVINGS INPUTS

DOE calculated annual NES as the difference in energy consumption between two projections: the base case (under the HUD code) and a standards case (under the proposed rule).

### 11.2.1 Unit Energy Consumption

As described in chapter 7 of this TSD, DOE modeled the annual energy consumption per square foot of floor space associated with the HUD code and the proposed standard for single-section and multi-section manufactured homes in 19 different cities. Using these energy use intensities and the typical sizes of single-section and multi-section homes detailed in chapter 7 of this TSD, DOE calculated the annual unit site energy consumption of single-section and multi-section manufactured homes.

### 11.2.2 Primary Energy and Full Fuel Cycle Factors

DOE converted the unit energy consumption of the HUD code and the proposed standard into primary energy consumption and full fuel cycle (FFC) energy consumption. DOE calculated primary energy savings (power plant consumption) from site electricity savings by applying a factor to account for losses associated with the generation, transmission, and distribution of electricity. DOE derived annual average site-to-power plant factors based on the version of the National Energy Modeling System (NEMS) that corresponds to *AEO 2015*.[20] The factors change over time in response to projected changes in the types of power plants projected to provide electricity to the country.

The FFC measure includes point-of-use (site) energy; the energy losses associated with generation, transmission, and distribution of electricity; and the energy consumed in extracting, processing, and transporting or distributing primary fuels. To compute the FFC by encompassing the energy consumed in extracting, processing, and transporting or distributing primary fuels, which we refer to as "upstream" activities, DOE developed multipliers using the data and projections generated by the National Energy Modeling System (NEMS) used for *AEO 2015*. The *AEO* provides extensive information about the energy system, including projections of future oil, natural gas and coal supply, energy use for oil and gas field and refinery operations, and fuel consumption and emissions related to electric power production. This information can be used to define a set of parameters representing the energy intensity of energy production.

Table 11.1 shows the primary energy factors and FFC factors for the different fuel types used in the analysis from 2020 to 2040 in 5-year increments. Because the analysis period goes beyond 2040, DOE assumed the primary energy and FFC factors for all years beyond 2040 were equal to the 2040 factors.

**Table 11.1 Primary Energy and FFC Factors, 2020-2040**

| Factor Type | Fuel Type | Dimensionless Factor | | | | |
|---|---|---|---|---|---|---|
| | | 2020 | 2025 | 2030 | 2035 | 2040 |
| Primary | Electricity | 3.042 | 2.813 | 2.623 | 2.533 | 2.558 |
| FFC | Electricity | 1.044 | 1.045 | 1.046 | 1.047 | 1.047 |
| | Natural Gas | 1.109 | 1.111 | 1.113 | 1.114 | 1.114 |
| | LPG/Oil | 1.176 | 1.176 | 1.174 | 1.172 | 1.170 |

### 11.2.3 Equipment Stock

DOE analyzed the NES for 30 years of manufactured home shipments, and considered the entire lifetime of each shipment. The shipment model, described in chapter 10 of this NOPR TSD, is used to project shipments of single-section and multi-section homes from 2017, the compliance date of the proposed standard, until 2046. As described in previously in chapter 8 of this TSD, DOE assumes the lifetime of the manufactured home to be 30 years. In a given year, the housing stock is the cumulative number of shipments up to that year less the number of homes that have exceeded their 30-year lifetime. For example, in 2047, the total housing stock is the sum of all shipments from 2017 to 2046 less the shipments from 2017. In each year, the total housing stock is multiplied by the unit energy consumption to get annual energy consumption for all housing stock. With annual energy consumption values over the entire analysis period for the HUD code scenario and the proposed rule scenario, DOE can calculate the NES.

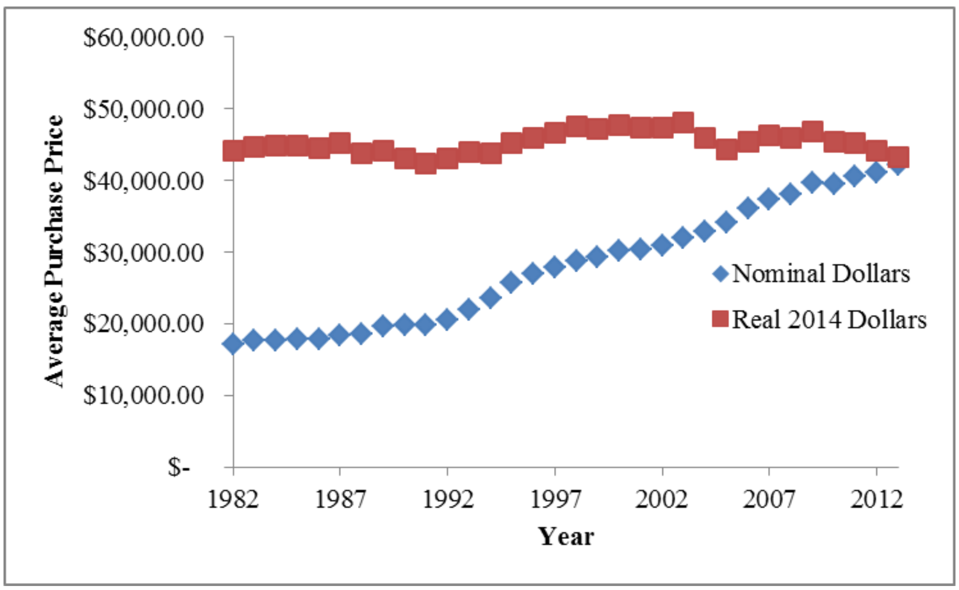
## 11.3 NET PRESENT VALUE INPUTS

For calculating the NPV, DOE calculated the total incremental installed cost of 30-years of shipments of new manufactured homes compliant with the proposed rule, and the associated operating cost savings over the entire lifetime of those 30 years of shipments. These costs and savings are discounted to a base year, 2015. The present value of total incremental installed cost increases is subtracted from the present value of all operating cost savings to calculate the NPV.

### 11.3.1 Incremental Installed Costs and Equipment Price Trend

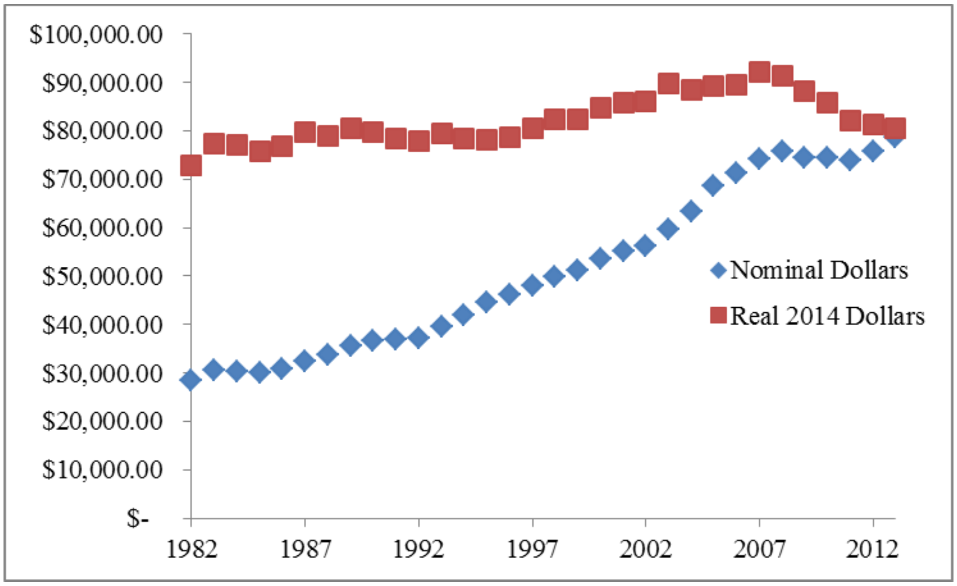
For each year of shipments, DOE calculated the incremental total installed cost of single-section and multi-section manufactured homes in each of the nineteen cities using the methodology described in chapter 8 of this TSD. As described in chapter 8 of this TSD, this incremental installed cost is a weighted average across three different methods of payment: personal property loans, real estate loans, and outright purchases.

DOE evaluated if the incremental cost increase associated with the proposed rule would change over the 30-year analysis period by analyzing historical trends. Using the producer price index (PPI) for manufactured homes,[21] DOE normalized 32 years of average nominal single-section and multi-section manufactured home purchase prices[19] to 2014$. According to Figure 11.1 and Figure 11.2, this analysis showed that the real price of manufactured homes has remained relatively constant from 1980 to 2013. Therefore, DOE assumed that in its projections of future price trends that the real price of single-section and multi-section manufactured homes would remain constant. To forecast the nominal price increase of manufactured homes, DOE used the inflation forecast rate built into the *AEO 2015*, 1.85 percent.[13] DOE used this value to be consistent with the forecasts of future energy prices from the *AEO 2015*, and to maintain consistency when discounting to 2015$, discussed further in section 11.3.5.




Source:
U.S. Census Bureau. *Average Sales Price of New Manufactured Homes by Region and Size of Home: 1980-2013(Dollars).*
Bureau of Labor and Statistics. *Producer Price Index Industry Data: Manufactured homes (mobile homes), all sizes, 1982-2014.*

**Figure 11.1 Average Purchase Price of Single-Section Manufactured Homes, 1982-2013, in Nominal Year Dollars and Real 2014$**




Source:
U.S. Census Bureau. *Average Sales Price of New Manufactured Homes by Region and Size of Home: 1980-2013 (Dollars).*
Bureau of Labor and Statistics. *Producer Price Index Industry Data: Manufactured homes (mobile homes), all sizes, 1982-2014.*

**Figure 11.2 Average Purchase Price of Multi-Section Manufactured Homes, 1982-2013, in Nominal Year Dollars and Real 2014$**

### 11.3.2 Unit Energy Consumption

In calculating the annual operating cost savings, or energy cost savings, associated with the proposed rule, DOE first calculated the site unit energy consumption as described in section 11.2.1. DOE took the difference between the unit energy consumption of base-case scenario (under HUD code) and the standards-case scenario (under the proposed rule) to calculate the unit energy savings. DOE calculated this value for all single-section and multi-section homes in all 19 cities.

### 11.3.3 Energy Prices

DOE used energy price forecasts from the *AEO 2015* to calculate the energy cost savings associated with the proposed rule for the entire analysis period. The *AEO 2015* energy price forecast ends in 2040.[13] Because the analysis period for this rule extends beyond 2040, DOE assumed that energy prices for all years beyond 2040 were identical to 2040 prices.

### 11.3.4 Equipment Stock

Section 11.2.3 describes the methodology for evaluating the stock of single-section and multi-section manufactured homes over the analysis period.

### 11.3.5 Discount Rates

DOE discounted the total incremental installed cost increase and the annual operating cost savings over the entire analysis period to 2015$. In order to discount these quantities to 2015$, DOE used both a 3-percent and a 7-percent real discount rate, in accordance with the Office of

Management and Budget's guidance to federal agencies on the development of regulatory analysis, particularly section E therein: Identifying and Measuring Benefits and Costs.[22]

## 11.4 RESULTS

The NES and NPV results described below show significant energy savings resulting from the proposed regulation and net economic benefits to consumers.

### 11.4.1 National Energy Savings

This section provides the NES that DOE calculated under the proposed rule for single-section and multi-section homes over 30 years of shipments. Table 11.2 provides the primary energy savings over the analysis period, and Table 11.3 provides the FFC energy savings over the analysis period for the 19 cities. All results presented are a weighted average of the four different fuel types, as described in chapter 10 of this TSD.

**Table 11.2 Cumulative Primary National Energy Savings of Manufactured Homes Purchased 2017 -2046 With a 30-Year Lifetime**

| Climate Zone | City | Primary Energy Savings *Quadrillion Btus* | |
|---|---|---|---|
| | | Single Section | Multi Section |
| 1 | Miami | 0.026 | 0.101 |
| | Houston | 0.141 | 0.166 |
| | Phoenix | 0.004 | 0.014 |
| 2 | Atlanta | 0.010 | 0.039 |
| | Charleston | 0.020 | 0.053 |
| | Jackson | 0.064 | 0.082 |
| | Birmingham | 0.030 | 0.061 |
| 3 | Memphis | 0.047 | 0.095 |
| | El Paso | 0.133 | 0.151 |
| | San Francisco | 0.005 | 0.064 |
| | Baltimore | 0.055 | 0.101 |
| | Albuquerque | 0.018 | 0.037 |
| 4 | Salem | 0.006 | 0.040 |
| | Chicago | 0.131 | 0.162 |
| | Boise | 0.004 | 0.018 |
| | Burlington | 0.051 | 0.089 |
| | Helena | 0.028 | 0.023 |
| | Duluth | 0.056 | 0.051 |
| | Fairbanks | 0.002 | 0.001 |
| | Nation Total | 0.833 | 1.346 |

**Table 11.3 Cumulative FFC National Energy Savings of Manufactured Homes Purchased 2017-2046 with a 30-Year Lifetime**

| Climate Zone | City | FFC Energy Savings *Quadrillion Btus* | |
|---|---|---|---|
| | | Single-Section | Multi-Section |
| 1 | Miami | 0.028 | 0.106 |

| | | | |
|---|---|---|---|
| | Houston | 0.148 | 0.174 |
| | Phoenix | 0.004 | 0.014 |
| 2 | Atlanta | 0.010 | 0.040 |
| | Charleston | 0.021 | 0.055 |
| | Jackson | 0.067 | 0.086 |
| | Birmingham | 0.031 | 0.064 |
| 3 | Memphis | 0.049 | 0.100 |
| | El Paso | 0.140 | 0.158 |
| | San Francisco | 0.006 | 0.069 |
| | Baltimore | 0.058 | 0.106 |
| | Albuquerque | 0.019 | 0.040 |
| 4 | Salem | 0.007 | 0.043 |
| | Chicago | 0.141 | 0.174 |
| | Boise | 0.005 | 0.019 |
| | Burlington | 0.057 | 0.099 |
| | Helena | 0.031 | 0.025 |
| | Duluth | 0.061 | 0.055 |
| | Fairbanks | 0.003 | 0.001 |
| | Nation Total | 0.884 | 1.428 |

### 11.4.2 Net Present Value

This section provides results of calculating the NPV under the proposed rule for single-section and multi-section homes over 30 years of shipments. Results, which are cumulative, are shown as the discounted dollar value of the net savings in 2015$. Table 11.4 provides the NPV results using a 7-percent real discount rate, and Table 11.5 provides the NPV results using a 3-percent real discount rate.

**Table 11.4 Net Present Value of Manufactured Homes Purchased 2017- 2046 with a 30-Year Lifetime at a 7-Percent Discount Rate**

| Climate Zone | City | NPV 7-Percent Discount Rate *Million 2015$* | |
|---|---|---|---|
| | | **Single-Section** | **Multi-Section** |
| 1 | Miami | $22.39 | $95.85 |
| | Houston | $159.12 | $224.46 |
| | Phoenix | $5.43 | $22.87 |
| 2 | Atlanta | $14.00 | $61.34 |
| | Charleston | $25.03 | $75.64 |
| | Jackson | $86.62 | $125.75 |
| | Birmingham | $39.33 | $92.09 |
| 3 | Memphis | $67.23 | $153.34 |
| | El Paso | $179.76 | $230.51 |
| | San Francisco | $5.74 | $80.17 |
| | Baltimore | $107.32 | $212.88 |
| | Albuquerque | $26.10 | $60.64 |
| 4 | Salem | $8.11 | $59.03 |
| | Chicago | $232.19 | $307.64 |

| | | | |
|---|---|---|---|
| | Boise | $6.36 | $28.52 |
| | Burlington | $101.69 | $188.98 |
| | Helena | $50.16 | $43.46 |
| | Duluth | $116.98 | $111.64 |
| | Fairbanks | $5.39 | $1.41 |
| | Nation Total | $1,258.94 | $2,176.22 |

**Table 11.5 Net Present Value of Manufactured Homes Purchased 2017 - 2046 with a 30-Year Lifetime at a 3-Percent Discount Rate**

| Climate Zone | City | NPV 3-Percent Discount Rate *Million 2015$* | |
|---|---|---|---|
| | | Single-Section | Multi-Section |
| 1 | Miami | $88.96 | $361.95 |
| | Houston | $557.77 | $724.64 |
| | Phoenix | $17.25 | $69.13 |
| 2 | Atlanta | $45.05 | $187.48 |
| | Charleston | $84.80 | $239.12 |
| | Jackson | $282.93 | $388.57 |
| | Birmingham | $129.32 | $285.89 |
| 3 | Memphis | $216.27 | $471.27 |
| | El Paso | $588.15 | $716.89 |
| | San Francisco | $21.70 | $278.19 |
| | Baltimore | $311.38 | $602.71 |
| | Albuquerque | $85.35 | $189.31 |
| 4 | Salem | $28.01 | $194.34 |
| | Chicago | $712.83 | $919.24 |
| | Boise | $21.17 | $90.87 |
| | Burlington | $317.83 | $574.52 |
| | Helena | $155.62 | $131.35 |
| | Duluth | $345.42 | $324.34 |
| | Fairbanks | $15.43 | $4.01 |
| | Nation Total | $4,025.23 | $6,753.81 |

# CHAPTER 12. MANUFACTURER IMPACT ANALYSIS

## 12.1 INTRODUCTION

The manufacturer impact analysis (MIA) analyzes the potential financial impact of energy conservation standards on manufacturers of manufactured homes. The MIA primarily relies on the Government Regulatory Impact Model (GRIM), an industry cash-flow model used to estimate changes in industry value as a result of energy conservation standards.

## 12.2 KEY INPUTS

The key GRIM inputs are data on industry financial metrics, manufacturer production costs, shipments, conversion expenditures, and assumptions about markups. Key drivers of manufacturer impacts in this industry are the upfront investment manufacturers must make to bring their offerings into compliance, increases in the production cost for manufacturers, and the industry's ability to pass costs onto their customers.

### 12.2.1 Financial Parameters

DOE used public sources of information, including company SEC 10-K filings,[23] corporate annual reports, the U.S. Census Bureau's Economic Census,[24] Hoover's reports,[25] and data from prior DOE rulemakings to establish representative financial parameters for use when modeling the industry. DOE used this public data to estimate the following industry-average parameters: cost of capital, tax rate, working capital rate, SG&A spending, R&D spending, depreciation, capital expenditures, net PPE, base case markups. DOE estimated the cost of capital for manufacturers to be 9.2 percent. The other financial parameters are presented in Table 12.1.

**Table 12.1 Financial Parameters**

| Financial Parameters as % of Revenue | |
|---|---|
| Tax Rate | 23.3% |
| Working Capital | 28.5% |
| Net Property, Plant & Equipment | 13.3% |
| Standard SG&A | 16.6% |
| Research and Development | 0.0% |
| Depreciation | 0.6% |
| Capital Expenditures | 1.0% |

### 12.2.2 Manufacturer Production Costs

Manufacturing higher-efficiency homes is generally more expensive than manufacturing lower efficiency homes due to the use of more costly components and additional labor. The changes in the manufacturer production costs (MPCs) can affect the revenues, gross margins, and cash flow of the industry, making these production costs key GRIM inputs for DOE's analysis.

In the MIA, DOE used the retail prices for the HUD code baseline and the proposed rule in each of the nineteen cities as a starting point for calculating MPCs. DOE calculated retail prices for the HUD code baseline using retail sales prices categorized by state from U.S. Census data.[19] DOE aggregated these prices into the nineteen cities using shipment weighted averages, described in chapter 10 of the NOPR TSD. DOE then used the incremental retail prices associated with the EEMs prescribed in the proposed rule, described in chapter 5 of the NOPR TSD, to calculate retail prices for manufactured homes built in compliance with the proposed rule. To back-calculate the MPCs, DOE first divided retail prices by the sales tax multiplier and the retail markup to find the manufacturer selling price (MSP). Then DOE divided the MSP by the manufacturer markup to calculate the MPC. DOE's retail prices assumed an average sales tax of 3%. The sales tax multiplier was 1.03. To arrive at the retail markup, DOE relied on analysis in the 2011 Direct Final Rule for Energy Conservation Standards for Residential Furnaces and Residential Central Air Conditioners and Heat Pumps, which included an analysis of the distribution chain for manufacturer homes. *See* 76 FR 37408. That analysis cited multiple sources, including legislative analysis[26] and research reports from the Business Encyclopedia of Business[27] and Highbeam Business.[28] DOE estimated a retail markup of 1.3. To determine the manufacturer markup, DOE relied on SEC filing data from publicly listed manufacturers of the covered product. Based on this data, DOE estimated a manufacturer markup of 1.25. The MPCs are presented in Table 12.2 and Table 12.3.

**Table 12.2 Average Manufacturer Production Costs for Single-Section Homes**

| Climate Zone | City | Single-Section MPC *2015$* | |
|---|---|---|---|
| | | HUD Code | Proposed Rule |
| 1 | Miami | 23,079 | 24,539 |
| | Houston | 26,255 | 27,714 |
| | Phoenix | 25,138 | 26,080 |
| 2 | Atlanta | 20,314 | 21,717 |
| | Charleston | 26,814 | 28,217 |
| | Jackson | 26,320 | 27,723 |
| | Birmingham | 26,131 | 27,534 |
| 3 | Memphis | 24,991 | 26,347 |
| | El Paso | 26,435 | 27,790 |
| | San Francisco | 26,938 | 28,293 |
| | Baltimore | 22,319 | 23,048 |
| | Albuquerque | 27,102 | 28,457 |
| 4 | Salem | 23,462 | 24,781 |
| | Chicago | 25,610 | 26,929 |
| | Boise | 25,448 | 26,767 |
| | Burlington | 25,199 | 26,518 |
| | Helena | 30,249 | 31,568 |
| | Duluth | 30,673 | 31,992 |
| | Fairbanks | 28,117 | 29,436 |

**Table 12.3 Average Manufacturer Production Costs for Multi-Section Homes**

| Climate Zone | City | Multi-Section MPC *2015$* | |
|---|---|---|---|
| | | HUD Code | Proposed Rule |
| 1 | Miami | 45,887 | 48,175 |
| | Houston | 48,209 | 50,496 |
| | Phoenix | 49,153 | 50,563 |
| 2 | Atlanta | 45,000 | 47,191 |
| | Charleston | 47,793 | 49,984 |
| | Jackson | 48,555 | 50,747 |
| | Birmingham | 46,738 | 48,929 |
| 3 | Memphis | 43,969 | 45,780 |
| | El Paso | 48,692 | 50,503 |
| | San Francisco | 60,827 | 62,638 |
| | Baltimore | 49,155 | 49,960 |
| | Albuquerque | 49,037 | 50,847 |
| 4 | Salem | 46,881 | 48,600 |
| | Chicago | 45,120 | 46,839 |
| | Boise | 53,382 | 55,101 |
| | Burlington | 49,739 | 51,458 |
| | Helena | 54,894 | 56,613 |
| | Duluth | 57,474 | 59,193 |
| | Fairbanks | 85,199 | 86,918 |

### 12.2.3 Shipments

The GRIM used shipment projections derived from DOE's shipments model in the NIA. Chapter 10 of the TSD describes the methodology and analytical model DOE used to forecast shipments.

### 12.2.4 Conversion Costs

Energy conservation standards may cause manufacturers to incur one-time conversion costs to bring their product designs and production facilities into compliance with new regulations. For the MIA, DOE classified these one-time conversion costs into two major groups: product conversion costs and capital conversion costs. Product conversion costs are one-time investments in research, development, labeling updates, and other costs to make product designs comply with energy conservation standards. Capital conversion costs are one-time investments in property, plant and equipment to adapt or change existing production lines to fabricate and assemble new product designs that comply with energy conservation standards.

DOE based its product conversion costs on the engineering time required to update model plans. Based on input from subject matter experts in the industry, DOE believes that the average manufacturer would have between 200 and 250 plans to update as a result of the standard.

Consulting with subject matter experts in the industry, DOE estimated that each plan would require 3 hours of engineering time to update. The Bureau of Labor Statistics lists the mean hourly wage for a mechanical engineer at $41.89/hour in 2014. Based on these inputs, DOE estimates product conversion costs of $32,500 per manufacturer or $1.4 million for the industry. Given that most manufacturers are able to produce manufactured homes that meet the proposed standard today, DOE does not expect large capital conversion costs. To be conservative, the Department included $5,000 per manufacturer in its modeling of capital conversion, or $0.2 million for the industry. Total industry conversion costs are $1.6 million at the proposed level.

### 12.2.5 Markups

DOE modeled two markup scenarios to capture uncertainty regarding potential impacts on prices and profitability following implementation of energy conservation standards: (1) a preservation of gross margin percentage markup scenario and (2) a preservation of per-unit operating profit markup scenario. These scenarios lead to different markup values that, when applied to MPCs, result in varying revenue and cash flow impacts.

Under the preservation of gross margin percentage scenario, DOE applied a consistent manufacturer markup of 1.25 before and after the energy conservation standard goes into effect. This assumes manufacturers would be able to maintain the same proportion of profit (as a percentage of revenues) as the standard becomes more stringent. As production costs and sales prices increase with more stringent efficiency levels, this scenario implies that profit in absolute dollars will increase. This manufacturer markup scenario implies that manufacturers will see more profit on a per-unit basis after the standard goes into effect. As a result, DOE assumes this scenario represents an upper bound to industry profitability.

In the preservation of operating profit scenario, manufacturer markups decrease as production costs and sales prices increase. The assumption behind this markup scenario is that the industry cannot increase prices to recover conversion costs, which are upfront investments required to comply with the standard. Additionally, though the manufacturers must use additional labor and potentially more expensive materials to meet the standard, they are only able to earn the same per-unit operating profit (in absolute dollars) as before the standard went into effect. As a result, operating margin falls at the proposed levels. Based on this criteria, DOE estimates that markups would drop to 1.247 at the proposed level. This markup scenario represents a low bound to industry profitability under an amended energy conservation standard.

## 12.3 MANUFACTURER IMPACT ANALYSIS RESULTS

### 12.3.1 Financial Results

The INPV measures the industry value and is used to compare the economic impacts of different standard levels. The INPV is the sum of all annual free cash flows discounted at the industry's cost of capital, or discount rate, to 2016. The GRIM for this rulemaking estimates cash flows from 2016 to 2046.

In the MIA, DOE compares the INPV of the base case (no energy conservation standards) to that of the proposed level. The difference between the base case and a standards case is an estimate of the economic impacts the energy conservation standard would have on the industry.

**Table 12.4. INPV Results: Preservation of Gross Margin Percentage Scenario***

| | Single-Section | Multi-Section | Total Industry |
|---|---|---|---|
| Base Case INPV *Million 2015$* | 229.0 | 487.8 | 716.7 |
| Standards Case INPV *Million 2015$* | 227.9 | 485.8 | 713.6 |
| Change in INPV *Million 2015$* | (1.1) | (2.0) | (3.1) |
| Change in INPV *%* | (0.5) | (0.4) | (0.4) |
| Total Conversion Costs *Million 2015$* | 0.5 | 1.1 | 1.6 |

* Values in parentheses are negative values.

**Table 12.5. INPV Results: Preservation of Operating Profit Markup Scenario***

| | Single-Section | Multi-Section | Total Industry |
|---|---|---|---|
| Base Case INPV *Million 2015$* | 229.0 | 487.8 | 716.7 |
| Standards Case INPV *Million 2015$* | 215.0 | 465.0 | 680.0 |
| Change in INPV *Million 2015$* | (14.0) | (22.8) | (36.8) |
| Change in INPV *%* | (6.1) | (4.7) | (5.1) |
| Total Conversion Costs *Million 2015$* | 0.5 | 1.1 | 1.6 |

* Values in parentheses are negative values.

DOE estimates the change in INPV to range from -$36.8 million to -$3.1 million, or a change of -5.1 percent to -0.4 percent. Conversion costs at the proposed level are projected to total approximately $1.6 million.

The Department notes that more efficient homes are generally more labor intensive to build. Per-unit labor requirements and production time requirements increase with a higher energy conservation standard. This would suggest an increase in employment if shipment volumes remain steady. However, DOE models price-elasticity in its shipments forecasts and the increase in labor intensity of manufactured homes is balanced by the decrease in total industry shipments in the standards case. At the proposed level, DOE estimates that production employment could drop from 16,715 full-time production workers in the base case to approximately 16,406 workers in the standards case, or a net change of 309 workers. DOE's production worker estimates are tied to two key assumptions. First, DOE assumes that 20-23% of the manufacturer production cost is due to labor inputs, and that the labor inputs remain relatively steady over the analysis period. Second, DOE estimates full burdened production worker wages to be $16.59/hour with a typical work year consisting of 2,118 hours based on US Census data for NAICS code 321911,[g] which is for "Manufactured Home (Mobile Home) Manufacturing." Using the shipment numbers, MPCs, and the MPC labor percentage, DOE is able to estimate production labor expenditures for the industry. DOE uses to the full burdened production worker wage to arrive at total number of worker hours and the number of full-time production workers.

In general, more efficient homes are more labor intensive to build but do not require fundamentally different construction techniques. Rather, the homes are assembled with more efficient components and with additional labor to limit air leakage through the thermal envelope. DOE believes that most manufacturers offer some models today that would meet the proposed standard, indicating a familiarity with the production process for more efficient homes. The Department does not anticipate any significant production capacity constraints.

# CHAPTER 13. ENVIRONMENTAL ASSESSMENT

## 13.1 PURPOSE AND NEED FOR AGENCY ACTION

DOE is preparing a draft Environmental Assessment (EA) pursuant to the Council on Environmental Quality's Regulations for Implementing the Procedural Provisions of the National Environmental Policy Act (40 CFR parts 1500-1508), the National Environmental Policy Act of 1969, as amended (42 U.S.C. 4321 et seq.), DOE's National Environmental Policy Act (NEPA) Implementing Procedures (10 CFR Part 1021), and DOE Order 451.1B. DOE is preparing the draft EA in parallel with this rulemaking, and it will be posted to the DOE website separately. DOE presents the results of the outdoor air analysis (a component of the environmental assessment) in this chapter 13 of the NOPR TSD. The outdoor air analysis provides the expected impact of the proposed energy conservation standards on pollutant emissions. The outcomes of

[g] United States Census Bureau, Annual Survey of Manufacturers (ASM) 2014, 2014 "Statistics for Industry Groups and Industries". http://www.census.gov/manufacturing/asm/

the environmental analysis are largely driven by changes in power plant types and quantities of electricity generated under each of the alternatives.

The purpose and need for agency action is to implement Section 413 of EISA, which requires that DOE establish standards for energy conservation in manufactured housing. EISA further provides that DOE must base the energy conservation standards on the most recent version of the IECC and any supplements to that document, except where DOE finds that the IECC is not cost-effective or where a more stringent standard would be more cost-effective, based on the impact of the IECC on the purchase price of manufactured housing and on total life-cycle construction and operating costs.

## 13.2 THE PROPOSED ACTION AND ALTERNATIVES

This EA summarizes the potential incremental environmental impacts that would result from implementing the proposed action, which establishes energy conservation standards for manufactured housing that are based on the 2015 IECC, as discussed in chapter 6 of this NOPR TSD. DOE evaluated the impacts relative to the alternative of no-action. Under the no-action alternative, DOE would not promulgate energy conservation standards for manufactured housing. Under this alternative, manufactured homes would continue to be regulated by HUD. Chapter 2 of this TSD describes the energy efficiency requirements of the HUD code.

## 13.3 ENVIRONMENTAL IMPACTS

This section provides the potential environmental impacts that may result from implementing the proposed rule compared to the no-action alternative. The proposed energy conservation standards would apply to all 50 states and U.S. territories. The proposed standards would not affect land uses, cause any direct disturbance to the land, or directly affect biological resources in any one area. Therefore, the proposed standards are not expected to have adverse effects on sensitive environmental resources, including wetlands and floodplains, prime agricultural lands, endangered species, sensitive ecosystems, historic or archaeological sites. Furthermore, the proposed rule would not be affected by a terrorist act. Impacts on these resources are not discussed in further detail in this EA.

The proposed action is expected to reduce energy consumption relative to the no-action, or HUD baseline, alternative. These changes in energy consumption are the primary drivers in analyzing environmental effects. Each of the action alternatives would affect air emissions resulting from power plant operations. Therefore, section 13.4 describes the outdoor air emissions analysis. The latter part of this chapter describes potential impacts to other environmental resources. This environmental assessment focuses on the impacts of the proposed rule for the United States as a whole, rather than specific local affected environments, because the standards would affect manufactured homes located throughout all regions of the United States.

## 13.4 OUTDOOR AIR

The primary focus of the outdoor air analysis is the expected impact of the proposed energy conservation standards on pollutant emissions. The outcomes of the environmental analysis are largely driven by changes in power plant types and quantities of electricity generated under each of the alternatives. The emissions analysis consists of two components. The first component estimates the effect of potential energy conservation standards on power sector or site combustion emissions of carbon dioxide ($CO_2$), nitrogen oxides ($NO_X$), sulfur dioxide ($SO_2$) and mercury (Hg). These emissions are those directly related to the consumption of electricity or combustion fuel. The second component estimates the impacts of a potential standard on emissions of two additional greenhouse gases, methane ($CH_4$) and nitrous oxide ($N_2O$), as well as the reductions to emissions of all species due to "upstream" activities in the fuel production chain. These upstream activities comprise extraction, processing, and transporting fuels to the site of combustion. The associated emissions are referred to as upstream emissions. Together, these emissions account for the FFC, in accordance with DOE's FFC Statement of Policy. 76 FR 51282 (Aug. 18, 2011).

The analysis of power-sector emissions uses marginal emissions intensity factors calculated by DOE. As of 2014, DOE is using a new methodology based on results published for the *AEO 2015* reference case and a set of side cases that implement a variety of efficiency-related policies.[13] The new methodology is described in the report "Utility Sector Impacts of Reduced Electricity Demand" authored by Coughlin.[29] The *AEO* does not publish estimates of the $CH_4$ and $N_2O$ emissions associated with combustion of fossil fuels. For these pollutants, the power sector emissions are estimated using emissions intensity factors published by the U.S. Environmental Protection Agency (EPA).[30] The FFC upstream emissions are estimated based on the methodology developed by Coughlin.[31] The upstream emissions include both emissions from fuel combustion during extraction, processing and transportation of fuel, and "fugitive" emissions (direct leakage to the atmosphere) of $CH_4$ and $CO_2$.

The emissions intensity factors are expressed in terms of physical units per megawatt hour (MWh) or million British thermal units (MMBtu) of site energy savings. Total emissions reductions are estimated multiplying the energy savings calculated in the national impact analysis (chapter 11 of this TSD) by the emissions intensity factors.

### 13.4.1 Emissions Descriptions

An air pollutant is any substance in the air that can cause harm to humans or the environment. Pollutants may be natural or man-made (*i.e.,* anthropogenic) and may take the form of solid particles (*i.e.,* particulates or particulate matter), liquid droplets, or gases.

***Sulfur dioxide.*** $SO_2$ belongs to the family of sulfur oxide gases ($SO_X$). These gases dissolve easily in water. Sulfur is prevalent in all raw materials, including crude oil, coal, and ore that contains common metals like aluminum, copper, zinc, lead, and iron. $SO_X$ gases are formed when fuel containing sulfur, such as coal and oil, is burned, and when gasoline is extracted from oil, or metals are extracted from ore. $SO_2$ dissolves in water vapor to form acid, and interacts with other gases and particles in the air to form sulfates and other products that can be harmful to people and their environment.[32]

***Nitrogen oxides.*** In the context of air pollution, $NO_X$ is the generic term for the nitrogen oxide gases NO and $NO_2$. $NO_X$ gases generally form in combustion systems via the reaction of nitrogen and oxygen at high temperatures. The primary manmade sources of $NO_X$ are motor vehicles, electric utilities, and other industrial, commercial, and residential sources that burn fossil fuels. Electric utilities account for about 22 percent of $NO_X$ emissions in the United States.[33] In the atmosphere, $NO_X$ gases will react to form smog and acid rain, and also contribute significantly to the formation of tropospheric, or ground-level, ozone, which can trigger serious respiratory problems. $NO_X$ also contributes to the formation of fine particles that can impair human health.[33]

***Mercury.*** Coal-fired power plants emit Hg found in coal during the burning process. While coal-fired power plants are the largest remaining source of human-generated Hg emissions in the United States, they contribute very little to the global Hg pool or to contamination of U.S. waters.[34] U.S. coal-fired power plants emit Hg in three different forms: oxidized Hg (likely to deposit within the United States); elemental Hg, which can travel thousands of miles before depositing to land and water; and Hg that is in particulate form. Atmospheric Hg is then deposited on land, lakes, rivers, and estuaries through rain, snow, and dry deposition. Once there, it can transform into methylmercury and accumulate in fish tissue through bioaccumulation.

Americans are exposed to methylmercury primarily by eating contaminated fish. Because the developing fetus is the most sensitive to the toxic effects of methylmercury, women of childbearing age are regarded as the population of greatest concern. Children exposed to methylmercury before birth may be at increased risk of poor performance on neurobehavioral tasks, such as those measuring attention, fine motor function, language skills, visual-spatial abilities, and verbal memory.[35]

***Carbon dioxide and other greenhouse gases.*** $CO_2$ is of significant interest because of its classification as a greenhouse gas (GHG). GHGs trap the sun's radiation inside the Earth's atmosphere and either occur naturally in the atmosphere or result from human activities. Naturally occurring GHGs include water vapor, $CO_2$, methane ($CH_4$), nitrous oxide ($N_2O$), and ozone ($O_3$). Human activities add to the levels of most of these naturally occurring gases. For example, $CO_2$ is emitted to the atmosphere when solid waste, fossil fuels (oil, natural gas, and coal), wood, and wood products are burned. In 2007, more than 90 percent of anthropogenic $CO_2$ emissions resulted from burning fossil fuels.[34]

Concentrations of $CO_2$ in the atmosphere are naturally regulated by numerous processes, collectively known as the "carbon cycle." The movement of carbon between the atmosphere and the land and oceans is dominated by natural processes, such as plant photosynthesis. While these natural processes can absorb some of the anthropogenic $CO_2$ emissions produced each year, billions of metric tons are added to the atmosphere annually. In the United States, in 2007, $CO_2$ emissions from electricity generation accounted for 39 percent of total U.S. GHG emissions.[34]

### 13.4.2 Air Quality Regulations and Emissions Impacts

Each annual version of the *AEO* incorporates the projected impacts of existing air quality regulations on emissions. *AEO 2015* generally represents current federal and state legislation and final implementation regulations in place as of the end of October 2013.

Sulfur dioxide emissions from affected electric generating units (EGUs) are subject to nationwide and regional emissions cap and trading programs. Title IV of the Clean Air Act sets an annual emissions cap on $SO_2$ for affected EGUs in the 48 contiguous states and the District of Columbia (D.C.). $SO_2$ emissions from 28 eastern states and D.C. were also limited under the Clean Air Interstate Rule (CAIR), which created an allowance-based trading program that that operates along with the Title IV program in those states and D.C. 70 FR 25162 (May 12, 2005). CAIR was remanded to EPA by the U.S. Court of Appeals for the District of Columbia Circuit (D.C. Circuit) but parts of it remained in effect. On July 6, 2011, EPA issued a replacement for CAIR, the Cross-State Air Pollution Rule (CSAPR). 76 FR 48208 (August 8, 2011). On August 21, 2012, the D.C. Circuit issued a decision to vacate CSAPR. See *EME Homer City Generation, LP v. EPA*, 696 F.3d 7, 38 (D.C. Cir. 2012). The court ordered EPA to continue administering CAIR. The *AEO 2015* emissions factors used for the present analysis assume that CAIR remains a binding regulation through 2040.

The attainment of emissions caps is typically flexible among affected EGUs and is enforced through the use of emissions allowances and tradable permits. Under existing EPA regulations, any excess $SO_2$ emissions allowances resulting from the lower electricity demand caused by the imposition of an energy conservation standard could be used to permit offsetting increases in $SO_2$ emissions by any regulated EGU. In past rulemakings, DOE recognized that there was uncertainty about the effects of energy conservation standards on $SO_2$ emissions covered by the existing cap-and-trade system, but it concluded that no reductions in power sector emissions would occur for $SO_2$ as a result of such proposed standards.

Beginning in 2016, however, $SO_2$ emissions will fall as a result of the Mercury and Air Toxics Standards (MATS) for power plants. 77 FR 9304 (Feb. 16, 2012). In the final MATS rule, EPA established a standard for hydrogen chloride as a surrogate for acid gas hazardous air pollutants (HAP), and also established a standard for $SO_2$ (a non-HAP acid gas) as an alternative equivalent surrogate standard for acid gas HAP. The same controls are used to reduce HAP and non-HAP acid gas; thus, $SO_2$ emissions will be reduced as a result of the control technologies installed on coal-fired power plants to comply with the MATS requirements for acid gas. *AEO 2015* assumes that, in order to continue operating, coal plants must have either flue gas desulfurization or dry sorbent injection systems installed by 2016. Both technologies, which are used to reduce acid gas emissions, also reduce $SO_2$ emissions. Under the MATS, emissions will be far below the cap established by CAIR, so it is unlikely that excess $SO_2$ emissions allowances resulting from the lower electricity demand would be needed or used to permit offsetting increases in $SO_2$ emissions by any regulated EGU. Therefore, energy conservation standards would reduce $SO_2$ emissions in 2016 and beyond.

CAIR established a cap on $NO_X$ emissions in 28 eastern states and the District of Columbia. Energy conservation standards are expected to have little effect on $NO_X$ emissions in those States covered by CSAPR because excess $NO_X$ emissions allowances resulting from the lower electricity demand could be used to permit offsetting increases in $NO_X$ emissions. However, standards would be expected to reduce $NO_X$ emissions in the states not affected by CAIR. As a result, DOE estimated $NO_X$ emissions reductions from potential standards for those states.

The MATS limit Hg emissions from power plants, but they do not include emissions caps and, as such, DOE's energy conservation standards would likely reduce Hg emissions. DOE estimated Hg emissions reductions using emissions factors based on *AEO 2015*, which incorporates the MATS.

DOE notes that the Supreme Court recently remanded EPA's 2012 rule regarding national emission standards for hazardous air pollutants from certain electric utility steam generating units. See Michigan v. EPA (Case No. 14-46, 2015). DOE has tentatively determined that the remand of the MATS rule does not change the assumptions regarding the impact of energy efficiency standards on $SO_2$ emissions. Further, while the remand of the MATS rule may have an impact on the overall amount of mercury emitted by power plants, it does not change the impact of the energy efficiency standards on mercury emissions. DOE will continue to monitor developments related to this case and respond to them as appropriate.

### 13.4.3 Analytical Methodology

Total emissions reductions are estimated by multiplying the emissions factors for each end use and year by the corresponding calculated energy savings associated with a particular efficiency scenario. The electricity end uses relevant to manufactured housing are residential space heating, residential space cooling, and residential water heating. Sections 13.4.4, 13.4.5, and 13.4.6 list the power sector or site emissions factors for these three end uses for selected years. Years beyond 2040 were assumed to have the same emissions factors as the year 2040.

### 13.4.4 Power Sector and Site Emissions Factors

The analysis of power-sector, or site, emissions uses marginal emissions intensity factors derived from analysis of the *AEO 2015* reference case and a number of side cases incorporating enhanced equipment efficiencies. To model the impact of a standard, DOE calculates factors that relate a unit reduction to annual site electricity demand for a given end use to corresponding reductions to installed capacity by fuel type, fuel use for generation, and power-sector emissions. Details on the approach have been described by Coughlin.[29] The *AEO* does not publish estimates of the $CH_4$ and $N_2O$ emissions associated with combustion of fossil fuels. For these pollutants, the power-sector emissions are estimated using emissions intensity factors published by the EPA.[30] This publication provides emissions intensity factors for different grades of coal, petroleum fuels and natural gas. DOE uses these fuel-specific emissions factors to develop time-dependent emissions factors as a function of the changing fuel mix in the power sector.

**Table 13.1 Power-Sector Emissions Factors for Residential Space Heating**

| | Unit | 2020 | 2025 | 2030 | 2035 | 2040 |
|---|---|---|---|---|---|---|
| $CO_2$ | kg/MWh | 831 | 743 | 674 | 618 | 563 |
| Hg | g/MWh | 0.00230 | 0.00179 | 0.00151 | 0.00127 | 0.00113 |
| $NO_X$ | g/MWh | 731 | 696 | 650 | 615 | 564 |
| $SO_2$ | g/MWh | 617 | 482 | 405 | 340 | 304 |
| $CH_4$ | g/MWh | 83.5 | 66.9 | 57.1 | 48.9 | 43.9 |
| $N_2O$ | g/MWh | 12.0 | 9.6 | 8.1 | 6.9 | 6.2 |

**Table 13.2 Power-Sector Emissions Factors for Residential Space Cooling**

| | Unit | 2020 | 2025 | 2030 | 2035 | 2040 |
|---|---|---|---|---|---|---|
| $CO_2$ | kg/MWh | 786 | 709 | 643 | 594 | 546 |
| Hg | g/MWh | 0.00199 | 0.00155 | 0.00131 | 0.00109 | 0.00098 |
| $NO_X$ | g/MWh | 722 | 688 | 641 | 610 | 566 |
| $SO_2$ | g/MWh | 535 | 418 | 351 | 294 | 263 |
| $CH_4$ | g/MWh | 72.6 | 58.3 | 49.8 | 42.7 | 38.4 |
| $N_2O$ | g/MWh | 10.4 | 8.3 | 7.1 | 6.0 | 5.4 |

**Table 13.3 Power-Sector Emissions Factors for Residential Water Heating**

| | Unit | 2020 | 2025 | 2030 | 2035 | 2040 |
|---|---|---|---|---|---|---|
| $CO_2$ | kg/MWh | 813 | 730 | 662 | 609 | 556 |
| Hg | g/MWh | 0.00220 | 0.00172 | 0.00144 | 0.00121 | 0.00108 |
| $NO_X$ | g/MWh | 723 | 690 | 644 | 611 | 561 |
| $SO_2$ | g/MWh | 591 | 462 | 388 | 326 | 291 |
| $CH_4$ | g/MWh | 80.2 | 64.3 | 54.9 | 47.0 | 42.2 |
| $N_2O$ | g/MWh | 11.6 | 9.2 | 7.8 | 6.6 | 6.0 |

Site combustion of fossil fuels in buildings (for example in water-heating, space-heating, or cooking applications) also produces emissions of $CO_2$ and other pollutants. DOE used emissions factors published by the EPA,[30] which are constant in time. These factors are presented in Table 13.4.

**Table 13.4 Site Combustion Emissions Factors**

| Species | Natural Gas *g/mcf** | Fuel Oil/Liquefied Petroleum Gas *g/bbl*** |
|---|---|---|
| $CO_2$ | 54484 | 446241 |
| $NO_X$ | 70.3152 | 11531 |
| $SO_2$ | 0.27242 | 219.66 |
| $CH_4$ | 1.0280 | 13.260 |
| $N_2O$ | 0.10280 | 8.6481 |
| *g/mcf = grams per one-thousand cubic feet<br>**g/bbl = grams per barrel of oil | | |

### 13.4.5 Upstream Emissions Factors

The upstream emissions accounting uses the same approach as the upstream energy accounting described by Coughlin.[29,31] When demand for a particular fuel is reduced, there is a corresponding reduction in the emissions from combustion of that fuel at either the building site or the power plant. The associated reduction in energy use for upstream activities leads to further reductions in emissions. These upstream emissions are defined to include the combustion emissions from the fuel used upstream, the fugitive emissions associated with the fuel used upstream, and the fugitive emissions associated with the fuel used on site.

Fugitive emissions of $CO_2$ occur during oil and gas production, but are small relative to combustion emissions. They comprise about 2.5 percent of total $CO_2$ emissions for natural gas and 1.7 percent for petroleum fuels. Fugitive emissions of methane occur during oil, gas, and coal production. Combustion emissions of $CH_4$ are very small, while fugitive emissions (particularly for gas production) may be relatively large. Hence, fugitive emissions make up more than 99 percent of total methane emissions for natural gas, about 95 percent for coal, and 93 percent for petroleum fuels.

Upstream emissions factors account for both fugitive emissions and combustion emissions in extraction, processing, and transport of primary fuels. DOE estimated fugitive emissions factors for methane from coal mining and natural gas production based on a review of recent studies compiled by Burnham.[36] This review includes estimates of the difference between fugitive emissions factors for conventional production of natural vs. unconventional (shale or tight gas). These estimates rely in turn on data gathered by EPA under new greenhouse gas reporting requirements for the petroleum and natural gas industries.[37,38] As more data are made available, DOE will continue to update these estimated emissions factors.

For ease of application in its analysis, DOE developed all of the emissions factors using site (point of use) energy savings in the denominator. Table 13.5 presents the electricity upstream emissions factors for selected years. These were used to estimate the emissions associated with the decreased electricity use. The caps that apply to power sector NOx emissions do not apply to upstream combustion sources. Table 13.6 and Table 13.7 present upstream emissions factors for natural gas and fuel oil/LPG, respectively.

**Table 13.5 Electricity Upstream Emissions Factors**

| | Unit | 2020 | 2025 | 2030 | 2035 | 2040 |
|---|---|---|---|---|---|---|
| $CO_2$ | kg/MWh | 30.3 | 30.7 | 30.8 | 30.4 | 30.0 |
| Hg | g/MWh | 0.0000134 | 0.0000126 | 0.0000117 | 0.0000111 | 0.0000108 |
| $NO_X$ | g/MWh | 388 | 395 | 399 | 396 | 391 |
| $SO_2$ | g/MWh | 5.62 | 5.45 | 5.20 | 5.06 | 5.00 |
| $CH_4$ | g/MWh | 2127 | 2163 | 2200 | 2196 | 2160 |
| $N_2O$ | g/MWh | 0.275 | 0.270 | 0.261 | 0.253 | 0.246 |

**Table 13.6 Natural Gas Upstream Emissions Factors**

| | Unit | 2020 | 2025 | 2030 | 2035 | 2040 |
|---|---|---|---|---|---|---|
| $CO_2$ | kg/mcf | 7.89 | 7.96 | 7.90 | 7.85 | 7.88 |
| $NO_X$ | g/mcf | 115 | 116 | 115 | 114 | 114 |
| $SO_2$ | g/mcf | 0.0344 | 0.0348 | 0.0344 | 0.0341 | 0.0343 |
| $CH_4$ | g/mcf | 686 | 689 | 686 | 686 | 687 |
| $N_2O$ | g/mcf | 0.0126 | 0.0128 | 0.0127 | 0.0126 | 0.0126 |

**Table 13.7 Fuel Oil/Liquefied Petroleum Gas Upstream Emissions Factors**

| | Unit | 2020 | 2025 | 2030 | 2035 | 2040 |
|---|---|---|---|---|---|---|
| $CO_2$ | kg/bbl | 70.0 | 69.1 | 67.8 | 67.7 | 67.5 |
| Hg | g/bbl | 0.00000693 | 0.00000647 | 0.00000622 | 0.00000621 | 0.00000609 |
| $NO_X$ | g/bbl | 814 | 810 | 791 | 787 | 781 |
| $SO_2$ | g/bbl | 15.4 | 15.3 | 15.0 | 14.9 | 14.8 |
| $CH_4$ | g/bbl | 882 | 872 | 857 | 855 | 854 |
| $N_2O$ | g/bbl | 0.630 | 0.625 | 0.611 | 0.608 | 0.603 |

### 13.4.6 Emissions Impact Results

Table 13.8 lists the estimated cumulative emissions reductions, for single-section and multi-section manufactured homes, under the proposed rule, for homes sold from 2017 through 2046.

**Table 13.8 Emissions Reductions Under the Proposed Rule**

| **Pollutant** | **Home Size** | |
|---|---|---|
| | **Single-Section** | **Multi-Section** |
| | **Reductions** | |

| | | |
|---|---|---|
| **Site Emissions** | | |
| $CO_2$ (million metric tons) | 56.5 | 91.1 |
| Hg (metric tons) | 0.0904 | 0.146 |
| NOx (thousand metric tons) | 223 | 356 |
| $SO_2$ (thousand metric tons) | 27.6 | 44.4 |
| $CH_4$ (thousand metric tons) | 3.78 | 6.09 |
| $N_2O$ (thousand metric tons) | 0.632 | 1.02 |
| **Upstream Emissions** | | |
| $CO_2$ (million metric tons) | 4.01 | 6.45 |
| Hg (metric tons) | 0.000944 | 0.00153 |
| NOx (thousand metric tons) | 51.8 | 83.2 |
| $SO_2$ (thousand metric tons) | 0.615 | 0.991 |
| $CH_4$ (thousand metric tons) | 239 | 385 |
| $N_2O$ (thousand metric tons) | 0.0294 | 0.0474 |
| **Full-Fuel-Cycle Emissions** | | |
| $CO_2$ (million metric tons) | 60.5 | 97.6 |
| Hg (metric tons) | 0.0913 | 0.148 |
| NOx (thousand metric tons) | 275 | 439 |
| $SO_2$ (thousand metric tons) | 28.2 | 45.4 |
| $CH_4$ (thousand metric tons) | 243 | 391 |
| $N_2O$ (thousand metric tons) | 0.661 | 1.07 |

# CHAPTER 14. MONETIZATION OF EMISSION REDUCTIONS BENEFITS

## 14.1 INTRODUCTION

As part of the development of this proposed rule, DOE considered the estimated monetary benefits likely to result from the reduced emissions of carbon dioxide and nitrogen oxides that are expected to result from adoption of the proposed rule. This chapter summarizes the basis for the monetary values assigned to emissions and presents the modeled benefits of estimated reductions.

## 14.2 MONETIZING CARBON DIOXIDE EMISSIONS

One challenge for anyone attempting to calculate the monetary benefits of reduced emissions of $CO_2$ is what value to assign to each unit eliminated. The value must encompass a broad range of physical, economic, social, and political effects. Analysts developed the concept of the social cost of carbon (SCC) to represent the broad cost or value associated with producing—or reducing—a quantifiable amount of $CO_2$ emissions.

### 14.2.1 Social Cost of Carbon

The SCC is an estimate of the monetized damages associated with an incremental increase in carbon emissions in a given year. The SCC is intended to include (but is not limited to) changes in net agricultural productivity, human health, property damages from increased flood risk, and the value of ecosystem services. SCC estimates are provided in dollars per metric ton of carbon dioxide. A value for the domestic SCC is meant to represent the damages in the United States resulting from a unit change in carbon dioxide emissions, whereas a global SCC is meant to reflect the value of damages worldwide.

Under section 1(b)(6) of Executive Order 12866,[39] agencies must, to the extent permitted by law, "assess both the costs and the benefits of the intended regulation and, recognizing that some costs and benefits are difficult to quantify, propose or adopt a regulation only upon a reasoned determination that the benefits of the intended regulation justify its costs." The purpose of the SCC estimates required by the Executive Order is to enable agencies to incorporate the monetized social benefits of reducing $CO_2$ emissions into cost-benefit analyses of regulatory actions. The estimates are presented with an acknowledgement of the many uncertainties involved and with a clear understanding that they will need updating in response to increasing knowledge of the science and economics of climate impacts.

As part of the interagency process that developed the SCC estimates, technical experts from numerous agencies met regularly to explore the technical literature in relevant fields, discuss key model inputs and assumptions, and consider public comments. The primary objective of the process was to develop a range of SCC values using a defensible set of assumptions regarding model inputs that was grounded in the scientific and economic literature. In this way, key uncertainties and model differences transparently and consistently inform the range of SCC estimates developed for use in the rulemaking process.

### 14.2.2 Monetizing Carbon Dioxide Emissions

When attempting to assess the incremental economic impacts of carbon dioxide emissions, the analyst faces several serious challenges. A report from the National Research Council[40] points out that any assessment will suffer from uncertainty, speculation, and lack of information about (1) future emissions of greenhouse gases, (2) the effects of past and future emissions on the climate system, (3) the effects of changes in climate on the physical and biological environment, and (4) the translation of those environmental impacts into economic damages. As a result, any effort to quantify and monetize the harms associated with climate change raises serious questions of science, economics, and ethics and should be viewed as provisional.

Despite the limits of both quantification and monetization, SCC estimates can be useful in estimating the social benefits of reducing $CO_2$ emissions. An agency can estimate the benefits from reduced (or costs from increased) emissions in any future year by multiplying the change in emissions in that year by the SCC values appropriate for that year. Then the net present value of the benefits can be calculated by multiplying each of the future benefits by an appropriate discount factor and summing across all affected years. This approach assumes that the marginal damages from increased emissions are constant for small departures from the baseline emissions path, an approximation that is reasonable for policies that have effects on emissions that are small relative to cumulative global carbon dioxide emissions.

## 14.3 DEVELOPMENT OF SOCIAL COST OF CARBON VALUES

In 2009, an interagency process was initiated to develop a preliminary assessment of how best to quantify the benefits from reducing carbon dioxide emissions. To provide consistency in how benefits are evaluated across federal agencies, the Administration sought to develop a transparent and defensible method, specifically designed for the rulemaking process, to quantify avoided climate change damages from reduced $CO_2$ emissions. The interagency group did not undertake any original analysis. Instead, it combined SCC estimates from the literature to use as interim values until a more comprehensive analysis could be conducted. The outcome of the preliminary assessment was a set of five interim values: global SCC estimates for 2007 (in 2006$) of $55, $33, $19, $10, and $5 per ton of $CO_2$.[41] Those interim values represented the first sustained interagency effort within the U.S. government to develop an SCC for use in regulatory analysis. The results of that preliminary effort were presented in several proposed and final rules.

### 14.3.1 Current Approach and Key Assumptions

After the release of the interim values, the interagency group reconvened regularly to improve the SCC estimates. Specifically, the group considered public comments and further explored the technical literature in relevant fields. The interagency group relied on three integrated assessment models commonly used to estimate the SCC. The models are known by their acronyms of FUND, DICE, and PAGE. Those three models frequently are cited in peer-reviewed literature and were used in the most recent assessment of the Intergovernmental Panel on Climate Change. Each model was given equal weight in developing SCC values.

Each model takes a slightly different approach to calculating how increases in emissions produce economic damages. A key objective of the interagency process was to enable a consistent exploration of the three models while respecting the different approaches taken by the key modelers in the field. An extensive review of the literature identified three sets of input parameters for the models: climate sensitivity; socioeconomic and emissions trajectories; and discount rates. A probability distribution for climate sensitivity was specified as an input to all three models. In addition, the interagency group used a range of scenarios for the socioeconomic parameters and a range of values for the discount rate. All other model features were left unchanged, relying on the model developers' best estimates and judgments.

The interagency group selected four SCC values for use in regulatory analyses. Three values are based on the average SCC from the three integrated assessment models, at discount rates of 2.5 percent, 3 percent, and 5 percent. The fourth value, which represents the 95$^{th}$ percentile of the SCC estimate across all three models at a 3-percent discount rate, is included to represent larger-than-expected effects from temperature changes farther out in the tails of the SCC distribution. The values increase in real terms over time. Additionally, the interagency group determined that a range of values from 7 percent to 23 percent should be used to adjust the global SCC to calculate domestic effects, although preference is given to consideration of the global benefits of reducing $CO_2$ emissions. Table 14.1 presents the values in the 2010 interagency group report.[41]

**Table 14.1 Annual SCC Values for 2010-2050 From 2010 Interagency Report**

| Year | SCC Case | | | |
|---|---|---|---|---|
| | 5% Discount Rate, Average | 3% Discount Rate, Average | 2.5% Discount Rate, Average | 3% Discount Rate, 95$^{th}$ Percentile |
| | *2007$ per metric ton* | | | |
| 2010 | 4.7 | 21.4 | 35.1 | 64.9 |
| 2015 | 5.7 | 23.8 | 38.4 | 72.8 |
| 2020 | 6.8 | 26.3 | 41.7 | 80.7 |
| 2025 | 8.2 | 29.6 | 45.9 | 90.4 |
| 2030 | 9.7 | 32.8 | 50.0 | 100.0 |
| 2035 | 11.2 | 36.0 | 54.2 | 109.7 |
| 2040 | 12.7 | 39.2 | 58.4 | 119.3 |
| 2045 | 14.2 | 42.1 | 61.7 | 127.8 |
| 2050 | 15.7 | 44.9 | 65.0 | 136.2 |

The SCC values used for the analysis of the effects of potential standards for this rulemaking were generated using the most recent versions of the three integrated assessment models that have been published in the peer-reviewed literature, as described in the 2013 update from the interagency working group (revised November 2013).[42] Table 14.2 shows the updated sets of

SCC estimates in 5-year increments from 2010 to 2050. The central value that emerges is the average SCC across models at a 3-percent discount rate. To capture the uncertainties involved in regulatory impact analysis, however, the interagency group emphasizes the importance of including all four sets of SCC values.

**Table 14.2 Annual SCC Values for 2010–2050 from 2013 Interagency Update**

| Year | SCC Case | | | |
|---|---|---|---|---|
| | 5% Discount Rate, Average | 3% Discount Rate, Average | 2.5% Discount Rate, Average | 3% Discount Rate, 95th Percentile |
| | *2007$ per metric ton* | | | |
| 2010 | 11 | 33 | 52 | 90 |
| 2015 | 12 | 38 | 58 | 109 |
| 2020 | 12 | 43 | 65 | 129 |
| 2025 | 14 | 48 | 70 | 144 |
| 2030 | 16 | 52 | 76 | 159 |
| 2035 | 19 | 57 | 81 | 176 |
| 2040 | 21 | 62 | 87 | 192 |
| 2045 | 24 | 66 | 92 | 206 |
| 2050 | 27 | 71 | 98 | 221 |

The SCC grows over time because future emissions are expected to produce larger incremental damages as physical and economic systems become more stressed in response to greater climatic change. In the current methodology, the interagency group allowed the growth rate to be determined endogenously by the assessment models by running them for a set of perturbation years through 2050. These growth rates are enumerated in Table 14.3.

**Table 14.3 Average Annual Growth Rates of SCC Estimates Between 2010 and 2050**

| Year | Discount Rate % | | | |
|---|---|---|---|---|
| | 5% Discount Rate, Average | 3% Discount Rate, Average | 2.5% Discount Rate, Average | 3% Discount Rate, 95th Percentile |
| | Average Growth Rate % | | | |
| 2010 - 2020 | 1.2 | 3.2 | 2.4 | 4.3 |
| 2020 – 2030 | 3.4 | 2.1 | 1.7 | 2.4 |
| 2030 – 2040 | 3.0 | 1.8 | 1.5 | 2.0 |
| 2040 – 2050 | 2.6 | 1.6 | 1.3 | 1.5 |

The interagency group recognizes that current models are imperfect and incomplete. Because key uncertainties remain, current SCC estimates should be treated as provisional and revisable. Estimates doubtless will evolve in response to improved scientific and economic understanding. The 2009 National Research Council report points out the tension between producing quantified estimates of the economic damages from an incremental ton of carbon and the limits of current modeling efforts. Several analytic challenges are being addressed by the research community, some by research programs housed in many of the Federal agencies participating in the interagency process. The interagency group intends to review and reconsider SCC estimates periodically to incorporate expanding knowledge of the science and economics of climate impacts, as well as improvements in modeling.

In summary, in considering the potential global benefits resulting from reduced $CO_2$ emissions, DOE used the values from the 2013 interagency report, applying the GDP price deflator to adjust the values to 2015$. For the four SCC values, the values of emissions in 2015 were $13.5, $42.9, $65.4, and $122.9 per metric ton avoided (values expressed in 2015$). DOE derived values after 2050 using the relevant growth rates for 2040 to 2050 in the interagency update listed in Table 14.2. SCC values for years between those listed in Table 14.3 were estimated by linear interpolation. DOE multiplied the $CO_2$ emissions reduction estimated for each year by the SCC value for that year under each discount rate. To calculate a present value of the stream of monetary values, DOE discounted the values in each of the four cases using the same discount rate that had been used to obtain the SCC values in each case.

## 14.4 VALUATION OF OTHER EMISSIONS REDUCTIONS

DOE considered the potential monetary benefit of reduced $NO_X$ emissions under the proposed rule. As noted in chapter 13 of this NOPR TSD, the energy conservation standards would reduce $NO_X$ emissions in those states that are not affected by emissions caps. DOE estimated the monetized value of $NO_X$ emissions reductions resulting from the proposed rule based on environmental damage estimates found in the relevant scientific literature. Available estimates suggest a very wide range of monetary values, ranging from $370 per metric ton to $3,800 per metric ton of $NO_X$ from stationary sources, measured in 2001$ (equivalent to a range of $489 to $5,023 per metric ton in 2015$).[43] DOE calculated monetary benefits using an intermediate value of $2,755 per metric ton of $NO_X$ in 2015$. Furthermore, In accordance with OMB guidance, DOE conducted two calculations of the monetary benefits using each of the above values used for $NO_X$, one using a real discount rate of 3 percent and another using a real discount rate of 7 percent.[22]

DOE is aware of multiple agency efforts to determine the appropriate range of values used in evaluating the potential economic benefits of reduced Hg emissions. DOE has decided to await further guidance regarding consistent valuation and reporting of Hg emissions before it once again monetizes Hg in its rulemakings.

## 14.5 RESULTS

Table 14.4 presents the global values of $CO_2$ emissions reductions under the proposed rule.

**Table 14.4 Global Net Present Value of Reduced Emissions of $CO_2$ for Each SCC Value for Manufactured Homes Shipped 2017-2046**

| Home Size | SCC Case | | | |
|---|---|---|---|---|
| | **5% Discount Rate, Average** | **3% Discount Rate, Average** | **2.5% Discount Rate, Average** | **3% Discount Rate, 95th Percentile** |
| | ***Million 2015$*** | | | |
| **Site Emissions** | | | | |
| Single Section | 344.1 | 1,691.9 | 2,732.6 | 5,214.5 |
| Multi Section | 555.1 | 2,729.1 | 4,407.7 | 8,411.2 |
| **Upstream Emissions** | | | | |
| Single Section | 24.0 | 119.0 | 192.5 | 367.0 |
| Multi Section | 38.6 | 191.4 | 309.5 | 590.3 |
| **Full-Fuel-Cycle Emissions** | | | | |
| Single Section | 368.2 | 1,810.9 | 2,925.0 | 5,581.5 |
| Multi Section | 593.7 | 2,920.5 | 4,717.3 | 9,001.5 |

After calculating global values of $CO_2$ emissions reductions, DOE calculated domestic values as a range of from 7 percent to 23 percent of the global values. Results for domestic values are presented in Table 14.5.

**Table 14.5 Domestic Net Present Value of Reduced Emissions of $CO_2$ for Each SCC Value for Manufactured Homes Shipped 2017- 2046**

| Home Size | SCC Case | | | |
|---|---|---|---|---|
| | 5% Discount Rate, Average | 3% Discount Rate, Average | 2.5% Discount Rate, Average | 3% Discount Rate, 95th Percentile |
| | *Million 2015$* | | | |
| **Site Emissions** | | | | |
| Single Section | 24.1 to 79.2 | 118.4 to 389.1 | 191.3 to 628.5 | 365.0 to 1,199.3 |
| Multi Section | 38.9 to 127.7 | 191.0 to 627.7 | 308.5 to 1,013.8 | 588.8 to 1,934.6 |
| **Upstream Emissions** | | | | |
| Single Section | 1.7 to 5.5 | 8.3 to 27.4 | 13.5 to 44.3 | 25.7 to 84.4 |
| Multi Section | 2.7 to 8.9 | 13.4 to 44.0 | 21.7 to 71.2 | 41.3 to 135.8 |
| **Full-Fuel-Cycle Emissions** | | | | |
| Single Section | 25.8 to 84.7 | 126.8 to 416.5 | 204.8 to 672.8 | 390.7 to 1,283.8 |
| Multi Section | 41.6 to 136.6 | 204.4 to 671.7 | 330.2 to 1,085.0 | 630.1 to 2,070.3 |

Table 14.6 lists the net present values of the cumulative $NO_X$ emissions reductions under the proposed action. Monetary values were calculated using both 7-percent and 3-percent discount rates.

**Table 14.6 Net Present Value of Reduced Emissions of $NO_X$ for Each Discount Rate for Manufactured Homes Shipped 2017–2046**

| Home Size | Discount Rate | |
|---|---|---|
| | 3% | 7% |
| | *Million 2015$* | |
| **Site Emissions** | | |
| Single Section | 252.8 | 97.4 |
| Multi Section | 404.4 | 155.8 |
| **Upstream Emissions** | | |
| Single Section | 58.6 | 22.5 |
| Multi Section | 94.3 | 36.1 |
| **Full-Fuel-Cycle Emissions** | | |
| Single Section | 311.5 | 119.8 |
| Multi Section | 498.6 | 191.9 |

# CHAPTER 15. REGULATORY IMPACT ANALYSIS

## 15.1 INTRODUCTION

DOE has determined that the standards for manufactured housing outlined in the proposed rule constitute an "economically significant regulatory action" under Executive Order 12866, Regulatory Planning and Review. *See* 58 FR 51735, 58(190):51735, October 4, 1993. DOE has therefore committed to comparing regulatory alternatives to chosen standards by performing a regulatory impact analysis (RIA). *See* 61 FR 36981, 61(136):36978, July 15, 1996. This RIA, which DOE has prepared pursuant to Executive Order 12866, examines the economic impact of the 2009 edition of the IECC, the 2012 edition of the IECC, and the proposed rule. This RIA analyzes the impacts of the regulatory alternatives on purchase price of single-section and multi-section manufactured homes, impacts on total annualized economic costs and benefits to the nation and impacts on manufacturers. Because the proposed rule is based on the 2015 edition of the IECC, DOE did not analyze the 2015 IECC code as a regulatory alternative.

## 15.2 INPUTS

Table 15.1 shows the envelope requirements for the 2009 and 2012 IECC codes and the proposed rule as they would be applied to each of the 19 cities analyzed in this TSD. Using the inputs listed in Table 15.1, and the housing characteristics described in chapter 7 of this TSD, DOE performed energy use simulations using the methodology described in chapter 7 of this TSD. With these energy simulation results, DOE analyzed the economic impacts of these regulatory alternatives, and compared them to the economic impacts of the proposed rule.

## Table 15.1 Comparison of Component Requirements for Regulatory Alternatives and the Proposed Rule

| Climate Zone | | Location | Building Component | Efficiency Levels | | |
|---|---|---|---|---|---|---|
| IECC | Proposed | | | 2009 IECC | 2012 IECC | Proposed Rule |
| 1A | 1 | Miami | Wall Insulation *R*-value | 13 | 13 | 13 |
| | | | Ceiling Insulation *R*-value | 30 | 30 | 30 |
| | | | Floor Insulation *R*-value | 13 | 13 | 13 |
| | | | Window *U*-factor | 1.20 | 0.35 | 0.35 |
| | | | Window SHGC | 0.30 | 0.33 | 0.25 |
| | | | Envelope Leakage Limit | 7 | 5 | 5 |
| | | | Duct Leakage Limit | 8 | 4 | 4 |
| | | | Domestic Hot Water Pipe Insulation | NR | *R*-3 | *R*-3 |
| 2A | 1 | Houston | Wall Insulation *R*-value | 13 | 13 | 13 |
| | | | Ceiling Insulation *R*-value | 30 | 38 | 30 |
| | | | Floor Insulation *R*-value | 13 | 13 | 13 |
| | | | Window *U*-factor | 0.65 | 0.35 | 0.35 |
| | | | Window SHGC | 0.30 | 0.33 | 0.25 |
| | | | Envelope Leakage Limit | 7 | 5 | 5 |
| | | | Duct Leakage Limit | 8 | 4 | 4 |
| | | | Domestic Hot Water Pipe Insulation | NR | *R*-3 | *R*-3 |
| 2B | 1 | Phoenix | Wall Insulation *R*-value | 13 | 13 | 13 |
| | | | Ceiling Insulation *R*-value | 30 | 38 | 30 |
| | | | Floor Insulation *R*-value | 13 | 13 | 13 |
| | | | Window *U*-factor | 0.65 | 0.35 | 0.35 |
| | | | Window SHGC | 0.30 | 0.33 | 0.25 |
| | | | Envelope Leakage Limit | 7 | 5 | 5 |
| | | | Duct Leakage Limit | 8 | 4 | 4 |
| | | | Domestic Hot Water Pipe Insulation | NR | *R*-3 | *R*-3 |
| 3A | 2 | Atlanta | Wall Insulation *R*-value | 13 | 20 | 13 |
| | | | Ceiling Insulation *R*-value | 30 | 38 | 30 |
| | | | Floor Insulation *R*-value | 19 | 19 | 13 |
| | | | Window *U*-factor | 0.50 | 0.35 | 0.35 |
| | | | Window SHGC | 0.30 | 0.33 | 0.33 |
| | | | Envelope Leakage Limit | 7 | 3 | 5 |
| | | | Duct Leakage Limit | 8 | 4 | 4 |
| | | | Domestic Hot Water Pipe Insulation | NR | *R*-3 | *R*-3 |
| 3A | 2 | Charleston | Wall Insulation *R*-value | 13 | 20 | 13 |
| | | | Ceiling Insulation *R*-value | 30 | 38 | 30 |
| | | | Floor Insulation *R*-value | 19 | 19 | 13 |
| | | | Window *U*-factor | 0.50 | 0.35 | 0.35 |
| | | | Window SHGC | 0.30 | 0.33 | 0.33 |

| Climate Zone | | Location | Building Component | Efficiency Levels | | |
|---|---|---|---|---|---|---|
| **IECC** | **Proposed** | | | **2009 IECC** | **2012 IECC** | **Proposed Rule** |
| | | | Envelope Leakage Limit | 7 | 3 | 5 |
| | | | Duct Leakage Limit | 8 | 4 | 4 |
| | | | Domestic Hot Water Pipe Insulation | NR | *R*-3 | *R*-3 |
| 3A | 2 | Jackson | Wall Insulation *R*-value | 13 | 21 | 13 |
| | | | Ceiling Insulation *R*-value | 30 | 38 | 30 |
| | | | Floor Insulation *R*-value | 19 | 19 | 13 |
| | | | Window *U*-factor | 0.50 | 0.35 | 0.35 |
| | | | Window SHGC | 0.30 | 0.33 | 0.33 |
| | | | Envelope Leakage Limit | 7 | 3 | 5 |
| | | | Duct Leakage Limit | 8 | 4 | 4 |
| | | | Domestic Hot Water Pipe Insulation | NR | *R*-3 | *R*-3 |
| 3A | 2 | Birmingham | Wall Insulation *R*-value | 13 | 21 | 13 |
| | | | Ceiling Insulation *R*-value | 30 | 38 | 30 |
| | | | Floor Insulation *R*-value | 19 | 19 | 13 |
| | | | Window *U*-factor | 0.50 | 0.35 | 0.35 |
| | | | Window SHGC | 0.30 | 0.33 | 0.33 |
| | | | Envelope Leakage Limit | 7 | 3 | 5 |
| | | | Duct Leakage Limit | 8 | 4 | 4 |
| | | | Domestic Hot Water Pipe Insulation | NR | *R*-3 | *R*-3 |
| 3A | 3 | Memphis | Wall Insulation *R*-value | 13 | 21 | 21 |
| | | | Ceiling Insulation *R*-value | 30 | 38 | 30 |
| | | | Floor Insulation *R*-value | 19 | 19 | 19 |
| | | | Window *U*-factor | 0.50 | 0.35 | 0.35 |
| | | | Window SHGC | 0.30 | 0.33 | 0.33 |
| | | | Envelope Leakage Limit | 7 | 3 | 5 |
| | | | Duct Leakage Limit | 8 | 4 | 4 |
| | | | Domestic Hot Water Pipe Insulation | NR | *R*-3 | *R*-3 |
| 3B | 3 | El Paso | Wall Insulation *R*-value | 13 | 21 | 21 |
| | | | Ceiling Insulation *R*-value | 30 | 38 | 30 |
| | | | Floor Insulation *R*-value | 19 | 19 | 19 |
| | | | Window *U*-factor | 0.50 | 0.35 | 0.35 |
| | | | Window SHGC | 0.30 | 0.33 | 0.33 |
| | | | Envelope Leakage Limit | 7 | 3 | 5 |
| | | | Duct Leakage Limit | 8 | 4 | 4 |
| | | | Domestic Hot Water Pipe Insulation | NR | *R*-3 | *R*-3 |
| 3C | 3 | San Francisco | Wall Insulation *R*-value | 13 | 21 | 21 |
| | | | Ceiling Insulation *R*-value | 30 | 38 | 30 |
| | | | Floor Insulation *R*-value | 19 | 19 | 19 |
| | | | Window *U*-factor | 0.50 | 0.35 | 0.35 |
| | | | Window SHGC | NR (0.6)** | 0.33 | 0.33 |
| | | | Envelope Leakage Limit | 7 | 3 | 5 |

| Climate Zone | | Location | Building Component | Efficiency Levels | | |
|---|---|---|---|---|---|---|
| IECC | Proposed | | | 2009 IECC | 2012 IECC | Proposed Rule |
| | | | Duct Leakage Limit | 8 | 4 | 4 |
| | | | Domestic Hot Water Pipe Insulation | NR | *R*-3 | *R*-3 |
| 4A | 3 | Baltimore | Wall Insulation *R*-value | 13 | 21 | 21 |
| | | | Ceiling Insulation *R*-value | 38 | 38 | 30 |
| | | | Floor Insulation *R*-value | 19 | 19 | 19 |
| | | | Window *U*-factor | 0.35 | 0.35 | 0.35 |
| | | | Window SHGC | NR (0.33)** | 0.33 | 0.33 |
| | | | Envelope Leakage Limit | 7 | 3 | 5 |
| | | | Duct Leakage Limit | 8 | 4 | 4 |
| | | | Domestic Hot Water Pipe Insulation | NR | *R*-3 | *R*-3 |
| 4B | 3 | Albuquerque | Wall Insulation *R*-value | 13 | 21 | 21 |
| | | | Ceiling Insulation *R*-value | 38 | 38 | 30 |
| | | | Floor Insulation *R*-value | 19 | 19 | 19 |
| | | | Window *U*-factor | 0.35 | 0.35 | 0.35 |
| | | | Window SHGC | NR (0.33)** | 0.33 | 0.33 |
| | | | Envelope Leakage Limit | 7 | 3 | 5 |
| | | | Duct Leakage Limit | 8 | 4 | 4 |
| | | | Domestic Hot Water Pipe Insulation | NR | *R*-3 | *R*-3 |
| 4C | 4 | Salem | Wall Insulation *R*-value | 20 | 21 | 21 |
| | | | Ceiling Insulation *R*-value | 38 | 38 | 38 |
| | | | Floor Insulation *R*-value | 30 | 30 | 30* |
| | | | Window *U*-factor | 0.35 | 0.32 | 0.32 |
| | | | Window SHGC | NR (0.33)** | 0.33 | NR (0.33)** |
| | | | Envelope Leakage Limit | 7 | 3 | 5 |
| | | | Duct Leakage Limit | 8 | 4 | 4 |
| | | | Domestic Hot Water Pipe Insulation | NR | *R*-3 | *R*-3 |
| 5A | 4 | Chicago | Wall Insulation *R*-value | 20 | 21 | 21 |
| | | | Ceiling Insulation *R*-value | 38 | 38 | 38 |
| | | | Floor Insulation *R*-value | 30 | 30 | 30* |
| | | | Window *U*-factor | 0.35 | 0.32 | 0.32 |
| | | | Window SHGC | NR (0.33)** | 0.33 | NR (0.33)** |
| | | | Envelope Leakage Limit | 7 | 3 | 5 |
| | | | Duct Leakage Limit | 8 | 4 | 4 |
| | | | Domestic Hot Water Pipe Insulation | NR | *R*-3 | *R*-3 |
| 5B | 4 | Boise | Wall Insulation *R*-value | 20 | 21 | 21 |
| | | | Ceiling Insulation *R*-value | 38 | 38 | 38 |
| | | | Floor Insulation *R*-value | 30 | 30 | 30* |

| Climate Zone | | Location | Building Component | Efficiency Levels | | |
|---|---|---|---|---|---|---|
| IECC | Proposed | | | 2009 IECC | 2012 IECC | Proposed Rule |
| | | | Window *U*-factor | 0.35 | 0.32 | 0.32 |
| | | | Window SHGC | NR (0.33)** | 0.33 | NR (0.33)** |
| | | | Envelope Leakage Limit | 7 | 3 | 5 |
| | | | Duct Leakage Limit | 8 | 4 | 4 |
| | | | Domestic Hot Water Pipe Insulation | NR | *R*-3 | *R*-3 |
| 6A | 4 | Burlington | Wall Insulation *R*-value | 20 | 21+5 | 21 |
| | | | Ceiling Insulation *R*-value | 38† | 38 | 38 |
| | | | Floor Insulation *R*-value | 30 | 30 | 30* |
| | | | Window *U*-factor | 0.35 | 0.32 | 0.32 |
| | | | Window SHGC | NR (0.33)** | 0.33 | NR (0.33)** |
| | | | Envelope Leakage Limit | 7 | 3 | 5 |
| | | | Duct Leakage Limit | 8 | 4 | 4 |
| | | | Domestic Hot Water Pipe Insulation | NR | *R*-3 | R-3 |
| 6B | 4 | Helena | Wall Insulation *R*-value | 20 | 21+5 | 21 |
| | | | Ceiling Insulation *R*-value | 38† | 38 | 38 |
| | | | Floor Insulation *R*-value | 30 | 30 | 30* |
| | | | Window *U*-factor | 0.35 | 0.32 | 0.32 |
| | | | Window SHGC | NR (0.33)** | 0.33 | NR (0.33)** |
| | | | Envelope Leakage Limit | 7 | 3 | 5 |
| | | | Duct Leakage Limit | 8 | 4 | 4 |
| | | | Domestic Hot Water Pipe Insulation | NR | *R*-3 | *R*-3 |
| 7 | 4 | Duluth | Wall Insulation *R*-value | 21 | 21+5 | 21 |
| | | | Ceiling Insulation *R*-value | 38† | 38 | 38 |
| | | | Floor Insulation *R*-value | 38 | 38 | 30* |
| | | | Window *U*-factor | 0.35 | 0.32 | 0.32 |
| | | | Window SHGC | NR (0.33)** | 0.33 | NR (0.33)** |
| | | | Envelope Leakage Limit | 7 | 3 | 5 |
| | | | Duct Leakage Limit | 8 | 4 | 4 |
| | | | Domestic Hot Water Pipe Insulation | NR | *R*-3 | R-3 |
| 8 | 4 | Fairbanks | Wall Insulation *R*-value | 21 | 21+5 | 21 |
| | | | Ceiling Insulation *R*-value | 38† | 38 | 38 |
| | | | Floor Insulation *R*-value | 38 | 38 | 30* |
| | | | Window *U*-factor | 0.35 | 0.32 | 0.32 |
| | | | Window SHGC | NR (0.33)** | 0.33 | NR (0.33)** |
| | | | Envelope Leakage Limit | 7 | 3 | 5 |
| | | | Duct Leakage Limit | 8 | 4 | 4 |

| Climate Zone | | Location | Building Component | Efficiency Levels | | |
|---|---|---|---|---|---|---|
| IECC | Proposed | | | 2009 IECC | 2012 IECC | Proposed Rule |
| | | | Domestic Hot Water Pipe Insulation | NR | *R*-3 | *R*-3 |

* As described in the working group term sheet (see EERE-2009-BT-BC-0021-0107, p. 3, Recommendation 5.1), the floor *R*-value assumes *R*-21 batt+*R*-14 blanket to account for compression areas in the floor in climate zone 4.
** In absence of an SHGC requirement, the SHGC corresponding to the window meeting the *U*-factor requirement based on ASRAC Cost Analysis (see EERE-2009-BT-BC-0021-0091) was selected for use in simulations.
† The original IECC prescriptive requirements for ceiling insulation have been modified in some cases to provide consideration for constraints related to manufactured housing dimensions and construction. Where the IECC prescribes ceiling insulation greater than R-38, a value of R-38 is used.
NR: No requirement
Units:
Wall Insulation *R*-value: (hr-ft$^2$-°F/Btu)
Ceiling Insulation *R*-value: (hr-ft$^2$-°F/Btu)

## 15.3 RESULTS

The results described below compare the incremental purchase price and the net annualized economic impacts to the nation of the proposed rule and the regulatory alternatives.

### 15.3.1 Incremental Purchase Price

The 2012 IECC leads to the largest incremental purchase price increase compared to the 2009 IECC and the proposed rule in all but one of the 19 cities. The proposed rule leads to larger incremental purchase price increases compared to the 2009 IECC in each city.

**Table 15.2 Total Incremental Purchase Price of Single-Section Manufactured Homes Under the Regulatory Alternatives and the Proposed Standard Compared to the HUD Code**

| Climate Zone | City | Total Incremental Home Purchase Price *2015$* | | |
|---|---|---|---|---|
| | | 2009 IECC | 2012 IECC | Proposed Rule |
| 1 | Miami | 2,058.75 | 2,348.41 | 2,443.20 |
| | Houston | 2,058.75 | 2,738.53 | 2,443.20 |
| | Phoenix | 1,191.91 | 1,871.68 | 1,576.35 |
| 2 | Atlanta | 2,136.64 | 3,693.49 | 2,348.41 |
| | Charleston | 2,136.64 | 3,693.49 | 2,348.41 |
| | Jackson | 2,136.64 | 3,693.49 | 2,348.41 |
| | Birmingham | 2,136.64 | 3,693.49 | 2,348.41 |
| 3 | Memphis | 1,269.80 | 2,826.65 | 2,268.69 |
| | El Paso | 1,269.80 | 2,826.65 | 2,268.69 |
| | San Francisco | 808.99 | 2,826.65 | 2,268.69 |
| | Baltimore | 575.14 | 1,777.42 | 1,219.46 |
| | Albuquerque | 1,624.37 | 2,826.65 | 2,268.69 |
| 4 | Salem | 1,800.45 | 2,375.48 | 2,207.63 |
| | Chicago | 1,800.45 | 2,375.48 | 2,207.63 |
| | Boise | 1,800.45 | 2,375.48 | 2,207.63 |

| | | | | |
|---|---|---|---|---|
| | Burlington | 1,800.45 | 3,909.02 | 2,207.63 |
| | Helena | 1,800.45 | 3,909.02 | 2,207.63 |
| | Duluth | 2,119.07 | 4,227.64 | 2,207.63 |
| | Fairbanks | 2,119.07 | 4,227.64 | 2,207.63 |
| | National Average* | 1,704.34 | 2,933.49 | 2,226.12 |
| * National average represents a shipment weighted average. A detailed description of the shipments model can be found in chapter 10 of the NOPR TSD. | | | | |

**Table 15.3 Total Incremental Purchase Price of Multi-Section Manufactured Homes Under the Regulatory Alternatives and the Proposed Standard Compared to the HUD Code**

| Climate Zone | City | Total Incremental Home Purchase Price *2015$* | | |
|---|---|---|---|---|
| | | **2009 IECC** | **2012 IECC** | **Proposed Rule** |
| 1 | Miami | 3,298.31 | 3,668.22 | 3,828.76 |
| | Houston | 3,298.31 | 4,210.54 | 3,828.76 |
| | Phoenix | 1,830.58 | 2,742.81 | 2,361.02 |
| 2 | Atlanta | 3,430.48 | 5,313.24 | 3,668.22 |
| | Charleston | 3,430.48 | 5,313.24 | 3,668.22 |
| | Jackson | 3,430.48 | 5,313.24 | 3,668.22 |
| | Birmingham | 3,430.48 | 5,313.24 | 3,668.22 |
| 3 | Memphis | 1,962.75 | 3,845.51 | 3,030.44 |
| | El Paso | 1,962.75 | 3,845.51 | 3,030.44 |
| | San Francisco | 1,182.28 | 3,845.51 | 3,030.44 |
| | Baltimore | 762.83 | 2,163.48 | 1,348.40 |
| | Albuquerque | 2,444.86 | 3,845.51 | 3,030.44 |
| 4 | Salem | 2,308.49 | 3,150.20 | 2,877.44 |
| | Chicago | 2,308.49 | 3,150.20 | 2,877.44 |
| | Boise | 2,308.49 | 3,150.20 | 2,877.44 |
| | Burlington | 2,308.49 | 4,672.11 | 2,877.44 |
| | Helena | 2,308.49 | 4,672.11 | 2,877.44 |
| | Duluth | 2,750.10 | 5,113.72 | 2,877.44 |
| | Fairbanks | 2,750.10 | 5,113.72 | 2,877.44 |
| | National Average* | 2,429.41 | 3,939.09 | 3,109.20 |
| * National average represents a shipment weighted average. A detailed description of the shipments model can be found in chapter 10 of the NOPR TSD. | | | | |

### 15.3.2 Annualized Economic Impacts to the Nation

DOE analyzed the annualized economic impacts to the nation of the proposed rule and the regulatory alternatives. DOE used the NIA model and the emissions model, described in chapter 11 and chapter 13 of this NOPR TSD respectively, to calculate the annualized costs and savings from 30 years of shipments of manufactured homes compliant with the proposed rule and the regulatory alternatives. Table 15.4 contains the monetary savings attributable to saved energy and emissions, and the monetary costs attributable to the increase in purchase price.

As listed in Table 15.4, the 2012 IECC has greater net benefits than the proposed rule. This can be attributed to the more stringent envelope leakage limit in the 2012 IECC relative to the proposed rule. In all but three of the analyzed cities, the 2012 IECC has a more stringent requirement of 3 ACH for the envelope leakage limit. As discussed in chapter 6 of this NOPR TSD, the MH working group recommended not implementing an envelope leakage limit of 3 ACH because of a determination that it would be impractical and not cost-effective in manufactured housing. The MH working group instead recommended prescriptive requirements that could be visually inspected. These requirements would achieve an envelope leakage limit of 5 ACH. A detailed discussion of this issue can be found in chapter 6 of this TSD. Consequently, the proposed rule is favorable to both the 2009 and 2012 IECC alternatives when considering both monetary benefits and technical feasibility.

**Table 15.4 Total Annualized Benefits and Costs from the Consumer Perspective Under the Regulatory Alternatives and the Proposed Rule**

| | Discount Rate % | Monetized million *2015$/year* | | |
|---|---|---|---|---|
| | | **2009 IECC** | **2012 IECC** | **Proposed Rule** |
| Benefits* | | | | |
| Operating (Energy) Cost Savings | 7 | 286 | 636 | 516 |
| | 3 | 468 | 1,040 | 843 |
| $CO_2$, Average SCC Case† | 5 | 34 | 77 | 63 |
| $CO_2$, Average SCC Case† | 3 | 133 | 298 | 241 |
| $CO_2$, Average SCC Case† | 2.5 | 201 | 451 | 365 |
| $CO_2$, 95th Percentile SCC Case† | 3 | 410 | 919 | 744 |
| $NO_X$ Reduction at $2,773/metric ton† | 7 | 13 | 33 | 25 |
| | 3 | 22 | 54 | 41 |
| Total (Operating Cost Savings, $CO_2$ Reduction and $NO_X$ Reduction) | 7 plus $CO_2$ range | 334 to 709 | 746 to 1,588 | 604 to 1,285 |
| | 7 | 432 | 967 | 783 |
| | 3 | 623 | 1,392 | 1,126 |
| | 3 plus $CO_2$ range | 524 to 900 | 1,171 to 2,013 | 947 to 1,628 |
| **Costs*** | | | | |
| Incremental Purchase Price Increase | 7 | 170 | 281 | 220 |
| | 3 | 214 | 355 | 277 |
| **Net Benefits/Costs*** | | | | |
| Total (Operating Cost Savings, $CO_2$ Reduction and $NO_X$ Reduction, Minus Incremental Cost Increase to Homes) | 7 plus $CO_2$ range | 164 to 539 | 465 to 1,307 | 384 to 1,065 |
| | 7 | 262 | 686 | 563 |
| | 3 | 409 | 1,037 | 849 |
| | 3 plus $CO_2$ range | 310 to 686 | 816 to 1,658 | 670 to 1,351 |

*The benefits and costs are calculated for homes shipped in 2017-2046.
**All calculations utilize forecasts of energy prices from the 2015 *AEO* Reference case.
† The $CO_2$ values represent global monetized values (in 2015$) of the social cost of $CO_2$ emissions reductions over the analysis period under several different scenarios of the SCC model. The "average SCC case" refers to average predicted monetary savings as predicted by the SCC model. The "95th percentile case" refers to values calculated using the 95th percentile impacts of the SCC model, which accounts for greater than expected environmental damages. The value for $NO_X$ (in 2015$) is the average of the low and high values used in DOE's analysis.

### 15.3.3 Impacts on Manufacturers

Table 15.5 shows the potential impacts of standards set at the 2009 IECC code, 2012 IECC codes, and proposed rule levels. The INPV results are based on two markup scenarios. This results in a range of potential impacts. The more severe and negative impacts are the result of the Preservation of Operating Profit scenario. The less severe impacts are the result of the Preservation of Gross Margin Percentage scenario. These scenarios are described in chapter 12 of the NOPR TSD.

Of the scenarios analyzed, the 2012 IECC levels have the most severe potential negative impacts. This result stems from the fact that the 2012 IECC levels have the largest incremental purchase price increase. This price increase affects manufacturer operating margin and sales volumes.

**Table 15.5 Range of INPV Impacts for the Manufactured Home Industry***

| | 2009 IECC | 2012 IECC | Propose Rule |
|---|---|---|---|
| Base Case INPV<br>*Million 2015$* | 716.7 | 716.7 | 716.7 |
| Standards Case INPV<br>*Million 2015$* | 680.0 to 713.6 | 655.7 to 711.4 | 667.8 to 711.6 |
| Change in INPV<br>*Million 2015$* | (36.8) to (3.1) | (61.0) to (5.3) | (48.9) to (5.2) |
| Change in INPV<br>*%* | (5.1) to (0.4) | (8.5) to (0.7) | (6.8) to (0.7) |
| Total Conversion Costs<br>*Million 2015$* | 1.6 | 1.6 | 1.6 |

*Values in parentheses are negative values.

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## APPENDIX 11A. SENSITIVITY ANALYSES

### 11A.1 INTRODUCTION

DOE considered two separate sensitivity analyses related to shipments with the following changes: (1) a shipment growth rate of 6.5 percent instead of 1.8 percent, and (2) a price elasticity of demand of -2.40 instead of -0.48. To examine the impacts of the shipment sensitivities, DOE analyzed the National Energy Savings (NES) and the Net Present Value (NPV) for the proposed rule, the 2012 IECC, and 2009 IECC. The methodology for calculating NES and NPV is discussed in CHAPTER 11 of the NOPR TSD.

### 11A.2 SHIPMENT GROWTH RATE SENSITIVITY ANALYSIS RESULTS

DOE considered a shipment scenario in which the growth rate is 6.5 percent (instead of 1.8 percent) based on the trend in actual manufactured home shipments from 2011 to 2014. If this trend persists over the 30 year analysis period, total shipments affected by the proposed regulations will be significantly larger (see discussion in 10.4). For this sensitivity analysis, DOE modified the shipment growth rate while maintaining all other assumptions detailed in chapter 10 of the NOPR TSD.

Figure 11A.1 provides the shipment projections from 2017-2046 for the standards case[h] using a 1.8 percent shipment growth rate, which is described further in chapter 10 of the NOPR TSD, and using the 6.5 percent shipment growth rate.

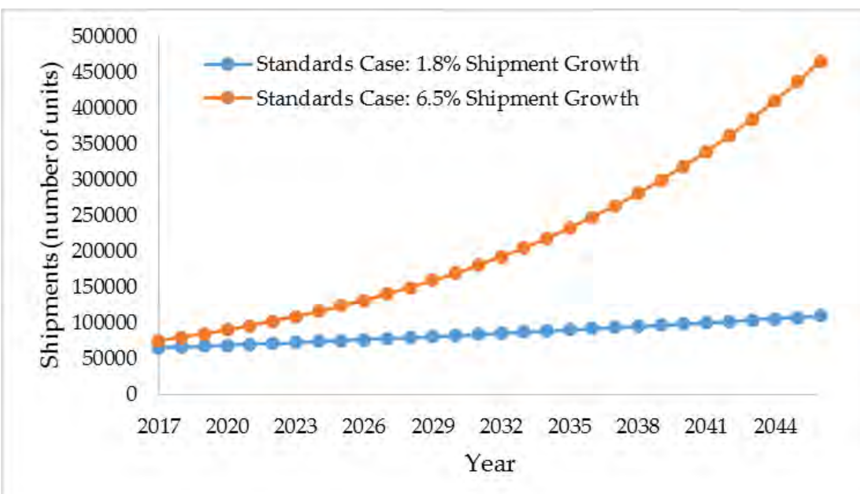



**Figure 11A.1. Shipment Projections for Standards Case Using 1.8% and 6.5% Shipment Growth Rates**

DOE then performed the NES and NPV calculations with the shipment model that contained the 6.5 percent shipment growth rate, and compared it to the results achieved with the

[h] Note, the standards case shipments differ from the base case shipments due to the effects of price elasticity discussed in chapter 10 of the NOPR TSD. Both the standards and base cases use the same shipment growth assumption for a given sensitivity scenario.

primary shipments model that contained the 1.8 percent shipment growth rate. Table 11A.1 provides the NES and NPV results for the proposed rule, 2012 IECC, and 2009 IECC. The efficiency requirements associated with each of these levels is discussed in CHAPTER 15 of the NOPR TSD.

**Table 11A.1. Shipments Growth Rate Sensitivity Analysis NES and NPV Results**

| | National Energy Savings (Full Fuel Cycle Quads) | | | Net Present Value 3% Discount Rate (Billion 2015$) | | | Net Present Value 7% Discount Rate (Billion 2015$) | | |
|---|---|---|---|---|---|---|---|---|---|
| | Proposed Rule | 2012 IECC | 2009 IECC | Proposed Rule | 2012 IECC | 2009 IECC | Proposed Rule | 2012 IECC | 2009 IECC |
| 1.8% Shipment Growth (primary scenario) | 2.3 | 2.84 | 1.28 | 10.93 | 13.23 | 4.93 | 3.47 | 4.16 | 1.38 |
| 6.5% Shipment Growth | 5.8 | 7.13 | 3.20 | 26.19 | 31.75 | 11.99 | 7.38 | 8.86 | 3.00 |

Because there is an increase in shipments resulting from the larger shipment growth rate, the NES and NPV results in turn also increase. However, the ranking of largest to smallest NES and NPV among the proposed rule, 2012 IECC, and 2009 IECC remains the same for 6.5 percent shipment growth rate scenario relative to the 1.8 percent primary shipment growth rate scenario.

## 11A.3 PRICE ELASTICITY OF DEMAND SENSITIVITY ANALYSIS RESULTS

DOE also considered a shipment scenario in which the price elasticity is -2.4 (instead of -0.48). HUD has used an estimate of -2.4 in analysis of revisions to its regulations[i] promulgated at 24 CFR 3282 based on a 1992 paper written by Carol Meeks. [44] This estimate increases the reduction in shipments resulting from the increased price of a proposed rule compliant manufactured home. For this sensitivity analysis, DOE used the -2.40 price elasticity of demand while maintaining all other assumptions detailed in chapter 10 of the NOPR TSD.

Figure 11A.2 provides the shipment projections from 2017-2046 for the standards case using the -0.48 price elasticity, which is described further in chapter 10 of the NOPR TSD, and using the -2.40 price elasticity.

[i] For example, see http://www.regulations.gov/#!documentDetail;D=HUD-2014-0033-0001.


**Figure 11A.2. Shipment Projections for Standards Case Using -0.48 and -2.4 Price Elasticity**

DOE then performed the NES and NPV calculations with the shipment model that contained the -2.4 price elasticity estimate, and compared it to the results achieved with the primary shipments model that contained the -0.48 price elasticity estimate. Table 11A.2 provides the NES and NPV results for the proposed rule, 2012 IECC, and 2009 IECC.

**Table 11A.2. Price Elasticity of Demand Sensitivity Analysis NES and NPV Results**

| | **National Energy Savings (Full Fuel Cycle Quads)** | | | **Net Present Value 3% Discount Rate (Billion 2015$)** | | | **Net Present Value 7% Discount Rate (Billion 2015$)** | | |
|---|---|---|---|---|---|---|---|---|---|
| | Proposed Rule | 2012 IECC | 2009 IECC | Proposed Rule | 2012 IECC | 2009 IECC | Proposed Rule | 2012 IECC | 2009 IECC |
| -0.48 Price Elasticity (primary scenario) | 2.3 | 2.84 | 1.28 | 10.93 | 13.23 | 4.93 | 3.47 | 4.16 | 1.38 |
| -2.4 Price Elasticity | 2.12 | 2.53 | 1.20 | 10.04 | 11.78 | 4.60 | 3.19 | 3.71 | 1.29 |

Because there is a decrease in shipments resulting from the more negative price elasticity, the NES and NPV results in turn also decrease. However, the ranking of largest to smallest NES and NPV among the proposed rule, the 2012 IECC, and 2009 IECC remains the same for the -2.4 price elasticity scenario relative to the -0.48 price elasticity scenario.

# LOG 171:

# Substantiating Documents

**405.2 Access for cleaning.** Plumbing fixtures shall be installed so as to afford easy *access* for cleaning both the fixture and the area around the fixture.

**405.3 Setting.** Fixtures shall be set level and in proper alignment with reference to adjacent walls.

**405.3.1 Water closets, urinals, lavatories and bidets.** A water closet, urinal, lavatory or bidet shall not be set closer than 15 inches (381 mm) from its center to any side wall, partition, vanity or other obstruction, or closer than 30 inches (762 mm) center-to-center between adjacent fixtures. There shall be at least a 21-inch (533 mm) clearance in front of the water closet, urinal, lavatory or bidet to any wall, fixture or door. Water closet compartments shall not be less than 30 inches (762 mm) wide and 60 inches (1524 mm) deep.

**Exception:** For one- and two-family dwellings and townhouses, see the *North Carolina Residential Code*.

**405.3.2 Public lavatories.** Deleted.

**405.4 Floor and wall drainage connections.** Connections between the drain and floor outlet plumbing fixtures shall be made with a floor flange. The flange shall be attached to the drain and anchored to the structure. Connections between the drain and wall-hung water closets shall be made with an *approved* extension nipple or horn adaptor. The water closet shall be bolted to the hanger with corrosion-resistant bolts or screws. Joints shall be sealed with an *approved* elastomeric gasket, flange-to-fixture connection complying with ASME A112.4.3 or an *approved* setting compound.

**405.4.1 Floor flanges.** Floor flanges for water closets or similar fixtures shall not be less than 0.125 inch (3.2 mm) thick for brass, 0.25 inch (6.4 mm) thick for plastic, and 0.25 inch (6.4 mm) thick and not less than a 2-inch (51 mm) caulking depth for cast-iron or galvanized malleable iron.

Floor flanges of hard lead shall weigh not less than 1 pound, 9 ounces (0.7 kg) and shall be composed of lead alloy with not less than 7.75-percent antimony by weight. Flanges shall be secured to the building structure with corrosion-resistant screws or bolts.

**405.4.2 Securing floor outlet fixtures.** Floor outlet fixtures shall be secured to the floor or floor flanges by screws or bolts of corrosion-resistant material.

**405.4.3 Securing wall-hung water closet bowls.** Wall-hung water closet bowls shall be supported by a concealed metal carrier that is attached to the building structural members so that strain is not transmitted to the closet connector or any other part of the plumbing system. The carrier shall conform to ASME A112.6.1M or ASME A112.6.2.

**405.5 Water-tight joints.** Joints formed where fixtures come in contact with walls or floors shall be sealed.

**405.6 Plumbing in mental health centers.** Deleted.

**405.7 Design of overflows.** Where any fixture is provided with an overflow, the waste shall be designed and installed so that standing water in the fixture will not rise in the overflow when the stopper is closed, and no water will remain in the overflow when the fixture is empty.

**405.7.1 Connection of overflows.** The overflow from any fixture shall discharge into the drainage system on the inlet or fixture side of the trap.

**Exception:** The overflow from a flush tank serving a water closet or urinal shall discharge into the fixture served.

**405.8 Slip joint connections.** Slip joints shall be made with an *approved* elastomeric gasket and shall only be installed on the trap outlet, trap inlet and within the trap seal. Fixtures with concealed slip-joint connections shall be provided with an *access* panel or utility space at least 12 inches (305 mm) in its smallest dimension or other *approved* arrangement so as to provide *access* to the slip joint connections for inspection and repair. Where such access cannot be provided, access doors shall not be required, provided that all joints are soldered, solvent cemented or screwed to form a solid connection.

**405.9 Design and installation of plumbing fixtures.** Integral fixture fitting mounting surfaces on manufactured plumbing fixtures or plumbing fixtures constructed on site, shall meet the design requirements of ASME A112.19.2M or ASME A112.19.3M.

## SECTION 406
## AUTOMATIC CLOTHES WASHERS

**406.1 Approval.** Domestic automatic clothes washers shall conform to ASSE 1007.

**406.2 Water connection.** The water supply to an automatic clothes washer shall be protected against backflow by an *air gap* installed integrally within the machine conforming to ASSE 1007 or with the installation of a backflow preventer in accordance with Section 608.

**406.3 Waste connection.** The waste from an automatic clothes washer shall connect to a vertical drain of not less than 2 inches (51 mm) in diameter, or a horizontal drain of not less than 3 inches (76 mm) in diameter. The 2-inch (51 mm) trap in the waste connection may be used as a cleanout for both the 2-inch (51 mm) and the 3-inch (76 mm). Automatic clothes washers that discharge by gravity shall be permitted to drain to a waste receptor or an approved trench drain.

## SECTION 407
## BATHTUBS

**407.1 Approval.** Bathtubs shall conform to ANSI Z124.1, ASME A112.19.1M, ASME A112.19.4M, ASME A112.19.9M, CSA B45.2, CSA B45.3 or CSA B45.5.

**407.2 Bathtub waste outlets.** Bathtubs shall have waste outlets a minimum of $1^1/_2$ inches (38 mm) in diameter. The waste outlet shall be equipped with an *approved* stopper.

**407.3 Glazing.** Windows and doors within a bathtub enclosure shall conform to the safety glazing requirements of the *International Building Code*.

**407.4 Bathtub enclosure.** Doors within a bathtub enclosure shall conform to ASME A112.19.15.

secured to the building structure with corrosion-resistant screws or bolts.

**405.4.2 Securing floor outlet fixtures.** Floor outlet fixtures shall be secured to the floor or floor flanges by screws or bolts of corrosion-resistant material.

**405.4.3 Securing wall-hung water closet bowls.** Wall-hung water closet bowls shall be supported by a concealed metal carrier that is attached to the building structural members so that strain is not transmitted to the closet connector or any other part of the plumbing system. The carrier shall conform to ASME A112.6.1M or ASME A112.6.2.

**405.5 Water-tight joints.** Joints formed where fixtures come in contact with walls or floors shall be sealed.

**405.6 Plumbing in mental health centers.** In mental health centers, pipes or traps shall not be exposed, and fixtures shall be bolted through walls.

**405.7 Design of overflows.** Where any fixture is provided with an overflow, the waste shall be designed and installed so that standing water in the fixture will not rise in the overflow when the stopper is closed, and no water will remain in the overflow when the fixture is empty.

**405.7.1 Connection of overflows.** The overflow from any fixture shall discharge into the drainage system on the inlet or fixture side of the trap.

**Exception:** The overflow from a flush tank serving a water closet or urinal shall discharge into the fixture served.

**405.8 Slip joint connections.** Slip joints shall be made with an *approved* elastomeric gasket and shall only be installed on the trap outlet, trap inlet and within the trap seal. Fixtures with concealed slip-joint connections shall be provided with an *access* panel or utility space not less than 12 inches (305 mm) in its smallest dimension or other *approved* arrangement so as to provide *access* to the slip joint connections for inspection and repair.

**405.9 Design and installation of plumbing fixtures.** Integral fixture fitting mounting surfaces on manufactured plumbing fixtures or plumbing fixtures constructed on site shall meet the design requirements of ASME A112.19.2/CSA B45.1 or ASME A112.19.3/CSA B45.4.

## SECTION 406
## AUTOMATIC CLOTHES WASHERS

**406.1 Water connection.** The water supply to an automatic clothes washer shall be protected against backflow by an *air gap* that is integral with the machine or a backflow preventer shall be installed in accordance with Section 608. *Air gaps* shall comply with ASME A112.1.2 or A112.1.3.

**406.2 Waste connection.** The waste from an automatic clothes washer shall discharge through an *air break* into a standpipe in accordance with Section 802.4 or into a laundry sink. The trap and *fixture drain* for an automatic clothes washer standpipe shall be not less than 2 inches (51 mm) in diameter. The *fixture drain* for the standpipe serving an automatic clothes washer shall connect to a 3-inch (76 mm) or larger diameter fixture *branch* or *stack*. Automatic clothes washers that discharge by gravity shall be permitted to drain to a waste receptor or an *approved* trench drain.

## SECTION 407
## BATHTUBS

**407.1 Approval.** Bathtubs shall conform to ASME A112.19.1/CSA B45.2, ASME A112.19.2/CSA B45.1, ASME A112.19.3/CSA B45.4 or CSA B45.5/IAPMO Z124.

**407.2 Bathtub waste outlets and overflows.** Bathtubs shall be equipped with a waste outlet and an overflow outlet. The outlets shall be connected to waste tubing or piping not less than $1^1/_2$ inches (38 mm) in diameter. The waste outlet shall be equipped with a water-tight stopper.

**407.3 Glazing.** Windows and doors within a bathtub enclosure shall conform to the safety glazing requirements of the *International Building Code*.

**407.4 Bathtub enclosure.** Doors in a bathtub enclosure shall conform to ASME A112.19.15.

## SECTION 408
## BIDETS

**408.1 Approval.** Bidets shall conform to ASME A112.19.2/CSA B45.1.

**408.2 Water connection.** The water supply to a bidet shall be protected against backflow by an *air gap* or backflow preventer in accordance with Section 608.13.1, 608.13.2, 608.13.3, 608.13.5, 608.13.6 or 608.13.8.

**408.3 Bidet water temperature.** The discharge water temperature from a bidet fitting shall be limited to a maximum temperature of 110°F (43°C) by a water temperature limiting device conforming to ASSE 1070 or CSA B125.3.

## SECTION 409
## DISHWASHING MACHINES

**409.1 Approval.** Commercial dishwashing machines shall conform to ASSE 1004 and NSF 3.

**409.2 Water connection.** The water supply to a dishwashing machine shall be protected against backflow by an *air gap* that is integral with the machine or a backflow preventer shall be installed in accordance with Section 608. *Air gaps* shall comply with ASME A112.1.2 or A112.1.3.

**409.3 Waste connection.** The waste connection of a dishwashing machine shall comply with Section 802.1.6 or 802.1.7, as applicable.

## SECTION 410
## DRINKING FOUNTAINS

**410.1 Approval.** Drinking fountains shall conform to ASME A112.19.1/CSA B45.2 or ASME A112.19.2/CSA B45.1 and water coolers shall conform to AHRI 1010. Drinking fountains and *water coolers* shall conform to NSF 61, Section 9.

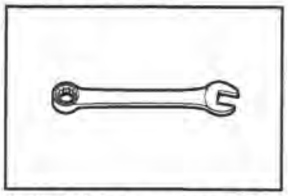
# INSTALLATION INSTRUCTIONS

## INSTALLATION REQUIREMENTS

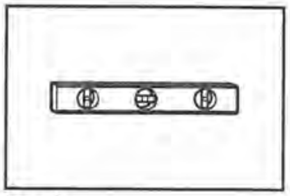
### Tools and Parts

Gather required tools and parts before starting installation.

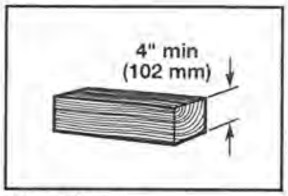
**Tools needed:**



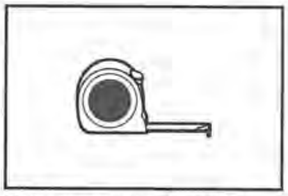
Adjustable or open end wrenches 15/32" (12 mm) and 1/2" (13 mm)



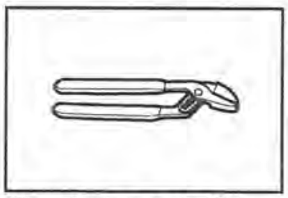
Level




Wood block



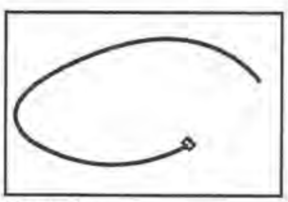
Ruler or measuring tape



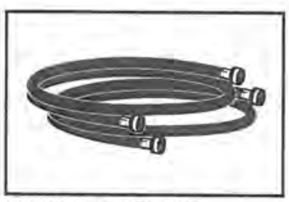
Pliers that open to 1⁹⁄₁₆" (39.5 mm)

**Parts supplied:**

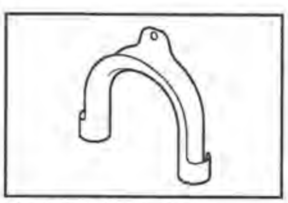
**NOTE:** All parts supplied for installation are in the washer basket.



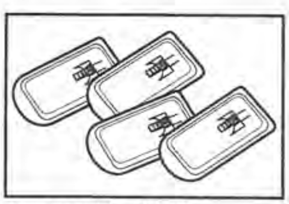
Cable tie



Inlet hoses (2) with washers

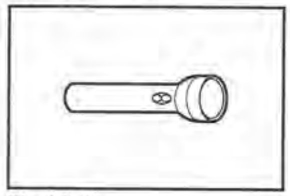


U-shaped hose form

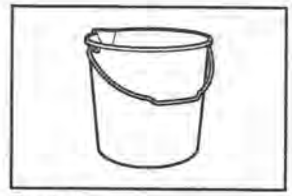


Transport bolt hole plugs (4)

**Optional tools:**



Flashlight

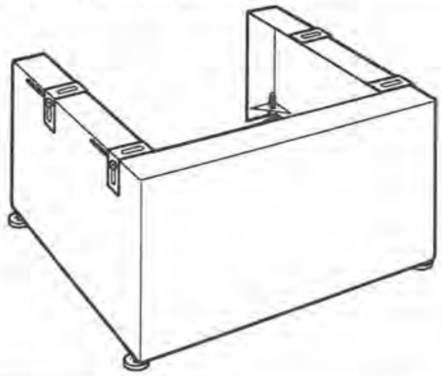


Bucket

**Options:**

**Pedestal:**

You have the option of purchasing a pedestal for this washer. You may select an 11.8" (300 mm) pedestal. The pedestal will add to the total height of the washer.



| Pedestal Height | Approximate Height with Washer | Color | Model Number |
|---|---|---|---|
| 11.8" (300 mm) | 44.7" (1135 mm) | White | LAB0050PQ |

**Alternate parts:** (Not supplied with washer)

Your installation may require additional parts. To order, please refer to toll-free numbers on the back page of this manual.

| If you have: | You will need: |
|---|---|
| Laundry tub or standpipe taller than 55" (1.4 m) | Sump pump system (if not already available) |
| Overhead sewer | Standard 20 gal. (76 L) 30" (762 mm) tall drain tub or utility sink, sump pump and connectors (available from local plumbing suppliers) |
| Floor drain system | Siphon Break Kit Part Number 285834<br>Connector Kit (x2) Part Number 285835<br>Additional Drain Hose Part Number 8318155 |
| Drain hose too short | Extension Drain Hose Part Number 285863<br>Connector Kit Part Number 285835 |
| Water faucets beyond reach of fill hoses | 2 longer water fill hoses:<br>6 ft (1.8 m) Part Number 76314<br>10 ft (3.0 m) Part Number 350008 |

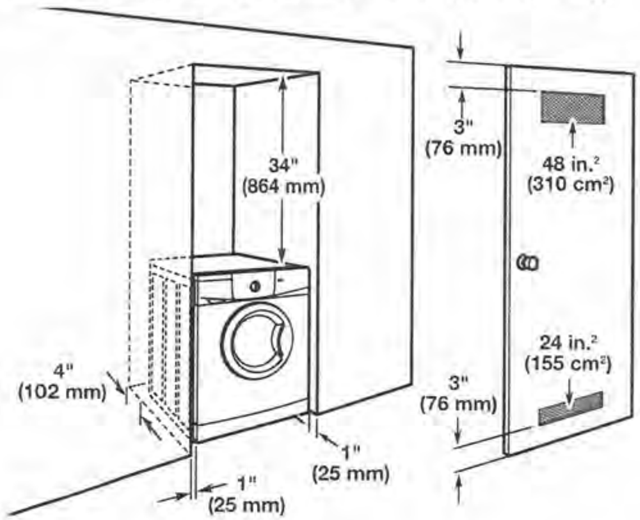
**Stack Kit:**

Are you planning to stack your washer and dryer? To do so you will need to purchase a Stack Kit.

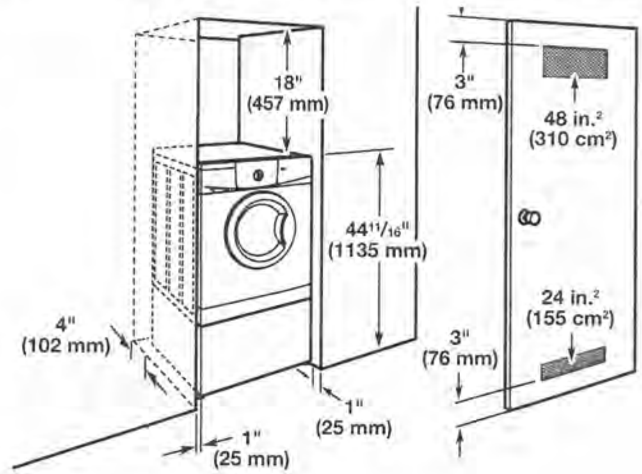
To order, call the dealer from whom you purchased your washer or refer to the "Assistance or Service" section. Ask for Part Number W10178021.

# LOCATION REQUIREMENTS (cont.)

**Recessed area or closet installation (washer only):**




**Recessed area or closet installation (washer on pedestal):**

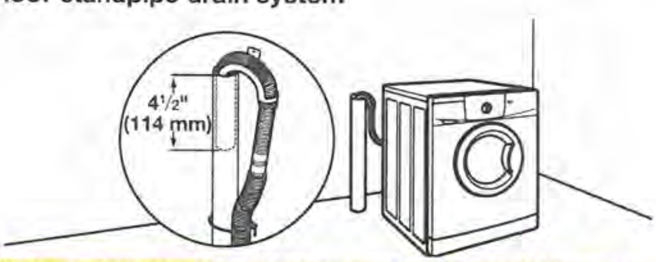



# DRAIN SYSTEM

Drain system can be installed using a floor drain, wall standpipe, floor standpipe, or laundry tub. Select method you need.

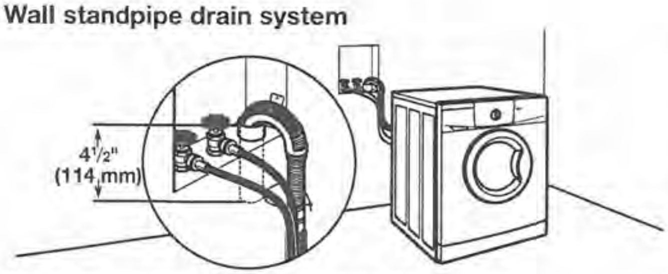
**IMPORTANT:** To avoid siphoning, only 4½" (114 mm) of drain hose should be inside standpipe. Always secure drain hose with cable tie.

**Floor standpipe drain system**



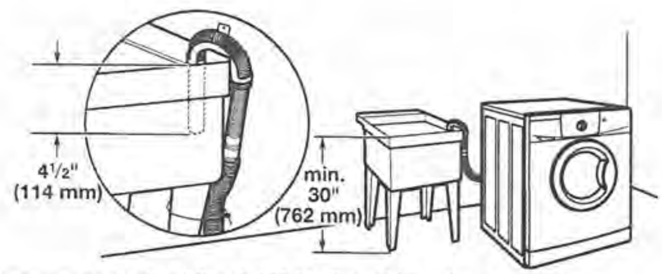

Minimum diameter for a standpipe drain: 2" (51 mm). Minimum carry-away capacity: 17 gal. (64 L) per minute. A 1/4" (6 mm) diameter to 1" (25 mm) diameter Standpipe Adapter Kit is available (Part Number 3363920). Top of standpipe must be at least 30" (762 mm) high; install no higher than 55" (1.4 m) from bottom of washer. If you have an overhead sewer and need to pump higher than 96 inches, a sump pump and associated hardware are needed. See "Alternate Parts".

**Wall standpipe drain system**



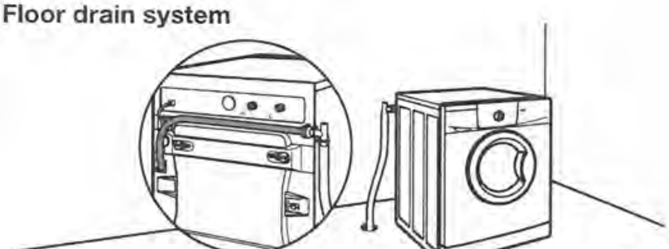

See requirements for floor standpipe drain system.

**Laundry tub drain system**



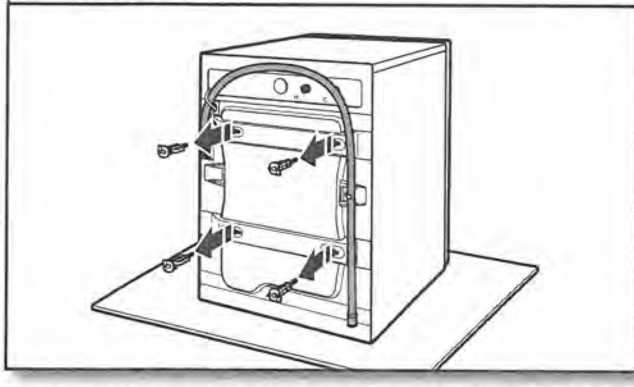

Minimum capacity: 20 gal. (76 L). Top of laundry tub must be at least 30" (762 mm) above floor; install no higher than 55" (1.4 m) from bottom of washer.

**Floor drain system**



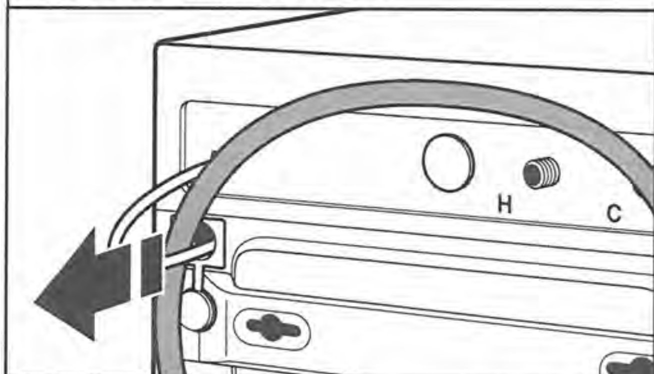
Floor drain system requires a Siphon Break Kit (Part Number 285834), 2 Connector Kits (Part Number 285835), and an Extension Drain Hose (Part Number 285863) that may be purchased separately. See "Alternate Parts". Minimum siphon break height: 28" (710 mm) from bottom of washer. (Additional hoses may be needed.)

## 3. Remove transport bolts from washer



Loosen bolts with a 15/32" (12 mm) wrench. Once the bolt is loose, move it to the center of the hole and completely pull out the bolt, including the plastic spacer covering the bolt.

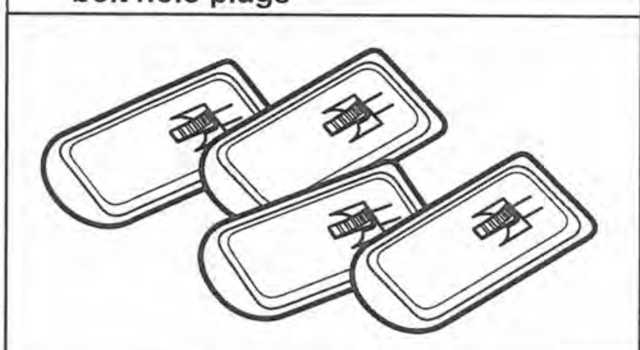
## 4. Remove power cord




Pull power cord through opening in rear panel.

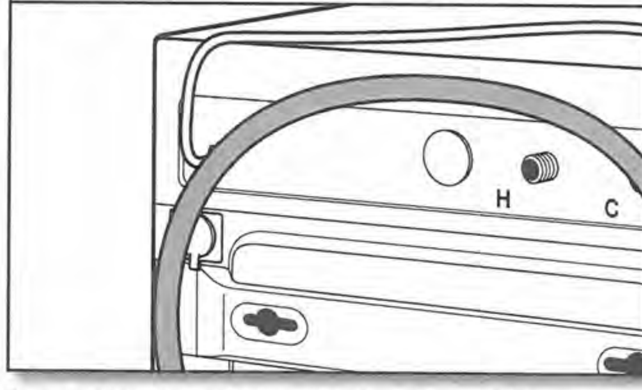
**NOTE:** If washer is transported at later date, call your local service center to avoid suspension and structural damage, a certified technician must properly set up washer for relocation.

## 5. Cover bolt holes with transport bolt hole plugs



Close bolt holes on cabinet back with four transport bolt hole plugs included with washer parts.

## 6. Place power cord over top



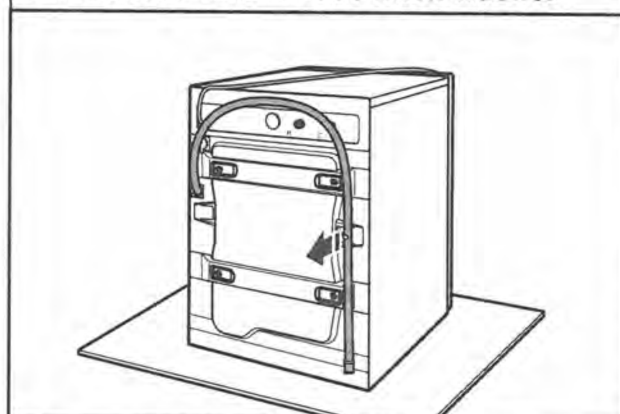

Remove the yellow shipping strap from the cord. Gently place power cord over top of washer to allow free access to back of washer.

**IMPORTANT:** Do not plug washer in until installation has been completed.

# ROUTE DRAIN HOSE

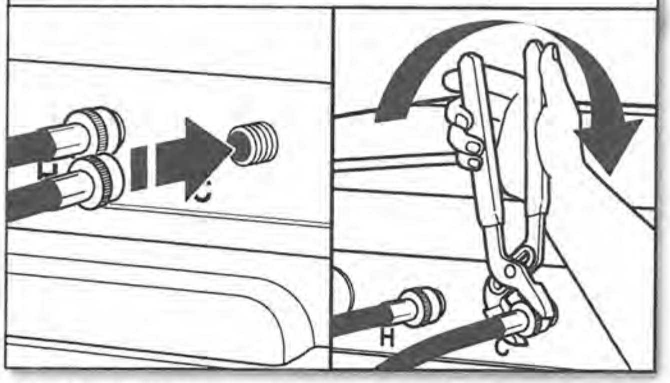
Proper routing of the drain hose protects your floor from damage due to water leakage. Read and follow these instructions.

## 7. Remove drain hose from washer



Gently pull the corrugated drain hose from the shipping clips.

## 12. Connect inlet hoses to washer

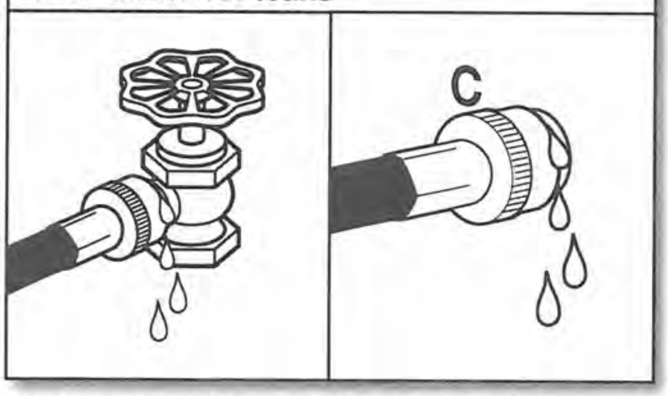



Attach hot water hose to hot water inlet valve. Screw coupling by hand until it is snug. Use pliers to tighten couplings an additional two-thirds turn. Repeat with cold water inlet valve.

**IMPORTANT:** To reduce risk of hose failure, replace the hoses every 5 years. Record hose installation or replacement dates for future reference.

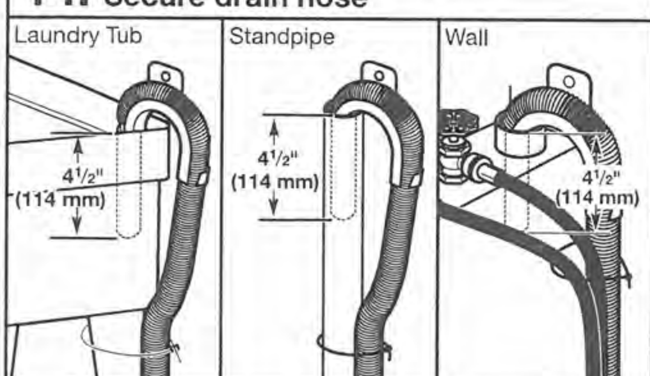
- Periodically inspect and replace hoses if bulges, kinks, cuts, wear, or leaks are found.

## 13. Check for leaks




Slowly turn on water faucets to check for leaks. A small amount of water may enter washer. It will drain later.

## 14. Secure drain hose

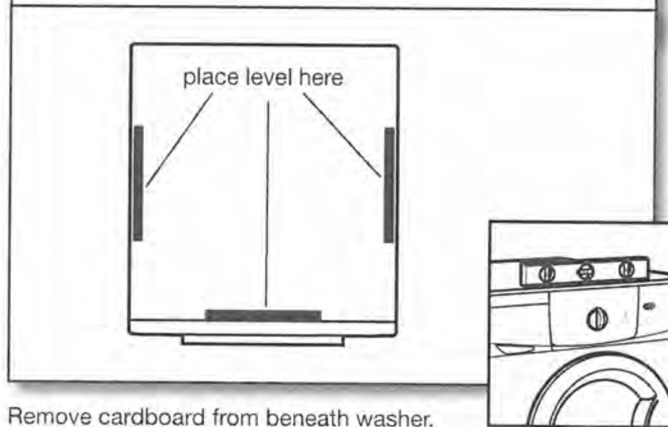



Secure drain hose to laundry tub leg, drain standpipe, or inlet hoses for wall standpipe with cable tie.

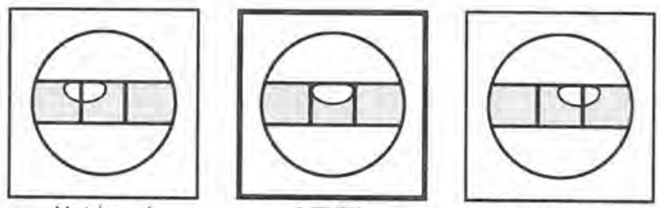
# LEVEL WASHER

Leveling your washer properly reduces excess noise and vibration.

## 15. Check levelness of washer




Remove cardboard from beneath washer. Place a level on top edges of washer, checking each side and front. If not level, tip washer and adjust feet up or down as shown in steps 17 and 18, repeating as necessary.



Not Level | **LEVEL** | Not Level

## 16. Rock washer to test foot contact

Grip washer from top and rock back and forth, making sure all four feet are firmly on floor. Repeat, rocking washer from side to side. If washer rocks, go to step 17 and adjust leveling feet. If all four feet are in firm contact with floor, go to Step 18.

# PVC and CPVC Pipes - Schedule 40 & 80

**Standard dimensions and weight of PVC - Polyvinyl Chloride - and CPVC - Chlorinated Polyvinyl Chloride - pipes according to ASTM D1785**



Typical weight and dimensions of industrial PVC and CPVC pipes equal to steel pipes schedule 40 and 80 are indicated in the table below.

- ASTM D1785 "Standard Specification for Poly(Vinyl Chloride) (PVC) Plastic Pipe, Schedules 40, 80, and 120" is manufactured to meet the needs of a broad range of industrial, commercial and residential piping systems. ASTM D1785 covers pipes made for water distribution and irrigation systems.
- ASTM F441 Standard Specification for Chlorinated Poly(Vinyl Chloride) (CPVC) Plastic Pipe, Schedules 40 and 80

Chlorinated Poly(Vinyl Chloride) (CPVC) pipes are usable for water distribution at elevated temperatures.

- Insert PVC and CPVC pipes in Sketchup 3D models with the Engineering ToolBox Plugin!

**PVC and CPVC Pipes - Schedule 40**

| Nominal Pipe Size *(inches)* | Outside Diameter *(inches)* (mm) | Minimum Wall Thickness *(inches)* (mm) | Inside Diameter*) *(inches)* (mm) | Weight *(lb/ft)* (kg/m) PVC | CPVC |
|---|---|---|---|---|---|
| 1/2 | 0.840 | 0.109 | 0.622 | 0.16 | 0.17 |
| 3/4 | 1.050 | 0.113 | 0.824 | 0.21 | 0.23 |
| 1 | 1.315 | 0.133 | 1.049 | 0.32 | 0.34 |
| 1 1/4 | 1.660 | 0.140 | 1.380 | 0.43 | 0.46 |
| 1 1/2 | 1.900 | 0.145 | 1.610 | 0.51 | 0.55 |
| 2 | 2.375 | 0.154 | 2.067 | 0.68 | 0.74 |
| 2 1/2 | 2.875 | 0.203 | 2.469 | 1.07 | 1.18 |
| 3 | 3.500 | 0.216 | 3.068 | 1.41 | 1.54 |
| 4 | 4.500 | 0.237 | 4.026 | 2.01 | 2.20 |
| 5 | 5.563 | 0.258 | 5.047 | 2.73 | |
| 6 | 6.625 | 0.280 | 6.065 | 3.53 | 3.86 |
| 8 | 8.625 | 0.322 | 7.981 | 5.39 | 5.81 |
| 10 | 10.750 | 0.365 | 10.020 | 7.55 | 8.24 |
| 12 | 12.750 | 0.406 | 11.938 | 10.01 | 10.89 |
| 14 | 14.000 | 0.437 | 13.124 | 11.80 | |
| 16 | 16.000 | 0.500 | 15.000 | 15.43 | |

**PVC and CPVC Pipes - Schedule 80**

| Nominal Pipe Size *(inches)* | Outside Diameter *(inches)* (mm) | Minimum Wall Thickness *(inches)* (mm) | Inside Diameter*) *(inches)* (mm) | Weight *(lb/ft)* (kg/m) PVC | CPVC |
|---|---|---|---|---|---|
| 1/2 | 0.840 | 0.147 | 0.546 | 0.20 | 0.22 |
| 3/4 | 1.050 | 0.154 | 0.742 | 0.27 | 0.30 |
| 1 | 1.315 | 0.179 | 0.957 | 0.41 | 0.44 |
| 1 1/4 | 1.660 | 0.191 | 1.278 | 0.52 | 0.61 |
| 1 1/2 | 1.900 | 0.200 | 1.500 | 0.67 | 0.74 |
| 2 | 2.375 | 0.218 | 1.939 | 0.95 | 1.02 |
| 2 1/2 | 2.875 | 0.276 | 2.323 | 1.45 | 1.56 |
| 3 | 3.500 | 0.300 | 2.900 | 1.94 | 2.09 |
| 4 | 4.500 | 0.337 | 3.826 | 2.75 | 3.05 |
| 5 | 5.563 | 0.375 | 4.813 | 3.87 | |
| 6 | 6.625 | 0.432 | 5.761 | 5.42 | 5.82 |
| 8 | 8.625 | 0.500 | 7.625 | 8.05 | 8.83 |
| 10 | 10.750 | 0.593 | 9.564 | 12.00 | 13.09 |
| 12 | 12.750 | 0.687 | 11.376 | 16.50 | 18.0 |
| 14 | 14.000 | 0.750 | 12.500 | 19.30 | |
| 16 | 16.000 | 0.843 | 14.314 | 25.44 | |

# WASHER INSTALLATION INSTRUCTIONS
# INSTRUCTIONS POUR L'INSTALLATION DE LA LAVEUSE

## Table of Contents



## Table des matières



Para obtener acceso al instrucciones de instalación en español, o para obtener información adicional acerca de su producto, visite: **www.whirlpool.com**

### INSTALLATION NOTES

Date of purchase: ______________________

Date of installation: ______________________

Installer: ______________________

Model number: ______________________

Serial number: ______________________

### NOTES SUR L'INSTALLATION

Date d'achat : ______________________

Date d'installation : ______________________

Installateur : ______________________

Numéro de modèle : ______________________

Numéro de série : ______________________

# WASHER SAFETY

### Your safety and the safety of others are very important.

We have provided many important safety messages in this manual and on your appliance. Always read and obey all safety messages.

This is the safety alert symbol.

This symbol alerts you to potential hazards that can kill or hurt you and others.

All safety messages will follow the safety alert symbol and either the word "DANGER" or "WARNING." These words mean:

**⚠DANGER**

**You can be killed or seriously injured if you don't immediately follow instructions.**

**⚠WARNING**

**You can be killed or seriously injured if you don't follow instructions.**

All safety messages will tell you what the potential hazard is, tell you how to reduce the chance of injury, and tell you what can happen if the instructions are not followed.

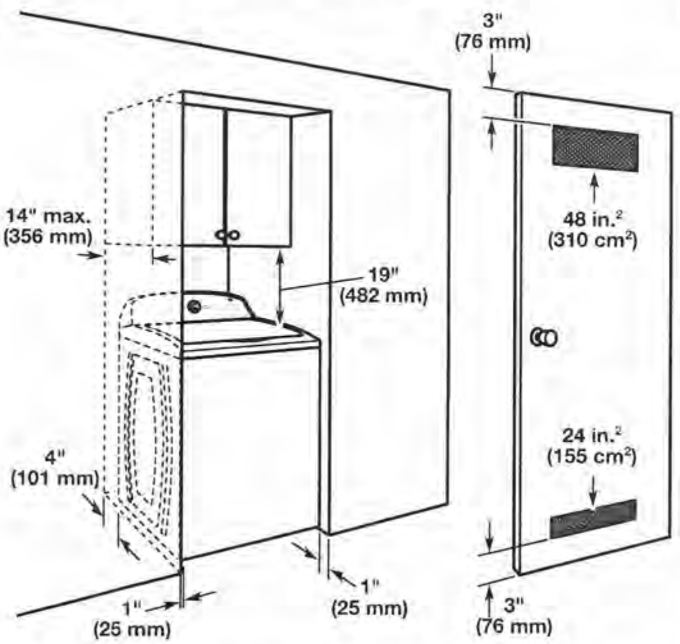
### You will need:

- A water heater set to 120° F (49° C).
- A grounded electrical outlet located within 4 ft (1.2 m) of power cord on back of washer.
- Hot and cold water faucets located within 3 ft (0.9 m) of hot and cold water fill valves on washer, and water pressure of 20-100 psi (138-690 kPa).
- A level floor with maximum slope of 1" (25 mm) under entire washer. Installing on carpet is not recommended.
- Floor must support washer's total weight (with water and load) of 315 lbs (143 kgs).

**IMPORTANT:** Do not install, store, or operate washer where it will be exposed to weather or in temperatures below 32° F (0° C). Water remaining in washer after use may cause damage in low temperatures. See "Washer Care" in your Use and Care Guide for winterizing information.

Proper installation is your responsibility.

### Recessed area or closet installation




Dimensions show recommended spacing allowed, except for closet door ventilation openings which are minimum required. This washer has been tested for installation with spacing of 0" (0 mm) clearance on the sides. Consider allowing more space for ease of installation and servicing, and spacing for companion appliances and clearances for walls, doors, and floor moldings. Add spacing of 1" (25 mm) on all sides of washer to reduce noise transfer. If a closet door or louvered door is installed, top and bottom air openings in door are required.

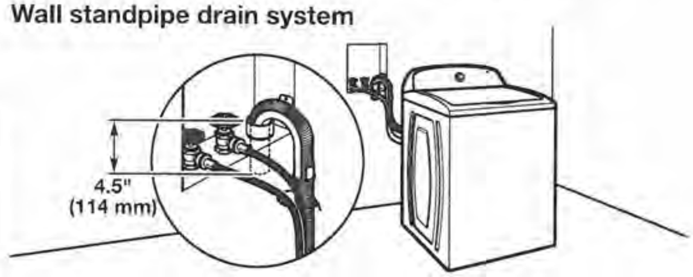
# DRAIN SYSTEM

Drain system can be installed using a floor drain, wall standpipe, floor standpipe, or laundry tub. Select method you need.

### Floor standpipe drain system

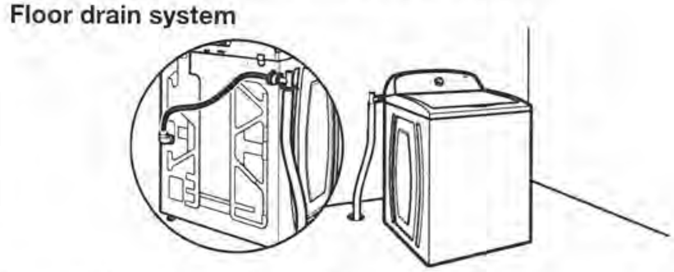

Minimum diameter for a standpipe drain: 2" (51 mm). Minimum carry-away capacity: 17 gal. (64 L) per minute. Top of standpipe must be at least 39" (990 mm) high; install no higher than 96" (2.44 m) from bottom of washer. If you must install higher than 96" (2.44 m), you will need a sump pump system.

### Wall standpipe drain system



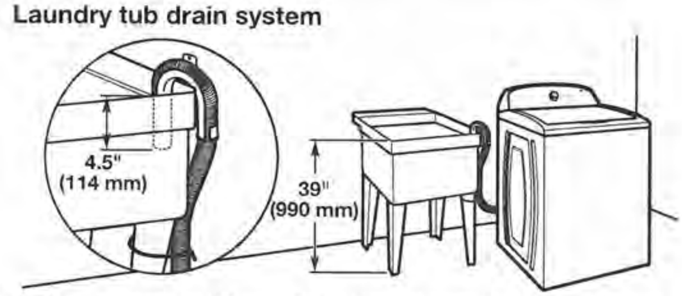

See requirements for floor standpipe drain system.

### Floor drain system



Floor drain system requires a Siphon Break Kit (Part Number 285834), 2 Connector Kits (Part Number 285835), and an Extension Drain Hose (Part Number 285863) that may be purchased separately. To order, please see toll-free phone numbers in your Use and Care Guide. Minimum siphon break: 28" (710 mm) from bottom of washer. (Additional hoses may be needed.)

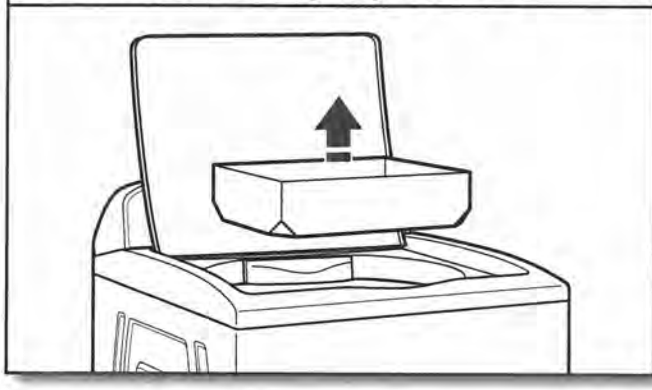
### Laundry tub drain system




Minimum capacity: 20 gal. (76 L). Top of laundry tub must be at least 39" (990 mm) above floor; install no higher than 96" (2.44 m) from bottom of washer.

**IMPORTANT:** To avoid siphoning, no more than 4.5" (114 mm) of drain hose should be inside standpipe or below the top of wash tub. Secure drain hose with cable tie.

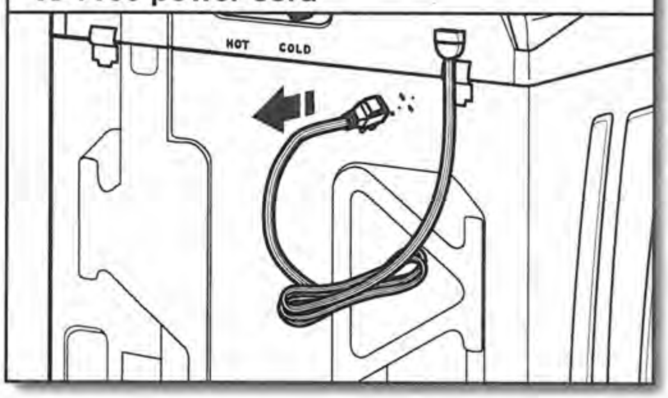
## 3. Remove packing tray from tub



Remove tape from washer lid, open lid and remove cardboard packing tray from tub. Be sure to remove all parts from tray.

**NOTE:** Keep tray in case you need to move washer later.

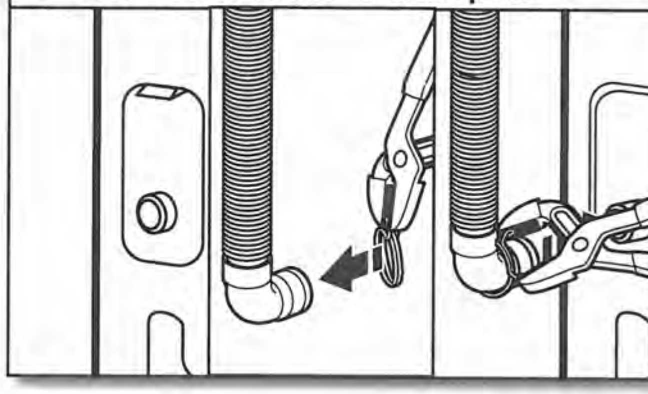
## 4. Free power cord




Firmly grasp power cord plug and pull to free from rear panel. Gently place power cord over console to allow free access to back of washer.

# CONNECT DRAIN HOSE

## 5. Attach drain hose to drain port

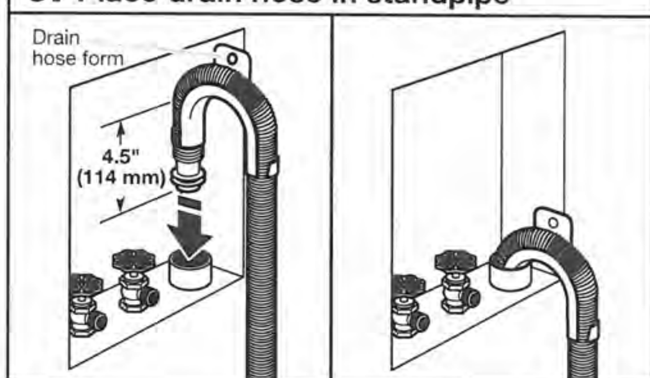


If clamp is not already in place on elbow end of drain hose, slide it over end as shown. Squeeze clamp with pliers and slide black elbow end of drain hose onto black drain port and secure with clamp.

For a laundry tub or standpipe drain, go to step 6.

For a floor drain, remove the preinstalled drain hose form as shown in Step 7. You may need additional parts with separate directions. See "Tools and Parts".

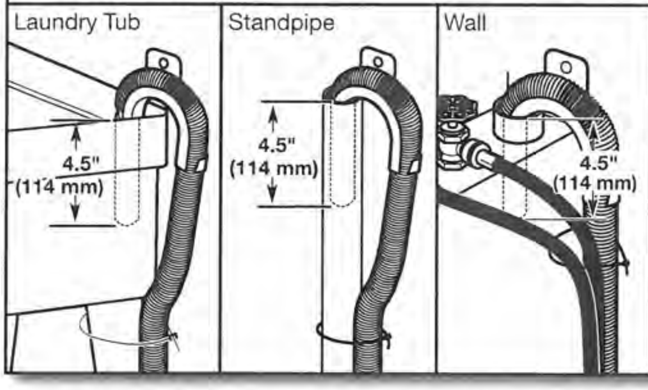
## 6. Place drain hose in standpipe




Place hose into standpipe (shown in picture) or over side of laundry tub.

**IMPORTANT:** 4.5" (114 mm) of drain hose should be inside standpipe; do not force excess hose into standpipe or lay on bottom of laundry tub. Drain hose form must be used.

## 12. Secure drain hose



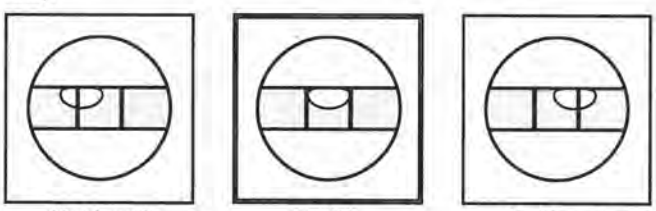

Secure drain hose to laundry tub leg, drain standpipe, or inlet hoses for wall standpipe with cable tie.

# LEVEL WASHER

**IMPORTANT:** Level washer properly to reduce excess noise and vibration.

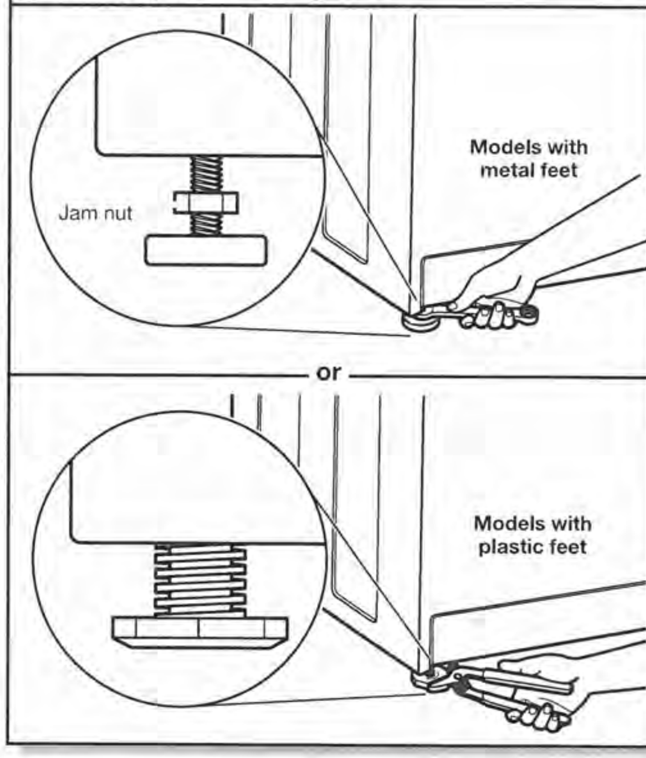
## 13. Check levelness of washer


Move the washer to its final location. Place a level on top edges of washer. Use side seam as a guide to check levelness of sides. Check levelness of front using lid, as shown. Rock washer back and forth to make sure all four feet make solid contact with floor. If washer is level, skip to step 15, (on models with metal feet) or step 16 (on models with plastic feet).



Not Level | **LEVEL** | Not Level

## 14. Adjust leveling feet



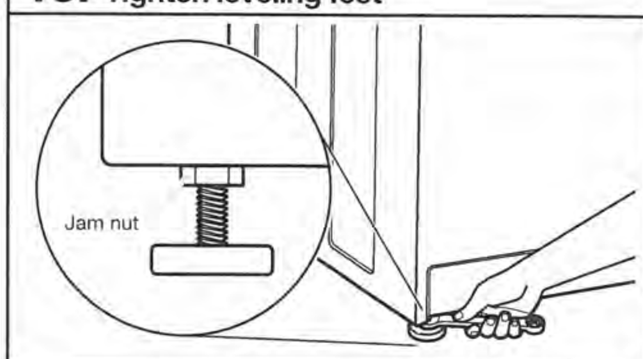

**If washer is not level:**

On models with metal feet, use a 9/16" or 14 mm open-end or adjustable wrench to turn jam nuts clockwise on feet until they are about 1/2" (13 mm) from the washer cabinet. Then turn the leveling foot clockwise to lower the washer or counterclockwise to raise the washer.

On models with plastic feet, use adjustable pliers to turn the plastic leveling foot counterclockwise to lower the washer or clockwise to raise the washer. On all models, recheck levelness of washer and repeat as needed.

**HELPFUL TIP:** You may want to prop up front of washer about 4" (102 mm) with a wood block or similar object that will support weight of washer.

## 15. Tighten leveling feet




On models with metal feet, when washer is level, use a 9/16" or 14 mm open-end or adjustable wrench to turn jam nuts counterclockwise on leveling feet tightly against washer cabinet.

**HELPFUL TIP:** You may want to prop washer with wooden block.

# LOG 184:

# Substantiating Documents

# Siding Installation in High-Wind Regions

FEMA
http://www.fema.gov

## HURRICANE IKE RECOVERY ADVISORY

**Purpose:** To provide basic design and installation tips for various types of siding that will enhance wind resistance in high-wind regions (i.e., greater than 90-mph gust design wind speed).

## Key Issues

- Siding is frequently blown off walls of residential and non-residential buildings during hurricanes. Also, wind-driven rain is frequently blown into wall cavities (even when the siding itself is not blown off). Guidance for achieving successful wind performance is presented below.
- To avoid wind-driven rain penetration into wall cavities, an effective moisture barrier (housewrap or building paper) is needed. For further information on moisture barriers, see Technical Fact Sheet No. 9 in FEMA 499, *Home Builder's Guide to Coastal Construction*, Technical Fact Sheet Series (available online at: http://www.fema.gov/library/viewRecord.do?id=1570). For further information on housewrap, see Technical Fact Sheet No. 23.
- Always follow manufacturer's installation instructions and local building code requirements.
- Use products that are suitable for a coastal environment. Many manufacturers do not rate their products in a way that makes it easy to determine whether the product will be adequate for the coastal environment. Use only siding products where the supplier can provide specific information on product performance in coastal or high-wind environments.
- For buildings located within 3,000' of the ocean line, stainless steel fasteners are recommended.

**Moisture barrier** (also known as a water-resistive barrier): In the context of residential walls, the moisture barrier is either housewrap or building paper (felt). The moisture barrier occurs between the wall sheathing and the siding. It is a dual-purpose layer that sheds water that gets through the siding and limits air flow through the wall. When properly sealed, housewrap is considered an air barrier. Although building paper provides some resistance to air flow, it is not considered an air barrier. Moisture barriers shed water, but they allow water vapor to pass through them.

For further guidance on principles, materials, and procedures for the design and construction of walls to make them resistant to water intrusion, see American Society for Testing and Materials (ASTM) E 2266, *Standard Guide for Design and Construction of Low-Rise Frame Building Wall Systems to Resist Water Intrusion.*

- Avoid using dissimilar metals together.
- The installation details for starting the first (lowest) course of lap siding can be critical. Loss of siding often begins at the lowest course and proceeds up the wall (Figures 4 and 12). This is particularly important for elevated buildings, where the wind blows under the building as well as against the sides.
- When applying new siding over existing siding, use shims or install a solid backing to create a uniform, flat surface on which to apply the siding, and avoid creating gaps or projections that could catch the wind.
- Coastal buildings require more maintenance than inland buildings. This maintenance requirement needs to be considered in both the selection and installation of siding.

## Vinyl Siding

Vinyl siding can be used successfully in a coastal environment if properly designed and installed.

- Windload resistance:

- Vinyl siding is required by the International Building Code® (IBC®) and the International Residential Code® (IRC®) to comply with ASTM D 3679, *Standard Specification for Rigid Poly(Vinyl Chloride) (PVC) Siding*, which requires the siding to withstand wind pressures equivalent to 110 mph on a building up to 30' in height in Exposure B. Most vinyl siding has also been tested for higher wind pressures, and can be used in locations with a higher basic wind speed, greater building height, more open exposure, or some combination of those. The design wind pressure or wind speed for which these products are rated is available from product literature, installation instructions, or listings of agencies such as the International Code Council® (ICC®) Evaluation Service.

- For design wind speeds greater than 110 mph, or building heights greater than 30', or Exposure C, choose a model of siding rated for those conditions or higher. The manufacturer's product literature or installation instructions should specify the fastener type, size and spacing, and any other installation details needed to achieve this rating.

## Definition of Wind Exposure Zones

**Exposure B:** Urban, suburban, wooded areas.

**Exposure C:** Open terrain, flat open country, grasslands, all water surfaces in hurricane-prone regions.

- Products that have been rated for high winds typically have an enhanced nailing hem and are sometimes made from thicker vinyl (Figure 1). Thick, rigid panels provide greater wind resistance, withstand dents, and lie flatter and straighter against the wall. Optimum panel thickness should be 0.040 to 0.048", depending on style and design. Thinner gauge vinyl works well for stable climates; thicker gauge vinyl is recommended for areas with high winds and high temperature changes.
- Position nails in the center of the nailing slot (Figure 2).
- To allow for thermal movement of the siding, do not drive the head of the nail tight against the nail hem (unless the hem has been specifically designed for this). Allow approximately 1/32" (which is about the thickness of a dime) clearance between the fastener head and the siding panel (Figure 3).

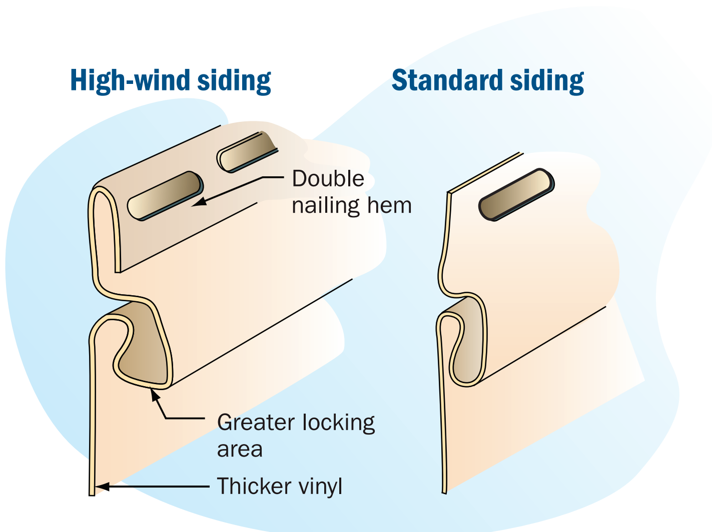



***Figure 1. Features of typical high-wind siding and standard siding.***

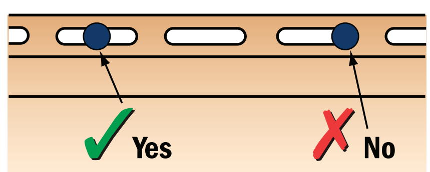



***Figure 2. Proper and improper fastener locations.***

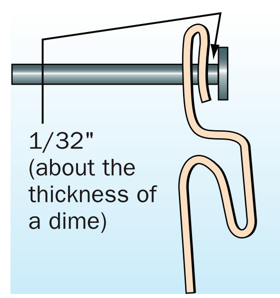



***Figure 3. Allow 1/32" clearance between the fastener head and the siding panel.***

- Drive nails straight and level to prevent distortion and buckling in the panel.
- Do not caulk the panels where they meet the receiver of inside corners, outside corners, or J-trim. Do not caulk the overlap joints.
- Do not face-nail or staple through the siding.
- Use aluminum, galvanized steel, or other corrosion-resistant nails when installing vinyl siding. Aluminum trim pieces require aluminum or stainless steel fasteners.
- Nail heads should be 5/16" minimum in diameter. Shank should be 1/8" in diameter.
- Use the manufacturer-specified starter strip to lock in the first course; do not substitute other accessories such as a J-channel or utility trim (Figure 4) unless specified by the manufacturer. If the manufacturer specifies a particular strip for high-wind applications, use it. Make sure that the starter strip is designed to positively lock the panel, rather than just hooking over a bulge in the strip; field test the interlock before proceeding with the installation.

- Make sure that every course of siding is positively locked into the previous course (Figure 5). Push the panel up into the lock from the bottom before nailing rather than pulling from the top. Do not attempt to align siding courses with adjacent walls by installing some courses loosely.
- Make sure that adjacent panels overlap properly, about half the length of the notch at the end of the panel, or approximately 1". Make sure the overlap is not cupped or gapped, which is caused by pulling up or pushing down on the siding while nailing. Reinstall any panels that have this problem.
- Use utility trim under windows or anywhere the top nail hem needs to be cut from siding to fit around an obstacle. Be sure to punch snap-locks into the siding to lock into the utility trim. Do not overlap siding panels directly beneath a window (Figure 6).

***Figure 4. Utility trim was substituted for the starter strip and the bottom lock was cut off the siding. Siding was able to pull loose under wind pressure.***

- At gable end walls, it is recommended that vinyl siding be installed over wood sheathing rather than over plastic foam sheathing, as was done at the house shown in Figure 7.
- Install vinyl siding in accordance with manufacturer's installation instructions and local building code requirements.
- It is recommended that vinyl siding installers be certified under the VSI Certified Installer Program sponsored by the Vinyl Siding Institute. For more information, go to http://www.vinylsiding.org/aboutsiding/installation/certinstaller.

***Figure 5. The siding panel was not properly locked into the panel below.***

***Figure 6. Proper detailing around windows and other obstacles is important. Use utility trim, punch snap-locks into siding, and don't overlap directly beneath a window.***

***Figure 7. The vinyl siding at this gable was installed over plastic foam insulation. Without wood sheathing, the wind pressures on the vinyl are increased. Also, if the siding blows away, the foam insulation is very vulnerable to blow-off. With loss of the foam insulation, wind-driven rain can freely enter the attic, saturate the ceiling insulation, and cause collapse of the ceiling.***

## Wood Siding

- Use decay-resistant wood such as redwood, cedar, or cypress. See the Sustainable Design section regarding certified wood.
- To improve longevity of paint, back-prime wood siding before installation.
- Carefully follow manufacturer's detailing instructions to prevent excessive water intrusion behind the siding.
- For attachment recommendations, see *Natural Wood Siding: Selection, Installation and Finishing*, published by the Western Wood Products Association (http://www.wwpa.org).

  This publication recommends an air gap between the moisture barrier and the backside of the siding to promote drainage and ventilation. Such a wall configuration is referred to as a rain screen wall. See the text box on page 5.
- Follow the installation details shown in Figure 8. (Note: Although these details do not show a rain screen, inclusion of vertical furring strips to create a rain screen is recommended.)

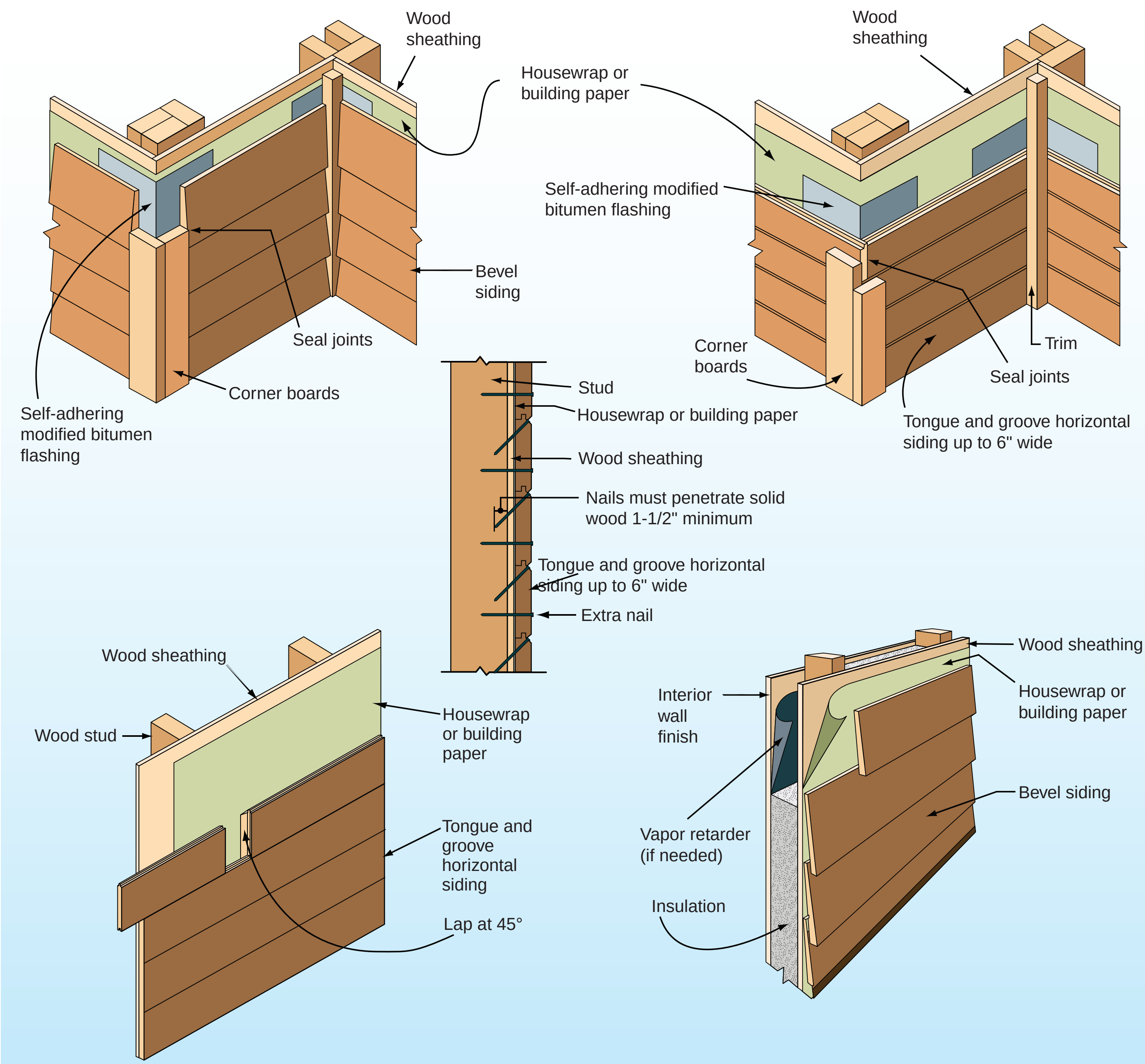



***Figure 8. Wood siding installation details.***

## Pressure-equalized rain screen wall system

In areas that experience frequent wind-driven rain and areas susceptible to high winds, it is recommended that a rain screen design be considered when specifying wood or fiber cement siding. (Typical vinyl siding products inherently provide air cavities behind the siding that facilitate drainage. Therefore, incorporation of vertical furring strips is normally not applicable to this type of wall covering.) A rain screen design is accomplished by installing suitable vertical furring strips between the moisture barrier and siding material (see Figure 9). The cavity facilitates drainage of water from the space between the moisture barrier and backside of the siding and it facilitates drying of the siding and moisture barrier.

**Furring strip attachment:** For 1" x 2" furring strips, tack strips in place and use siding nails that are ¾" longer than would be required if there were no strips (thereby maintaining the minimally required siding nail penetration into the studs). For thicker furring strips, an engineered attachment is recommended.

At the bottom of the wall, the cavity should be open to allow water drainage. However, the opening should be screened to avoid insect entry.

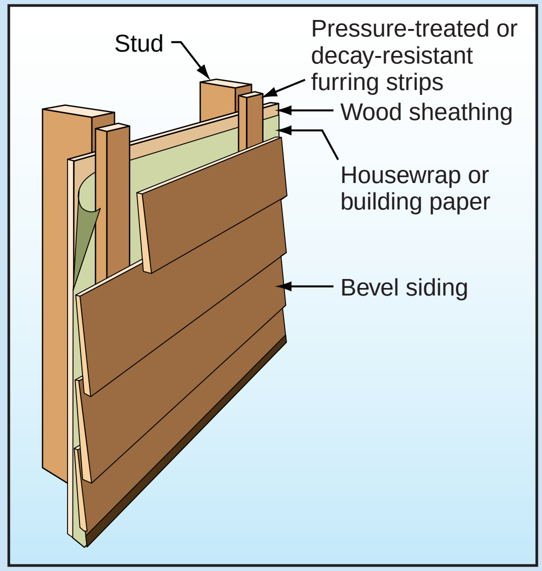



***Figure 9. Pressure-equalized rain screen system.***

At the wall/soffit juncture, the top of the cavity can open into the attic space to provide inlet air ventilation, thereby eliminating soffit vents and their susceptibility to wind-driven rain entry. If the rain screen cavity vent path is used in lieu of soffit vents, the depth of the cavity needs to be engineered to ensure that it provides sufficient air flow to ventilate the attic.

## Fiber Cement Siding

Installation procedures are similar to those for wood siding, but require specialized cutting blades and safety precautions because of the dust produced during cutting with power tools. Manufacturer's installation recommendations should be strictly adhered to, and particular attention paid to the painting and finishing recommendations for a high-quality installation.

- Always seal field-cut ends according to the manufacturer's instructions. Properly gap the intersection between siding edges and other building components and fill the gap with sealant.
- Always consult and follow the manufacturer's installation requirements for the needed wind speed rating or design pressure (refer to the manufacturer's building code compliance evaluation report). Observe the manufacturer's fastener specifications, including fastener type and size, spacing, and penetration requirements. Do not over drive or under drive.
- At gable end walls, it is recommended that fiber cement siding be installed over wood sheathing rather than over plastic foam sheathing.
- Keep blind nails between ¾ and 1" from the top edge of the panel (Figure 10). Be sure to drive nails at least 3/8" from butt ends, or use manufacturer-specified joiners.
- Face nailing (Figure 11) instead of blind nailing is recommended where the basic (design) wind speed is 100 miles per hour or greater. If the local building code or manufacturer specifies face nailing at a lower wind speed, install accordingly.
- Do not leave the underside of the first course exposed or extending beyond the underlying material (Figure 12). Consider the use of a trim board to close off the underside of the first course.

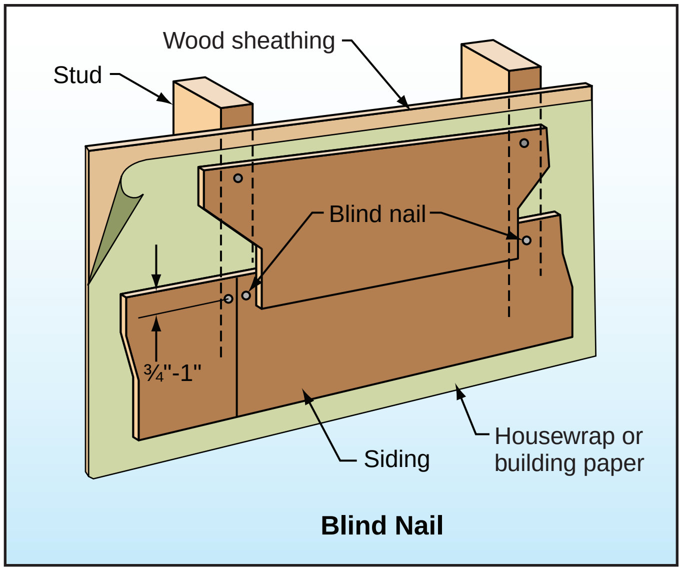



*Figure 10. Blind nailing.*

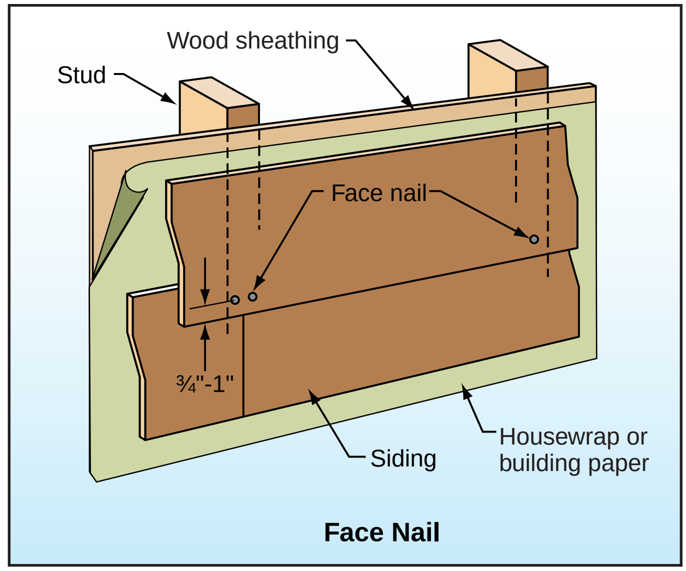



*Figure 11. Face nailing.*

## Sustainable Design

### Material selection for sustainable sources and durability

For wood products, select a Forest Stewardship Council (FSC) certified product. The FSC seeks to ensure that wood is harvested in a more responsible fashion, including protecting forest ecosystems, and avoids the use of chemicals and genetic engineering. While redwood, cedar, and cypress are decay-resistant and recommended for durability, they are generally cut from old growth timber. You can determine if the manufacturer is FSC certified by going to http://www.fsc-info.org.


*Figure 12. Blind nailed siding installed with exposed gap at bottom (red circle) is vulnerable to failure.*

For other siding products, consider long-term life spans for coastal environments, recycled content, and post-consumer use.

**The following publications discuss sustainable aspects of vinyl siding:**

*A Dozen Things You Might Not Know That Make Vinyl Siding Green* (available online at http://www.vinylsiding.org/aboutsiding/greenpaper/080919_VSI_Green_Paper_for_web.pdf).

*Siding with the Environment* (available online at http://www.vinylsiding.org/publications/final_Enviro_single_pg.pdf).

**Energy Conservation and Air Barriers:** Uncontrolled air leakage through the building envelope is often overlooked. The U.S. Department of Energy estimates that 40 percent of the cost of heating or cooling the average American home is lost to uncontrolled air leakage. In warmer climates, it is a lower percentage of loss. An air barrier system can reduce the heating, ventilation, and cooling (HVAC) system size, resulting in reduced energy use and demand.

Uncontrolled air leakage can also contribute to premature deterioration of building materials, mold and moisture problems, poor indoor air quality, and compromised occupant comfort. When uncontrolled air flows through the building envelope, water vapor moves with it. Controlling the movement of moisture by air infiltration requires controlling the air pathways and/or the driving force.

To effectively control air leakage through the building envelope, an effective air barrier is required. To be effective, it needs to be continuous; therefore, air barrier joints need to be sealed and the barrier needs to be sealed at penetrations through it. The Air Barrier Association of America recommends that materials used as a component of a building envelope air barrier be tested to have an air infiltration rate of less than 0.004 cfm/square foot, assemblies of materials that form the air barrier be tested to have an air infiltration rate of less than 0.04 cubic feet per minute (cfm)/square foot, and the whole building exterior enclosure have an air infiltration rate of less than 0.4 cfm/square foot.

**Air barrier systems installed behind siding:**

Housewrap is the most common air barrier material for residential walls. To be effective, it is critical that the joints between sheets of housewrap be sealed as recommended by the manufacturer, and penetrations (other than fasteners) should also be sealed. At transitions between the housewrap and door and window frame, use of self-adhering modified bitumen flashing tape is recommended.

An air barrier should be installed over a rigid material, or it will not function properly. It also needs to be restrained from pulling off of the wall under negative wind pressures. For walls, wood sheathing serves as a suitable substrate, and the siding (or furring strips in a rain screen wall system) provide sufficient restraint for the air barrier.

At the base of the wall, the wall air barrier should be sealed to the foundation wall. If the house is elevated on piles, the wall barrier should be sealed to an air barrier installed at the plane of the floor.

If the building has a ventilated attic, at the top of the wall, the wall air barrier should be sealed to an air barrier that is installed at the plane of the ceiling.

If the building has an unventilated attic or no attic, at the top of the wall, the wall air barrier should be sealed to an air barrier that is installed at the plane of the roof (the roof air barrier may be the roof membrane itself, or a separate air barrier element).

**Siding maintenance:**

For all siding products, it is very important to periodically inspect and maintain the product especially in a coastal environment. This includes recoating on a scheduled maintenance plan that is necessary according to the manufacturer's instructions and a periodic check of the sealant to ensure its durability. Check the sealant for its proper resiliency and that it is still in place. Sealant should be replaced before it reaches the end of its service life.

**Air barrier:** A component installed to provide a continuous barrier to the movement of air through the building envelope. Housewrap is a common air barrier material for residential walls. Although very resistant to airflow, housewrap is very vapor permeable and therefore is not suitable for use as a vapor retarder.

**Vapor retarder:** A component installed to resist diffusion of water vapor and provide a continuous barrier to movement of air through the building envelope. Polyethylene is a common vapor retarder material for residential walls. To determine whether or not a vapor retarder is needed, refer to the Moisture Control section of the *NRCA Roofing and Waterproofing Manual*, published by the National Roofing Contractors Association (NRCA) (http://www.nrca.net).

ASTM E 1677, *Standard Specification for an Air Retarder (AR) Material or System for Low-Rise Framed Building Walls*: This specification covers the minimum performance and acceptance criteria for an air barrier material or system for framed walls of low-rise buildings with the service life of the building wall in mind. The provisions contained in this specification are intended to allow the user to design the wall performance criteria and increase air barrier specifications to accommodate a particular climate location, function, or design of the intended building.

**R703.11 Vinyl siding.** Vinyl siding shall be certified and *labeled* as conforming to the requirements of ASTM D3679 by an *approved* quality control agency.

❖ Polyvinyl chloride (PVC) siding is specifically addressed here as an exterior wall covering. PVC siding must conform to the provisions of ASTM D3679. The vinyl siding must bear a label, which means that the manufacturer must have regular inspections by a third-party quality control agency.

**R703.11.1 Installation.** Vinyl siding, soffit and accessories shall be installed in accordance with the manufacturer's instructions.

❖ Vinyl siding must be applied to conform to the water-resistive barrier requirements of Sections R703.1 and R703.2 and the attachment requirements of Section R703.3 (see commentary, Sections R703.1, R703.2 and R703.3).

The installation must also comply with the manufacturer's instructions. ASTM D3679 requires installation of the siding in accordance with Practice D4756 (ASTM D4756) and the manufacturer's instructions. These instructions are necessary for compliance with the performance requirements of this chapter.

In the 2012 code, information on vinyl siding fastener specifications, penetration, and spacing was found only in Table R703.4 and its notes. These requirements are moved into new Sections R703.11.1.1, R703.11.1.2 and R703.11.1.3. This places the requirements into the text of the code provision where they are easily located and more clearly stated.

Vinyl siding can be used in conjunction with a variety of sheathing types, some of which contribute to resisting fastener withdrawal. It is necessary to ensure that, regardless of the sheathing type, the total penetration into a material capable of holding fasteners is equivalent to what was used during testing of the siding. For typical siding installations, this is $^3/_4$-inch penetration into framing plus approximately $^1/_2$ inch through wood sheathing, for a total of $1^1/_4$ inches of penetration into "nailable" material. This minimum penetration is required unless a different penetration is specified in the manufacturer's instructions. A definition of "nailable substrate" is added to define what is considered to be "nailable."

Where the siding is used over a nonnailable material, the total penetration must still be achieved, in this case by using a fastener long enough to accommodate the thickness of nonnailable material and penetrate the full $1^1/_4$ inches into framing or a combination of framing and other nailable material. By stating the requirement in terms of the total required penetration, it is clear what penetration is needed for all installations.

In addition, new Section R703.11.1.3 provides the maximum fastener spacing for both horizontal and vertical siding. The code previously had no provision for fastener spacing for vertical siding; the new requirement mirrors provisions in the *International Building Code*® (IBC®).

Polyvinyl chloride (PVC) may be used to cover the soffit. The material must be installed as panels and fastened to a supporting component or in accordance with the manufacturer's installation instructions.

**R703.11.1.1 Fasteners.** Unless specified otherwise by the manufacturer's instructions, fasteners for vinyl siding shall be 0.120-inch (3 mm) shank diameter nail with a 0.313-inch (8 mm) head or 16-gage staple with a $^3/_8$-inch (9.5 mm) to $^1/_2$-inch (12.7 mm) crown.

❖ See the commentary to Section R703.11.1.

**R703.11.1.2 Penetration depth.** Unless specified otherwise by the manufacturer's instructions, fasteners shall penetrate into building framing. The total penetration into sheathing, furring framing or other nailable substrate shall be a minimum $1^1/_4$ inches (32 mm). Where specified by the manufacturer's instructions and supported by a test report, fasteners are permitted to penetrate into or fully through nailable sheathing or other nailable substrate of minimum thickness specified by the instructions or test report without penetrating into framing. Where the fastener penetrates fully through the sheathing, the end of the fastener shall extend a minimum of $^1/_4$ inch (6.4 mm) beyond the opposite face of the sheathing or nailable substrate.

❖ See the commentary to Section R703.11.1.

**R703.11.1.3 Spacing.** Unless specified otherwise by the manufacturer's instructions, the maximum spacing between fasteners for horizontal siding shall be 16 inches (406 mm), and for vertical siding 12 inches (305 mm) both horizontally and vertically. Where specified by the manufacturer's instructions and supported by a test report, greater fastener spacing is permitted.

❖ See the commentary to Section R703.11.1.

**R703.11.1.4 Vinyl soffit panels.** Soffit panels shall be individually fastened to a supporting component such as a nailing strip, fascia or subfascia component or as specified by the manufacturer's instructions.

❖ See the commentary to Section R703.11.1.

**R703.11.2 Foam plastic sheathing.** Vinyl siding and insulated vinyl siding used with foam plastic sheathing shall be installed in accordance with Section R703.11.2.1, R703.11.2.2 or R703.11.2.3.

> **Exception:** Where the foam plastic sheathing is applied directly over wood structural panels, fiberboard, gypsum sheathing or other *approved* backing capable of independently resisting the design wind pressure, the vinyl siding shall be installed in accordance with Section R703.11.1.

❖ This section establishes a proper basis for vinyl siding and insulated vinyl siding applications with foam sheathing by applying appropriate adjustment factors to vinyl siding wind pressure ratings to address this specific assembly condition. Because the vinyl and foam sheathing assembly serve as the primary weather barrier or envelope for the building (when no additional structural sheathing is applied), the vinyl siding pressure rating values have been factored to provide a net safety factor of 2.0 instead of 1.5 as required by ASTM D3679 for applications of vinyl siding over "solid walls." The adjustment factors specified in Section R703.11.2.2 also account for difference in pressure equalization effects addressed in ASTM D3679, Annex A for the specific wall assembly conditions where vinyl siding is used with a foam sheathing backing material.

The requirements of Section R703.11.2 are intended to improve the wind-resistant performance of combinations of foam sheathing and vinyl siding commonly used to meet or exceed energy code requirements and newer green building guidelines or standards. The prescriptive requirements and adjustment factors are based on certified testing of various combinations of foam sheathing and vinyl siding products conducted at the NAHB Research Center, Inc., and testing serving as the basis for the wind pressure rating method for vinyl siding as explained in ASTM D3679, Annex A.

An exception exempts foam plastic sheathing from having to contribute to resisting wind if the backing behind it can resist the wind load by itself. If it cannot, then the foam plastic sheathing and vinyl siding together must comply with one of the following three provisions:

1. If the structure is located where the ultimate design wind speed does not exceed 115 mph and is in an Exposure Category B or less, the installation must meet Section R703.11.2.1.
2. If the structure is located where the ultimate design wind speed exceeds 115 mph or is in an Exposure Category C or D or otherwise cannot fully comply with all the requirements of Section R703.11.2.1, the installation must meet Section R703.11.2.2.
3. If the vinyl siding manufacturer's product specifications indicate that an approved design wind pressure rating when installed over foam plastic sheathing is provided, the vinyl siding and foam plastic sheathing are permitted to be installed in accordance with the manufacturer's instructions as stipulated by Section R703.11.2.3.

**R703.11.2.1 Basic wind speed not exceeding 115 miles per hour and Exposure Category B.** Where the ultimate design wind speed does not exceed 115 miles per hour (51 m/s), the exposure category is B and gypsum board, gypsum panel product or equivalent is installed on the side of the wall opposite the foam plastic sheathing, the minimum siding fastener penetration into wood framing shall be $1^1/_4$ inches (32 mm) using minimum 0.120-inch-diameter (3 mm) nail (shank) with a minimum 0.313-inch-diameter head, 16 inches (406 mm) on center. The foam plastic sheathing shall be minimum $^1/_2$-inch-thick (12.7 mm) (nominal) extruded polystyrene in accordance with ASTM C578, $^1/_2$-inch-thick (12.7 mm) (nominal) polyisocyanurate in accordance with ASTM C1289 or 1-inch-thick (25 mm) (nominal) expanded polystyrene in accordance with ASTM C578.

❖ See the commentary to Section R703.11.2.

**R703.11.2.2 Basic wind speed exceeding 115 miles per hour or Exposure Categories C and D.** Where the ultimate design wind speed exceeds 115 miles per hour (51 m/s), the exposure category is C or D, or all conditions of Section R703.11.2.1 are not met, the adjusted design pressure rating for the assembly shall meet or exceed the loads listed in Table R301.2(2) adjusted for height and exposure using Table R301.2(3). The design wind pressure rating of the vinyl siding for installation over solid sheathing as provided in the vinyl siding manufacturer's product specifications shall be adjusted for the following wall assembly conditions:

1. For wall assemblies with foam plastic sheathing on the exterior side and gypsum wall board, gypsum panel product or equivalent on the interior side of the wall, the vinyl siding's design wind pressure rating shall be multiplied by 0.39.
2. For wall assemblies with foam plastic sheathing on the exterior side and without gypsum wall board, gypsum panel product or equivalent on the interior side of wall, the vinyl siding's design wind pressure rating shall be multiplied by 0.27.

❖ See the commentary to Section R703.11.2.

**R703.11.2.3 Manufacturer specification.** Where the vinyl siding manufacturer's product specifications provide an *approved* design wind pressure rating for installation over foam plastic sheathing, use of this design wind pressure rating shall be permitted and the siding shall be installed in accordance with the manufacturer's instructions.

❖ See the commentary to Section R703.11.2.

**R703.12 Adhered masonry veneer installation.** Adhered masonry veneer shall comply with the requirements of Section R703.7.3 and the requirements in Sections 12.1 and 12.3 of TMS 402/ACI 530/ASCE 5. Adhered masonry veneer shall be installed in accordance with Section R703.7.1, Article 3.3C of TMS 602/ACI 530.1/ASCE 6 or the manufacturer's instructions.

❖ In the 2012 code, information on adhered masonry veneer installation was found only in Table R703.4 and its notes. These requirements were moved into this section and new Section R703.12.3, This places the requirements into the text of the code provision where they are easily located and more clearly stated. Adhered masonry veneer must be installed according to this section or the instructions of the manufacturer. A water-resistive barrier must be installed to comply with Sections R703.2 and R703.7.3 and the requirements of Sections 12.1 and 12.3 of TMS 402/ACI 530/ ASCE 5. Where no instructions from the manufacturer are provided, adhered masonry veneer must be supported and fastened in accordance with the lath requirements in Section R703.7.1 or Article 3.3C of TMS 602/ACI 530.1/ASCE 6.

**R703.12.1 Clearances.** On exterior stud walls, adhered masonry veneer shall be installed:

1. Minimum of 4 inches (102 mm) above the earth;
2. Minimum of 2 inches (51 mm) above paved areas; or

# 2017 Vinyl Siding Installation Manual

This manual is published by the Vinyl Siding Institute, Inc. (VSI) as a service to the industry. VSI members are manufacturers of vinyl siding and other polymeric siding and suppliers to the industry. The information provided in this publication is offered in good faith and believed to be reliable, but is made without warranty, express or implied, as to merchantability, fitness for a particular purpose, or any other matter. VSI does not endorse the proprietary products or processes of any manufacturer.

This publication is not intended to provide specific advice, legal or otherwise, on particular products or processes. Readers should consult with their own legal and technical advisors, vinyl siding suppliers, and other appropriate sources (including but not limited to product or package labels, technical bulletins, or sales literature) that contain information about known and reasonably foreseeable health and safety risks of their proprietary products and processes. VSI, its members, and contributors do not assume any responsibility for the users' compliance with applicable laws and regulations, nor for any persons relying on the information contained in this guide.

Information about individual manufacturers' products contained herein has been provided by those manufacturers, who are solely responsible for the accuracy and completeness of the data.

## Use of Manufacturers' Instructions

Some specialized products may require unique installation instructions. Please contact the manufacturer directly for information about installing those products.

For general information about vinyl siding, contact the Vinyl Siding Institute at:

**VINYL SIDING INSTITUTE**

VINYL SIDING INSTITUTE

National Housing Center
1201 15th Street NW, Suite 220
Washington, DC 20005
Website: www.vinylsiding.org

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**NOTE: Vinyl siding installers with at least two years of experience can become VSI Certified Installers, if they successfully complete a course and pass a written examination. Certified Installers receive an identification badge and are listed on VSI's website. For more information on the VSI Certified Installer Program, visit www.vinylsiding.org.**

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# FOREWORD

Known for its outstanding performance, vinyl siding is the exterior cladding of choice for homeowners, remodeling contractors, architects, and builders. Compared to other siding products, vinyl is attractive, durable, easy to maintain, and cost-effective. Vinyl siding is available in a variety of architectural styles, eye-catching colors, and design-enhancing profiles, finishes, and textures.

To ensure proper quality, vinyl siding must meet or exceed the requirements of ASTM D3679 *Standard Specification for Rigid Poly (VinylChloride) (PVC) Siding* and other applicable standards from ASTM International, including those regarding color retention. As a service to the industry, the Vinyl Siding Institute (VSI) sponsors a program that allows manufacturers to certify, with independent, third-party verification, that their siding meets or exceeds this specification. The program covers vinyl siding, as well as polypropylene siding (certified to meet or exceed ASTM D7254) and insulated siding (certified to meet or exceed ASTM D7793). Insulated siding is a type of continuous insulation that provides a minimum R-value of R-2.0. Insulated siding is widely accepted in energy efficiency programs and is defined in the International Energy Conservation Code. For a listing of certified products, see VSI's website at www.vinylsiding.org. In addition, look for the appropriate certification labels on boxes of siding (Fig. 1).

Figure 1.

This manual sets forth the basic guidelines for vinyl siding installation. The instructions herein are based, in part, on ASTM D4756 *Standard Practice for Installation of Rigid Poly (VinylChloride) (PVC) Siding and Soffit*, the standard method for installation of vinyl siding and soffit. Updated information has been added as necessary. **Additionally, it is recommended that installers review local building codes and manufacturers' literature for variations that may apply to specific products and/or geographic areas. The siding manufacturer's specific product installation instructions should be followed in the event of a conflict with general industry practice or guidance.**

The method of applying vinyl siding and soffit is essentially the same for new construction and re-siding. However, where there are differences, special instructions for new construction and re-siding are included, as well as recommendations for historic restoration projects. In all applications, care should be exercised to properly prepare the structure. See the Basic Installation Rules and additional details throughout this manual for proper installation techniques.

Polypropylene siding is an exterior cladding similar to vinyl siding; it should be installed according to the manufacturer's instructions, as well as applicable local building codes in your area.

While this installation manual reflects generally accepted vinyl siding installation practices at the time of publication, because of continuing advances in design and materials, it is particularly important to check manufacturer literature and current building code requirements for your area.

# IMPORTANT NOTES

## Building Codes

Installers need to be aware of building code requirements in the geographic areas where they are installing, and how the codes relate to the instructions given in this manual and by the siding manufacturer. The requirements of local building codes must always be observed, because they represent the legal requirements for an installation in a given jurisdiction. However, local codes are based on the national model building codes. Model codes themselves do not have the force of law until they are adopted by a state or local jurisdiction. In the United States, the primary source of model codes is the International Code Council, which publishes the International Building Code (IBC), International Residential Code (IRC), and International Energy Conservation Code (IECC). In Canada, the primary model code is the National Building Code (NBC), published by the National Research Council of Canada.

Most of the model building codes, and thus the local codes based on them, recognize that the product manufacturer usually knows how its product should be installed in order to provide best performance. Therefore, most building codes reference the manufacturer's instructions and state that the product must be installed according to the code and the manufacturer's instructions. However, any specific requirement in a local code will usually override any provision of the manufacturer's instructions, especially if the local requirement is more restrictive. Therefore, vinyl siding installations must always conform to local building codes, but the local code may also require that the installation conform to the siding manufacturer's instructions.

The codes provide the greatest recognition to products that have been certified to a recognized standard by an approved quality control agency. In fact, current editions of the IBC and IRC model codes require: vinyl siding to be certified to ASTM D3679; polypropylene siding be certified to ASTM D7254; insulated siding be certified to ASTM D7793; and all to be verified by an approved quality control agency. As relevant editions of the model codes are adopted by local jurisdictions, code officials will want to verify that the siding is properly certified (which can usually be determined by identifying the VSI certified product label on the box—see page 1) and that the installation conforms to the manufacturer's instructions. Always be sure that the instructions are available on the job site for an inspector to review.

This manual is not a building code and it is not a substitute for the manufacturer's instructions. However, it has been developed by referencing the provisions of the model building codes, the requirements of ASTM D4756, and generally accepted installation practices within the vinyl siding industry. This manual therefore reflects the most common installation requirements that apply to the vast majority of vinyl siding products. Use this manual to understand how vinyl siding and soffit should generally be installed, but be prepared to comply with any differing provisions of local codes and the manufacturer's instructions for a specific product.

## Installing for Wind Load Resistance

Vinyl siding is remarkably resistant to high wind, given its light weight and relatively simple installation. But in order for it to perform to its potential, it must first be properly selected, and then properly installed.

All certified vinyl siding is tested for wind load resistance and must meet certain minimum requirements. This testing results in a "standard wind load design pressure rating," or the maximum wind pressure the siding is designed to withstand when it is installed using the standard methods described in this manual. Those involved in selecting or specifying vinyl siding need to know how to ensure that the siding is rated high enough for the location and the building, but that is beyond the scope of this manual.

Vinyl siding installers need to make sure that the siding is installed in a way that allows it to meet its rating. The instructions in this manual provide the minimum requirements for most vinyl siding products for most installation situations. However, the manufacturer may have different instructions for their products, or may have special installation requirements that apply in high-wind locations. Always consult the manufacturer's instructions before starting a vinyl siding installation.

Following are some key installation details that tend to affect wind load resistance:

- **Proper starter strip:** Always use the starter strip specified by the manufacturer. A starter strip that is not matched to the lock design of the siding may allow the bottom course of siding to blow off, which can lead to loss of the whole wall of siding.
- **Connection to framing:** Most vinyl siding must be fastened through the sheathing directly to the building framing or other structural component. That can be wood studs, furring strips, or directly to masonry.
- **Fastener penetration depth:** Follow the manufacturer's instructions, but usually the fasteners need to penetrate a total of 1 1/4" (32mm) through wood or a material with equivalent holding power. Typically, that would be through 1/2" (12.7mm) of wood sheathing and 3/4" (19mm) into wood framing or furring.
- **Proper fastener:** In order to hold the siding on the wall, the fastener must resist withdrawal, and the head must hold the siding firmly. Be sure to follow the specifications in this manual or the manufacturer's instructions for the fastener diameter, length, and head size, or staple crown size.
- **Use of utility trim:** Securing the top edge of vinyl siding where it has been cut to fit under windows or roof lines is critical. Be sure to use utility trim (undersill trim) and to crimp the cut edge of the siding so that it is held tight.
- **Attaching directly to wood sheathing:** Sometimes the manufacturer's instructions allow the siding to be fastened directly to wood sheathing, without penetrating into studs or framing. When using this alternative, be sure to carefully follow the instructions for fastener type, size, spacing, and penetration depth. The same goes for vertical siding, which is almost always installed directly to wood sheathing.
- **Installing over foam sheathing:** Installing vinyl siding over foam plastic sheathing introduces special considerations. Foam sheathing transfers more of the wind pressure to the siding than does wood sheathing, and it does not offer any fastener withdrawal resistance. Be sure to follow the instructions for foam sheathing installation that appear in this manual.

## Water-resistive Barrier

Vinyl siding, insulated siding, and polypropylene siding are exterior claddings, not water-resistive barriers, and are designed to allow the material underneath to breathe. This factor provides a supplemental rainscreen that reduces the amount of water that reaches an underlying water-resistive barrier.

To achieve designed performance, and to comply with the 2015 International Residential Code, vinyl siding, insulated siding, and polypropylene siding must be installed over a water-resistive barrier, which is intended to prevent liquid water that has penetrated behind the exterior covering from further intruding into the exterior wall assembly.

Water-resistive barrier systems often consist of: a combination of exterior cladding such as vinyl siding; insulated siding or polypropylene siding; flashed wall openings and penetrations; water-resistive barrier material; and sheathing. Effective exterior wall systems will shed the water initially, control moisture flow by capillary and diffusion action, and minimize absorption into the wall structure.

The level of water resistance required is determined by the applicable building code, the structure, and the climate. Note that additional measures may provide increased protection against water intrusion than the minimum requirements of the building code.

## Storage

Exterior vinyl building materials require little maintenance for many years. Nevertheless, common sense dictates that builders and suppliers of vinyl products store, handle, and install vinyl materials in a manner that avoids damage to the product and/or the structure. When transporting vinyl siding to a job site, make certain to keep the cartons flat and supported along their entire length. At the job site, take the following precautions when storing vinyl siding cartons:

- Store the cartons on a flat surface and support the entire length of the cartons.
- Keep the cartons dry.
- Store the cartons away from areas where falling objects or other construction activity may cause damage.
- Do not store the cartons in stacks more than six boxes high, and make sure the stacks are stable.
- Do not store the cartons in any location where temperatures may exceed 130° F/54.4° C (e.g., on blacktop pavement during unusually hot weather or under dark tarps or plastic wraps without air circulation).

## Fire Safety Information

Safe homes use fire-safe claddings, which include vinyl siding. Vinyl siding provides good fire performance because it is composed mainly of polyvinyl chloride, more commonly known as vinyl or PVC. Due to its chlorine base, vinyl siding does not ignite quickly and is inherently flame-retardant.

All organic materials (anything containing carbon) will ignite. But the higher the temperature a material has to reach before it flames, the safer it is. PVC will not ignite, even from another flame, until it reaches about 730°F (387°C) and won't self-ignite until about 850°F (454°C). Those ignition temperatures are significantly higher than common framing lumber, which ignites from a flame at 500°F (260°C) and self-ignites at 770°F (410°C). Exterior cladding is not a factor in most fires, as 96 percent of fires start on the inside of structures. In fact, when fire-resistive construction is required by the building code, vinyl siding is specified as a cladding option in several UL fire-rated assemblies.

All building materials should be installed in accordance with local and state building code requirements.

## Re-siding Over Asbestos Siding

Asbestos siding is a regulated material, and the appropriate environmental agency or local building code official should be contacted before re-siding over this product.

## Historic Restoration

Vinyl siding and accessories can replicate many of the architectural details of historic homes; see the interactive *Designing Style* guide on VSI's website (www.vinylsiding.org) for more information. When using vinyl siding for historic restoration projects, VSI recommends the following:

- If a building is in a historic area, local historic district, or has been designated as a historic building, make sure that approval for the use of vinyl siding has been obtained from the local historic society or local Historic District Commission. This applies to building additions as well.
- Before a historic building is re-sided, it should be examined for moisture, insect infestation, structural defects, and other problems that may be present. These problems should be addressed and the building pronounced "healthy" before re-siding with any material.
- Do not damage or remove the original siding. If at all possible, do not alter the original structure, so that the application of vinyl siding is reversible (i.e., the original siding would remain intact in the future, so that if desired, the vinyl siding could be removed). Exception: "In cases where a nonhistoric artificial siding has been applied to the building, the removal of such a siding before application of vinyl siding would, in most cases, be acceptable." (Preservation Briefs, Number 8, U.S. Department of the Interior, 1984.)[1]
- Exercise every care to retain architectural details wherever possible. Do not remove, cover, or add details until the building owner's written approval has been obtained. Determine that the owner has consulted the local historic society for approval.
- Use siding that closely approximates the appearance of the original siding in color, size, and style. In historic districts, the goal is to match the product as closely as possible and retain the original trim.

## Disposal/Recycling

Dispose of all scrap or excess material in a manner that is consistent with local and state rules and regulations. PVC is a thermoplastic material that can be recycled; for more information, contact the siding distributor or manufacturer about the availability of recycling programs.

## Resources

VSI provides a number of resources to promote vinyl siding's beauty, durability, value, low maintenance, and other product attributes, through its *America Sides with Vinyl* campaign and the *VSI Product Certification Program*. Resources such as *Designing Style*, an interactive guide to many home designs made possible with vinyl siding, and the *Official List of Certified Products and Colors* can be found at www.vinylsiding.org.

[1] Preservation Briefs, Number 8, can be ordered by contacting the Superintendent of Documents at 202/512-1800. Or, the brief can be viewed via the Heritage Preservation website at *www2.cr.nps.gov*. GPO stock number: 024-005-01026-2.

# BASIC INSTALLATION RULES

Before getting started, it is important to review several rules of thumb for vinyl siding application. The following rules, which are repeated in this guide, are critical for proper vinyl siding installation:

1. Installed panels and accessories must move freely from side to side.
2. When installing a siding panel, push up from the bottom until the lock is fully engaged with the piece below it. Without stretching the panel, reach up and fasten it into place.
3. Fasten nails or other fasteners in the center of the nailing slot and make sure the fastener penetrates a total of at least 1 1/4” (32mm) into a nailable material such as wood sheathing and framing.
4. Do not force the panels up or down when fastening in position.
5. Do not drive the head of the fastener tightly against the siding nail hem. Allow approximately 1/32” (0.8mm) (about the thickness of a dime) clearance between the fastener head and the siding panel. Make sure the panels can move freely back and forth. Drive fasteners straight and level to prevent distortion and buckling of the panel.
6. Leave a minimum of 1/4” (6.4mm) clearance at all openings and stops to allow for normal expansion and contraction. When installing in temperatures below 40° F/4.4° C, increase minimum clearance to 3/8” (9.5mm).
7. Do not caulk the panels where they meet the receiver of inside corners, outside corners, or J-trim. Do not caulk the overlap joints.
8. Do not face-nail or staple through siding. Vinyl siding expands and contracts with outside temperature changes. Face-nailing can result in ripples in the siding.
9. In re-siding, furring or removal of uneven original siding may be necessary; take appropriate actions to ensure a smooth and continuous surface.
10. In new construction, avoid the use of green lumber as the underlayment. Keep in mind that siding can only be as straight and stable as what lies under it.
11. The installation of specific products may differ in details from the instructions given in this manual. Always follow the manufacturer’s instructions, using parts specified by the manufacturer, to ensure proper installation.

## Cleanup

The beauty of vinyl siding is maintained with little effort. Although vinyl siding will get dirty, like anything exposed to the atmosphere, a heavy rain will do wonders to clean it. Or, it's possible to wash it down with an ordinary garden hose. If neither rain nor hosing does a satisfactory job, follow these simple instructions:

1. Use an ordinary, long-handled car washing brush. This brush has soft bristles, and the handle fastens onto the end of the hose. It allows the siding to be washed just like a car. Avoid using stiff bristle brushes or abrasive cleaners, which may change the gloss of the cleaned area and cause the siding to look splotchy.
2. To remove soot and grime found in industrial areas, wipe down the siding with a solution made up of the following:
   - 1/3 cup (0.08 liter) powder detergent (e.g., Fab®, Tide®, or equivalent powder detergent)*
   - 2/3 cup (0.16 liter) powder household cleaner (e.g., Soilax®, Spic & Span®, or equivalent)*
   - 1 gallon (3.8 liters) water
3. If mildew is a problem, use the solution previously mentioned, but add 1 quart (0.95 liter) liquid laundry bleach.
4. When washing down the entire house, start at the bottom and work up to the top in order to prevent streaking.
5. For stubborn stains, use the following chart:

| STAIN | CLEANERS* |
|---|---|
| Bubble Gum | Fantastik®, Murphy's Oil Soap®, or solution of vinegar (30 percent) and water (70 percent) |
| Crayon | Lestoil® |
| DAP (Oil-based caulk) | Fantastik® |
| Felt-tip Pen | Fantastik® or water-based cleaners |
| Grass | Fantastik®, Lysol®, Murphy's Oil Soap®, or Windex® |
| Lipstick | Fantastik® or Murphy's Oil Soap® |
| Lithium Grease | Fantastik®, Lestoil®, Murphy's Oil Soap®, or Windex® |
| Mold and Mildew | Fantastik® or solution of vinegar (30 percent) and water (70 percent) |
| Motor Oil | Fantastik®, Lysol®, Murphy's Oil Soap®, or Windex® |
| Oil | Soft Scrub® |
| Paint | Brillo® Pad or Soft Scrub® |
| Pencil | Soft Scrub® |
| Rust | Fantastik®, Murphy's Oil Soap®, or Windex® |
| Tar | Soft Scrub® |
| Top Soil | Fantastik®, Lestoil®, or Murphy's Oil Soap® |

*Cleaning materials are listed in alphabetical order.

VSI does not endorse proprietary products or processes and makes no warranties for the products referenced herein. Reference to proprietary names is for illustrative purposes only and is not intended to imply that there are not equally effective alternatives.

Follow the precautionary labeling instructions on the cleaning agent container. Protect shrubs from direct contact with cleaning agents.

# TERMS TO KNOW

**Backerboard**—a flat material used on the face of the house, applied between the studs and the siding (or over existing wall surface), to provide an even surface for installing vinyl siding.

**Buttlock**—the bottom edge of a siding or soffit panel, or accessory piece, opposite the nailing slots, which locks onto the preceding panel.

**Channel**—the area of the accessory trim or corner post where siding or soffit panels are inserted. Channels also refer to the trim itself, and are named for the letters of the alphabet they resemble (e.g., J-channel, F-channel, etc.).

**Course**—a row of panels, one panel wide, running the length of the house from one side to the other, or, in the case of vertical siding, from top to bottom.

**Drip Cap/Head Flashing**—an accessory installed with vertical siding to ensure that water drips away from panels and does not infiltrate them.

**Double Channel Lineal**—a siding accessory that joins two soffit panels.

**Face**—refers to the side of a siding or soffit panel that is showing once the panel has been installed.

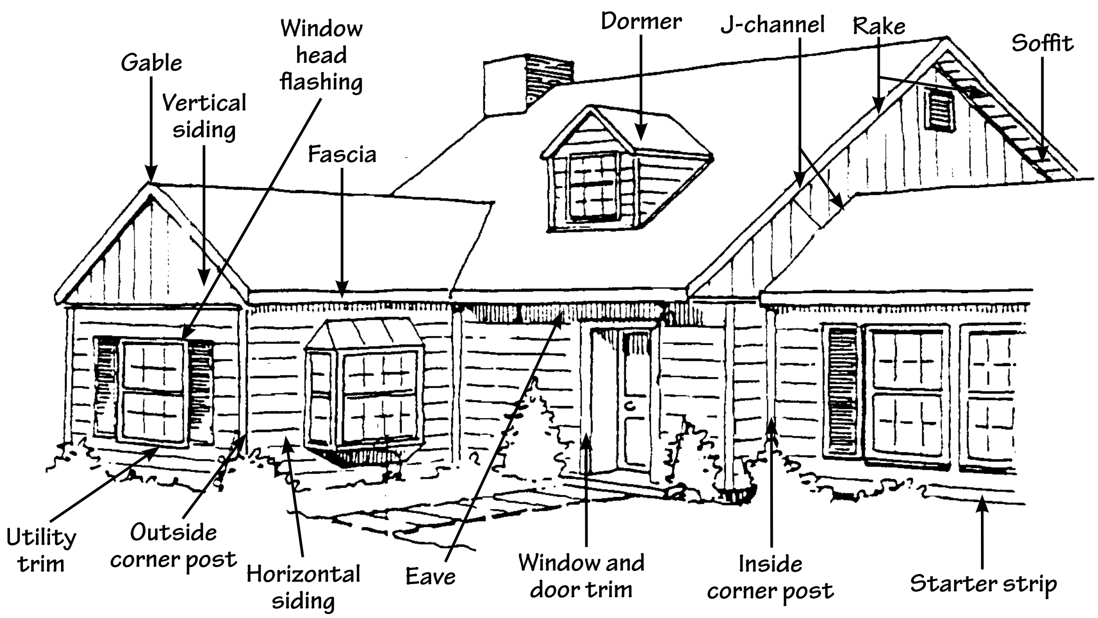
**Face-nailing**—the action of fastening directly onto the "face" side of a panel (instead of using the nail hem slot). This practice is generally not used in siding installation.

**Fascia**—the trim covering the ends of roof rafters. **Fascia Board**—a board attached to the ends of the rafters between the roofing material and the soffit overhang. **Fascia Cap or Cover**—the covering around a fascia board.

**Flashing**—a thin, flat material that meets the requirements of ICC AC148, positioned under or behind J-channels, corner posts, windows, etc., to keep draining water from penetrating the home.

**Furring/Furring Strip**—usually a wood 1" x 2" (25.4mm x 50.8mm) strip used to even a surface in preparation for installing vinyl siding. To "fur" a surface means to apply these strips.

Figure 2.



**Lap**—to overlap the ends of two siding panels or accessory pieces to allow for expansion and contraction of the vinyl product.

**Lug/Crimp**—the raised "ears" or tabs on a siding panel, created by a snap lock punch, which can be used to lock a siding panel into place when the nailing hem has been removed.

**Miter**—to make a diagonal cut, beveled to a specific angle (usually 45°). Sometimes miter cuts are made into an overlapping siding or soffit panel surface, to provide a neater appearance.

**Nail Hem (or Flange)**—the section of siding or accessories where the nailing slots are located.

**Nailing Strip**—an additional framing member installed to facilitate soffit installation.

**Nail Hole Slot Punch**—refer to page 11 for illustration and use.

**Plumb**—a position or measurement that is truly and exactly vertical, 90° from a level surface.

**Rake (roof)**—the inclined, usually projecting edge of a sloping roof.

**Rake (wall)—**the board or molding placed along the sloping sides of a gable to cover the ends of the siding.

**Scoring**—running a utility knife blade, sharpened awl, scoring tool, or other sharp implement across a soffit or siding panel face without cutting all the way through the panel. This weakens the vinyl siding surface in a specific area and allows the panel to be bent and broken off cleanly.

**Sealant**—any of a variety of compounds used to fill or seal joints in wood, metal, masonry, vinyl, and other materials.

**Shim**—a building material used to even a surface prior to installing vinyl siding.

**Snap Lock Punch**—refer to page 11 for illustration and use.

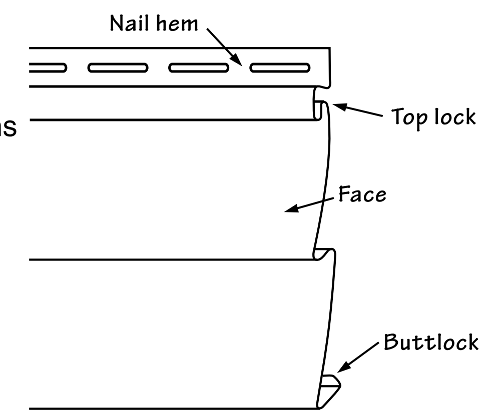


Figure 3.

**Soffit**—material used to enclose the horizontal underside of an eave, cornice, or overhang. Soffit is designed to be installed lengthwise from wall to fascia.

**Starter Strip**—an accessory applied directly to the surface of the building and used to secure the first course of siding to the home.

**Underlayment**—water-resistive material placed under vinyl siding panels.

**Utility Trim**—a piece of trim used any time the top lock has been removed from the siding, to secure a siding panel. Also referred to as "undersill" or "finish" trim; double utility trim is also available.

**Water-resistive Barrier—**a material applied between the sheathing and the siding that is intended to resist any water that penetrates through the siding and meets the requirements of ICC AC38.

**Weep Holes**—openings cut into siding or accessories to allow for water runoff.

**Zip Lock Tool**—also known as an unlocking tool; refer to page 11 for illustration and use.

# MATERIALS, TOOLS, AND ACCESSORIES

## Panel Profiles

Vinyl siding comes in a variety of shapes, textures, and colors, creating a wide array of looks for different houses. It is manufactured primarily from durable polyvinyl chloride in several different profiles, including single, double, triple, vertical, and Dutch lap (Fig. 4).

There are also various types of vinyl soffit (the material used to enclose the underside of an eave or overhang). Soffit can be vented, solid, or a combination of the two (Fig. 5) and is designed to maximize airflow, preventing moisture accumulation and heat buildup between the siding and the house.

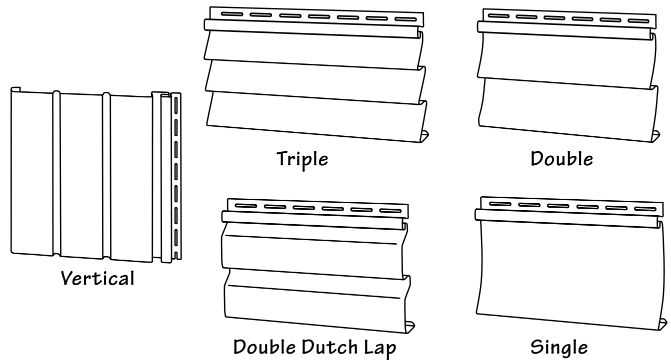



Figure 4.

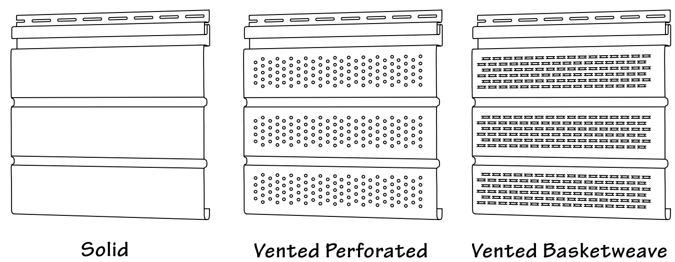



Figure 5.

## Basic Installation Tools and Equipment

Common hand tools, such as a hammer, fine-tooth saw, square, chalkline, level, and tape measure, are needed for proper installation (Fig. 6). Safety glasses are recommended for eye protection. Other basic tools include:

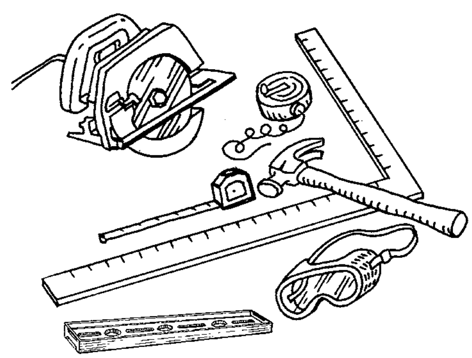


Figure 6.

### Power Saw

A bench or radial-arm power saw can speed the cutting of the siding or soffit. A fine-tooth plywood blade should be used with the blade installed in the reverse direction. Some applicators prefer a handheld power saw. In extremely cold weather, move the saw through the material slowly to prevent chipping or cracking (Fig. 7).

**NOTE: A saw blade set up in reverse direction should be used only for cutting vinyl. Do not attempt to use it on other materials such as wood, plywood, etc.**

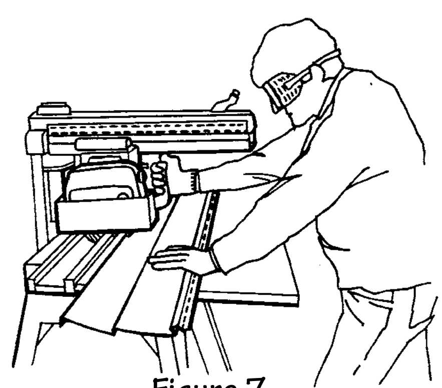


Figure 7.

### Utility Knife

Vinyl is easy to cut, trim, and score with a utility knife or scoring tool (Fig. 8).

### Tin Snips

Good quality tin snips or compound aviation-type snips will speed the cutting and shaping of the vinyl (Fig. 8).

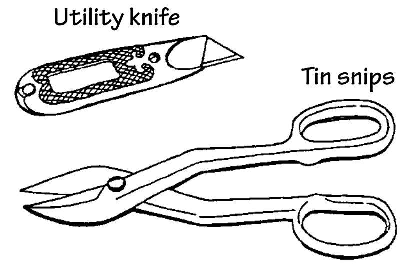



Figure 8.

## Special Tools

### Snap Lock Punch

A snap lock punch is used to punch lugs in the cut edges of siding to be used for the top or finishing course at the top of a wall, or underneath a window (Fig. 9).

### Nail Hole Slot Punch

Occasionally, it may be necessary to elongate a nail hem slot to hit a stud. The hole is elongated to allow for expansion and contraction (Fig. 9).

### Zip Lock (Unlocking) Tool

Remove or replace a siding panel with the zip lock tool. Insert the curved end of the tool under the end of the panel and hook onto the back lip of the buttlock. To disengage the lock, pull down and slide the tool along the length of the panel. Use the same procedure to relock a panel (Fig. 9).

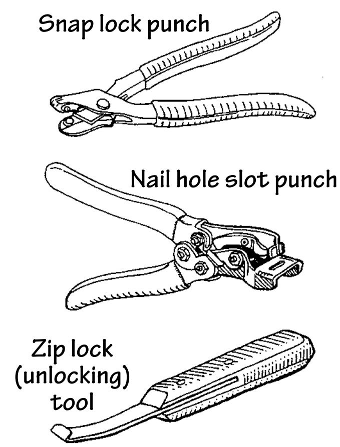



Figure 9.

## Accessories

### Outside and Inside Corner Posts

Corner posts are used to provide a finished edge at an inside or outside corner. The siding from adjoining walls fits neatly into the inside or outside corner post channels. Appropriate widths of channel openings are available to accommodate various configurations of siding.

### Trim and Molding

A complete line of accessories is used to give every installation a professional appearance, while providing a water-resistive facade. Some accessories include trim, starter strips, J-channels, F-channels, drip caps, utility trim, and double utility trim (Fig. 10). Each of these accessories will be addressed in more detail throughout this manual.

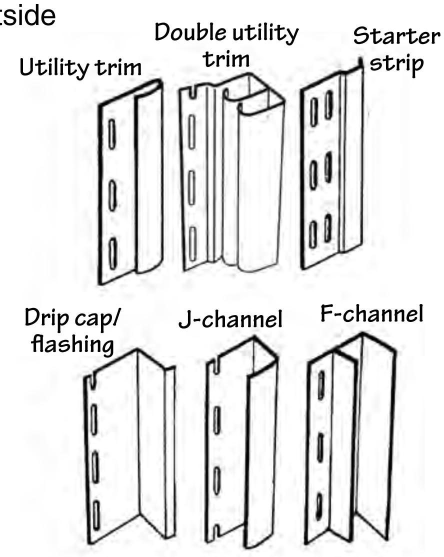



Figure 10.

**NOTE: *Vinyl siding manufacturers produce various sizes of J-channels, corner posts, and other accessories. Remember to order accessories of the proper size to match the siding panels. Consult the manufacturer for the appropriate size.***

# GETTING STARTED

## Materials

### Sheathing/Backerboard

Vinyl siding should be applied over a sheathing that provides a smooth, flat surface. Consult local building codes for sheathing requirements. Vinyl siding must never be applied directly to studs without sheathing. As an alternative, installation of specific types of drop-in contoured foam underlayments for various styles of vinyl siding are available. Some manufacturers of vinyl siding do not recommend the use of drop-in backers with certain vinyl siding configurations.

### Sheathing Nailability

Vinyl siding can be installed over common wood sheathings such as plywood, oriented strand board (OSB), or other materials (e.g., foam plastic insulating sheathing). The thickness of wood sheathing counts toward the total thickness that the fasteners must penetrate into nailable material, usually 1 1/4" (32mm). But foam plastic sheathing does not contribute toward holding the fastener, so its thickness cannot be counted toward the total. In this case, the fastener would have to be long enough to penetrate through the sheathing and 1 1/4" (32mm) into the wood framing.

### Water-resistive Barrier

Vinyl siding should be installed over a continuous water-resistive barrier to stop the intrusion of incidental water. Refer to page 3 for more information on water-resistive barriers. Check your local building code for requirements in your geographic area.

### Flashing

Code-compliant flashing should be integrated with the water-resistive barrier and applied around windows, doors, and other openings. Flashing should also be applied to inside and outside corners, and the intersection of walls and roofing to prevent water infiltration.

## How to Measure

### Estimating Required Materials

- All houses can be broken down into shapes of rectangles or triangles, or a combination of both.
- The area to be sided can be determined by measuring the height and width of the house, including windows (Fig. 11).
- Total all of the measurements for the areas to be sided. Windows and doors are not usually deducted. Including them will provide an allowance factor for waste. If the windows and doors are extremely large (such as a garage or sliding glass doors), some deductions can be made (Fig. 12-14).

Height___feet (meters) x width___feet (meters) = ___square feet (square meters)

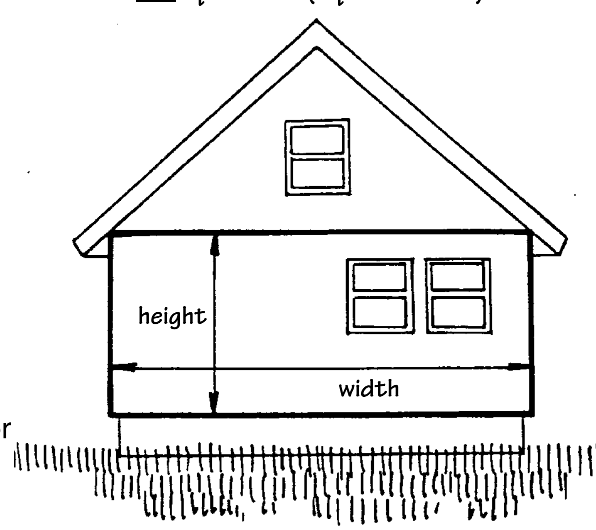



Figure 11. Wall areas

- To estimate the amount of starter strip required, measure the linear feet around the entire base of the house.
- Add siding to all material estimates to allow for waste, depending on the pitch of the roof and other house-specific factors.
- To estimate the total pounds of fasteners required, multiply the total square feet of siding by 0.005 for aluminum nails and 0.01 for roofing nails, staples, and screws.

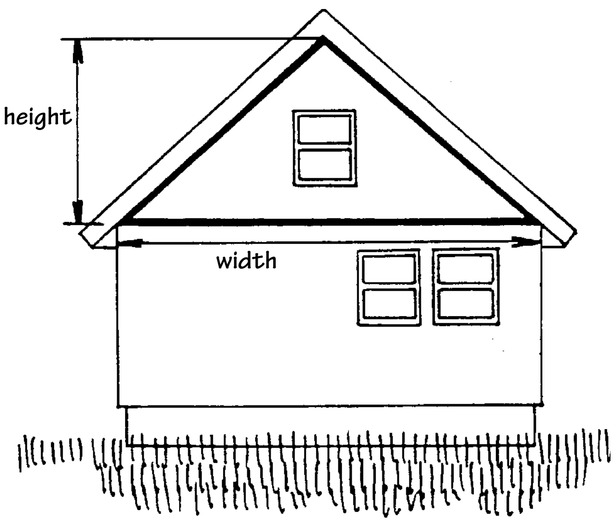



**Figure 12. *Gable areas***

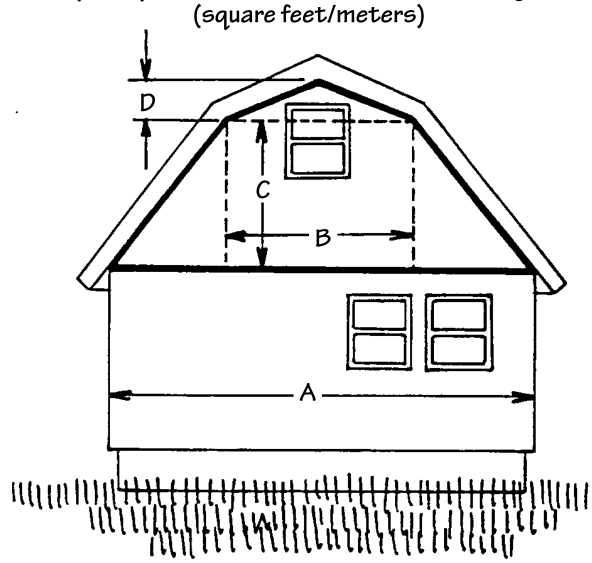



**Figure 13. *Gambrel roof house***

- Every 100 square feet (9.29 square meters) is called a "square" for ordering purposes.

**NOTE: *The amount of siding needed/ waste generated for a vertical siding job will be determined by the height of the wall versus the length of the panels.***

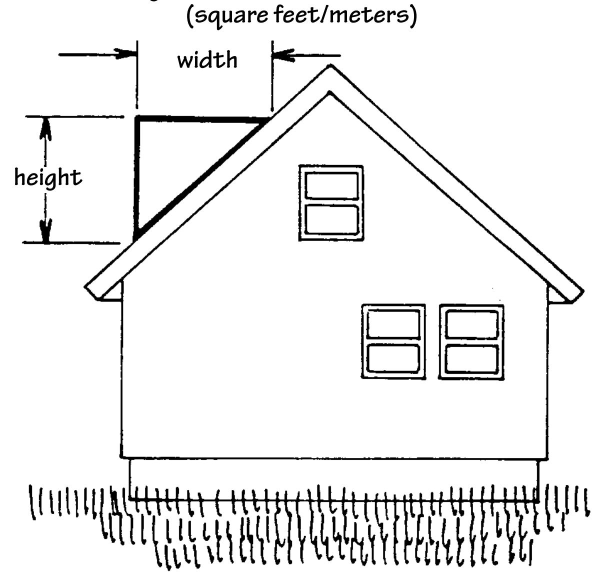



**Figure 14. Dormer areas**

# Estimating Worksheet

**Use the following worksheet to estimate the required materials*:**

| | | |
|---|---|---|
| **Siding** | Walls | ______square feet/meters |
| | Gable ends | ______square feet/meters |
| | Dormer sides | ______square feet/meters |
| | Upper gambrel walls | ______square feet/meters |
| | Total wall surface area | ______square feet/meters (A) |
| | Large areas not to be covered: (garage doors/sliding doors) | ______square feet/meters |
| | | x 0.50 = |
| | Uncovered area | ______square feet/meters (B) |
| | Subtract B from A for | |
| | **Total net surface area** | ______square feet/meters |
| **Soffit** | | ______square feet/meters |
| **Porch ceiling** | | ______square feet/meters |
| **Lattice** | | ______linear feet/meters |
| **Accessories** | Starter strip | ______linear feet/meters |
| | Utility trim | ______linear feet/meters |
| **Receiving channel** | J-channel | ______linear feet/meters |
| | Designer J-channel | ______linear feet/meters |
| | Flexible J-channel | ______linear feet/meters |
| | F-channel | ______linear feet/meters |
| | 3 1/2" /5" lineals | ______linear feet/meters |
| | Dual undersill trim | ______linear feet/meters |
| **Outside corners** | Outside corner post | ______linear feet/meters |
| | Designer corner trim | ______linear feet/meters |
| **Inside corners** | Inside corner post | ______linear feet/meters |
| | J-channel | ______linear feet/meters |
| **Other** | Soffit cover trim | ______linear feet/meters |
| | Soffit double channel lineal | ______linear feet/meters |
| | Light blocks | ______ |
| | Width of accessory recess opening: | |
| | (circle one) 1/2" (12.7mm) 5/8" (15.9mm) 3/4" (19mm) 1 1/4" (31.8mm) | |
| **Nails** | Pounds required | |
| | Length (1 1/2" minimum) (38.1mm) | ______pounds |

| | | | |
|---|---|---|---|
| **Tools needed** | __ hammer | __ tin snips | __ tape measure |
| | __ chalkline | __ utility knife | __ level |
| | __ square | __ hacksaw | __ power saw |
| | __ nail hole slot punch | __ snap lock punch | |
| | __ unlocking tool | __ fine-tooth saw blade | |

* Add a factor of 10 percent to all material estimates to allow for waste.

## Fastener Choices

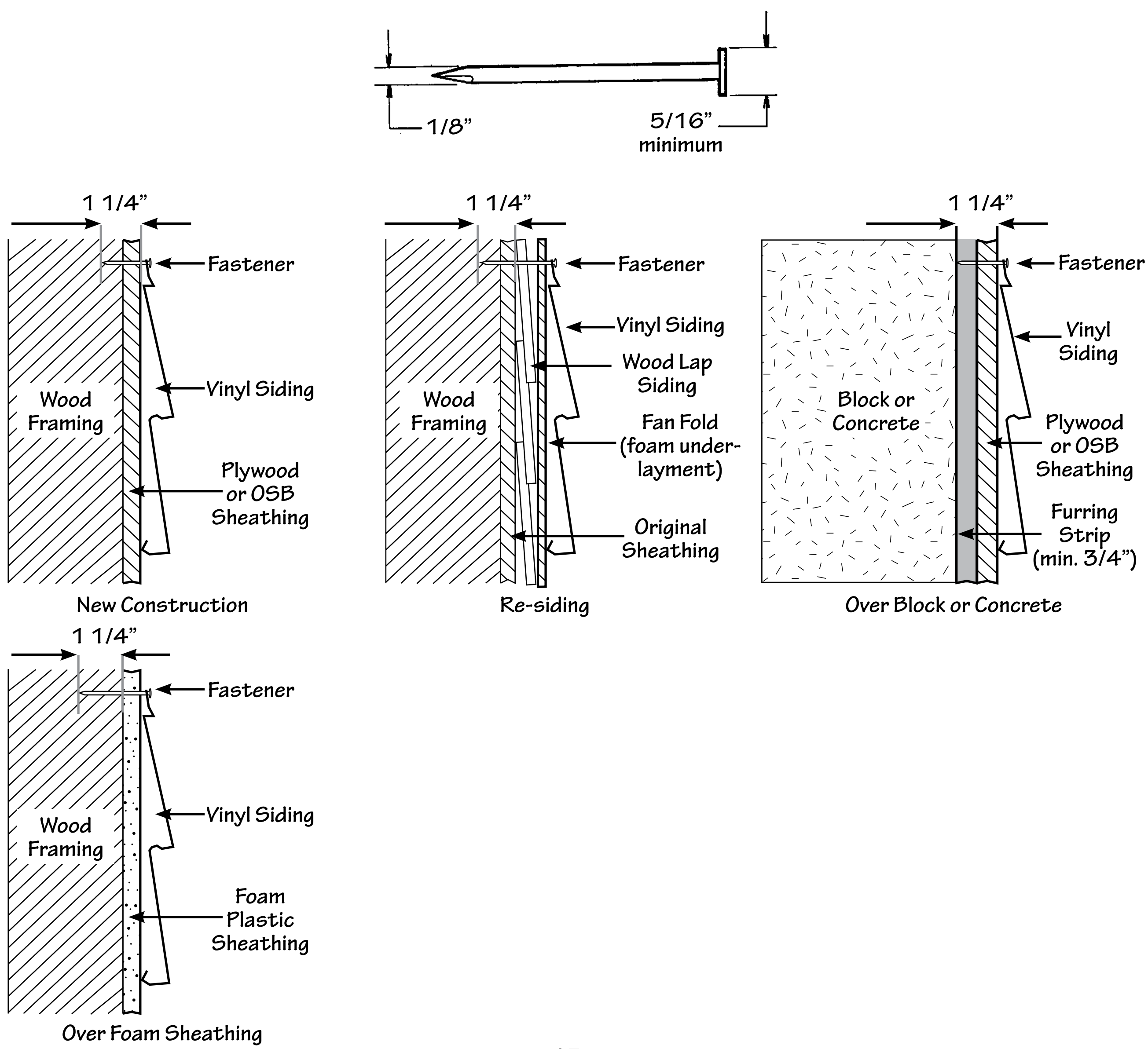
Use aluminum, galvanized steel, or other corrosion-resistant nails, staples, or screws when installing vinyl siding. Aluminum trim pieces require aluminum or stainless steel fasteners. All fasteners must be able to penetrate a minimum of 1 1/4” (32mm) into nailable material, such as wood sheathing and framing (Fig. 15).

When the fastener must penetrate through a non-nailable material such as foam sheathing, the thickness of that material does not count toward the total. In such cases, the fastener will need to be long enough to penetrate through the non-nailable material and then 1 1/4” (32mm) into wood framing or other nailable material. (Review the siding manufacturer’s instructions and your local building codes for variations that may apply to specific siding or geographic areas.)

### Nails

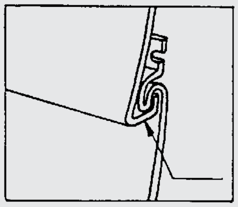
Nail heads should be 5/16” (7.9mm) minimum in diameter. Shank should be 1/8” (3.2mm) in diameter (Fig. 15).

Figure 15.



# Fastening Procedure

Vinyl siding can expand and contract 1/2" (12.7mm) or more over a 12' 6" (3.81m) length during normal, year-round changes in temperature. Whether using a nail, screw, or staple to fasten the siding, the following basic rules must be followed:



- Make sure the panels are fully locked along the length of the bottom, but do not force them up tight when fastening.

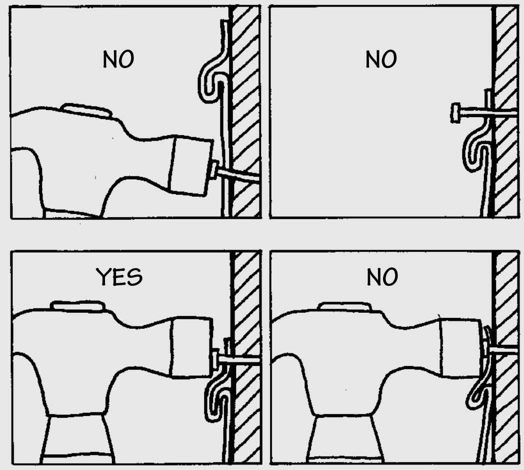



Figure 16.

- Do not drive the head of the fastener tightly against the siding nail hem. Allow approximately 1/32" (0.8mm) clearance (the thickness of a dime) between the fastener head and the vinyl. **Tight nailing, screwing, or stapling will cause the vinyl siding to buckle with changes in temperature (Fig. 16).**
- When fastening, start in the center of the panel and work toward the ends.
- Center the fasteners in the slots to permit expansion and contraction of the siding (Fig. 17).

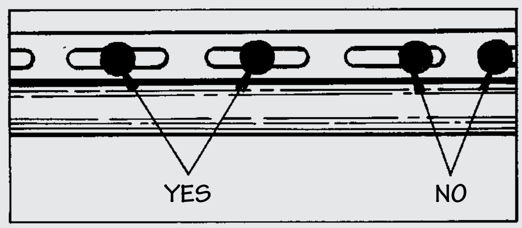



Figure 17.

- Drive fasteners straight and level to prevent distortion and buckling of the panel (Fig. 18).

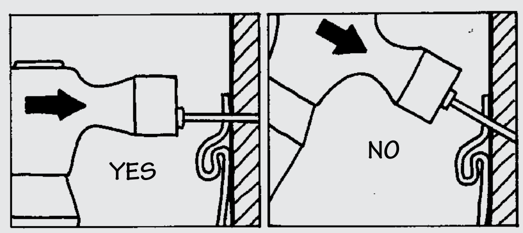



Figure 18.

- Space the fasteners a maximum of 16" (406mm) apart for horizontal siding panels, every 12" (305mm) for vertical siding panels, and every 8" to 12" (203mm to 305mm) for accessories. These distances may be increased if the manufacturer permits greater spacing based on wind load testing. Start fastening vertical siding and corner posts in the top of the uppermost slots to hold them in position (Fig. 19). Place all other fasteners in the center of the slots.
- If a nail slot does not allow centering/securing into a nailable surface, use a nail hole slot punch to extend the slot and allow centering of the fastener.

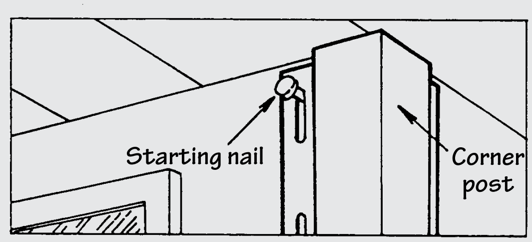



Figure 19.

### Screw Fasteners

Screw fasteners can be used if the screws do not restrict the normal expansion and contraction movement of the vinyl siding panel on the wall. Screws must be centered in the slot with approximately 1/32" (0.8mm) space between the screw head and the vinyl. Screws must be able to penetrate no less than 1 1/4" (32mm) into framing or furring and should be:

- Size #8, truss head or pan head
- Corrosion-resistant, self-tapping sheet metal type

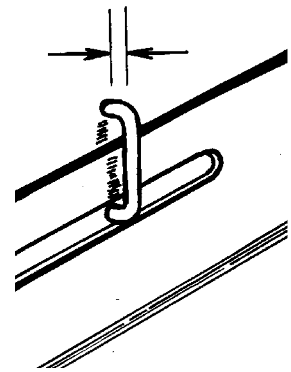
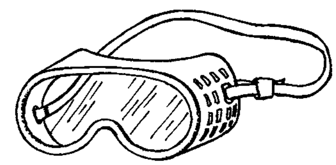



Figure 20.

### Staples

If staples are being used instead of nails or screws, consult your local building codes. The manufacturer may permit the use of staples as an alternative to nails. Be sure to observe any limitations with respect to the wind load design pressure rating when the siding is installed with staples. The staples must (Fig. 20):

- Not be less than 16-gauge semi-flattened to an elliptical cross-section.
- Penetrate not less than 1 1/4" (32mm) into framing or furring, or as specified in the manufacturer's instructions.
- Be wide enough in the crown to allow free movement of the siding (approximately 1/32" [0.8mm] away from the nailing hem).



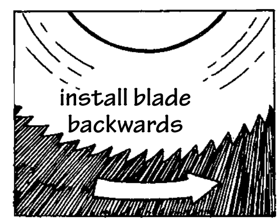



Figure 21.

## Cutting the Siding

When cutting vinyl siding or soffit, follow these guidelines:

- Safety goggles are always recommended for all cutting and nailing operations. As on any construction job, use proper safety equipment and follow safe construction practices.
- With a circular saw, always install the fine-tooth (plywood) blade backwards on the saw for a smoother, cleaner cut, especially in cold weather (Fig. 21). Cut slowly. Do not attempt to cut materials other than vinyl with a reversed direction saw blade.

  **Caution! Use of a backwards blade on any other materials could be unsafe.**
- With tin snips, avoid closing the blades completely at the end of a stroke for a neater, cleaner cut (Fig. 22).
- With a utility knife or scoring tool, score the vinyl face up with medium pressure and snap it in half. It is not necessary to cut all the way through the vinyl (Fig. 23).

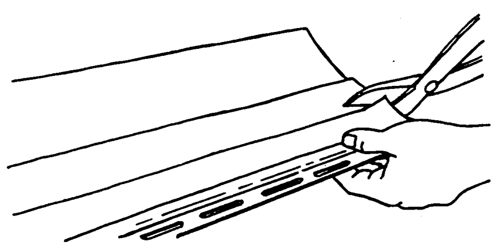


Figure 22.

Figure 23.

## Preparing the Walls

A flat, level wall surface is necessary for proper installation of vinyl siding. Install flashing **before** starting to apply the siding.

Unless already installed, a water-resistive barrier should be applied to the house prior to installing vinyl siding. Refer to page 3 for more information on water-resistive barriers. Consult your local building code for requirements in your geographic area.

Make sure that the construction of the wall allows for a total of 1 1/4” (32mm) fastener penetration into wood material. If the wall is covered with foam plastic sheathing, make sure that nails will be long enough to penetrate 1 1/4” (32mm) into the framing behind the foam. Make sure that any furring strips are thick enough to provide this penetration depth, or cover them with wood sheathing to provide the needed depth. (See Fastener Choices and Fig. 15 on page 15.)

### New Construction

- Tip: To reduce the possibility of floor-plate compression, drywall, roofing, or other heavy building materials should be installed or stored throughout the house prior to the installation of vinyl siding. Floor-plate compression can result in buckled siding at the intersection of the floor and the wall.

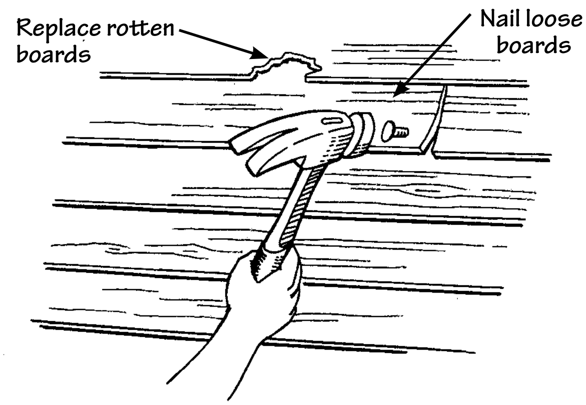



Figure 24.

### Re-siding

- Nail down loose boards of existing siding, and replace any rotten ones (Fig. 24). **Do not install vinyl siding over rotting wood.**
- Scrape off loose caulk and re-caulk around windows, doors, and other areas to protect from moisture penetration.
- Remove all protrusions such as gutters, downspouts, and light fixtures.
- Check all walls for evenness and install furring strips where necessary. When installing furring strips, please take appropriate measures to establish a smooth and continuous surface. (Fig. 25).

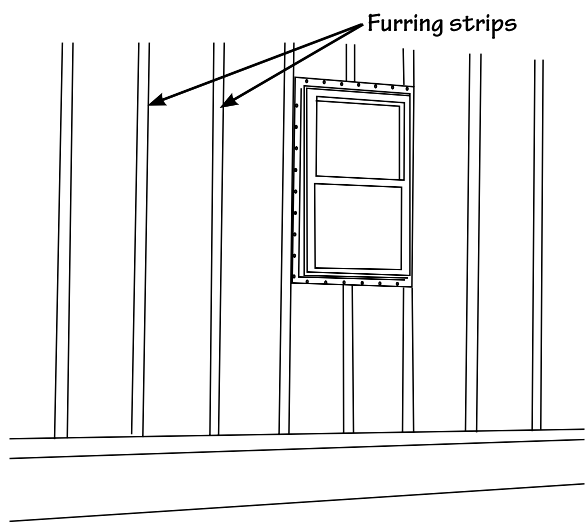



Figure 25.

> **NOTE: In cases where the lower portion of a horizontal siding panel must be trimmed so that it may be installed over steps, porches, etc., the panel should be built out (“furred”) for proper angle and rigidity. Utility trim can be used to seal the cut edge of the panel and then secured to the wall.**

# INSTALLING ACCESSORIES

Before the siding itself can be hung, a number of accessories must be installed first, including starter strips, corner posts, window flashing, trim, and J-channels over the roof lines and around openings.

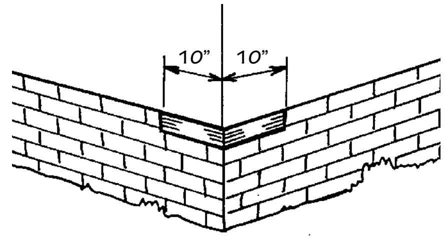



Figure 26.

## Outside and Inside Corner Posts

- A water-resistive material should be used to flash the inside and outside corners a minimum of 10" (254mm) on each side before installation of the corner posts (Fig. 26).

**NOTE: *Depending on the type of construction, vinyl soffit and fascia or the corner posts can be installed first.***

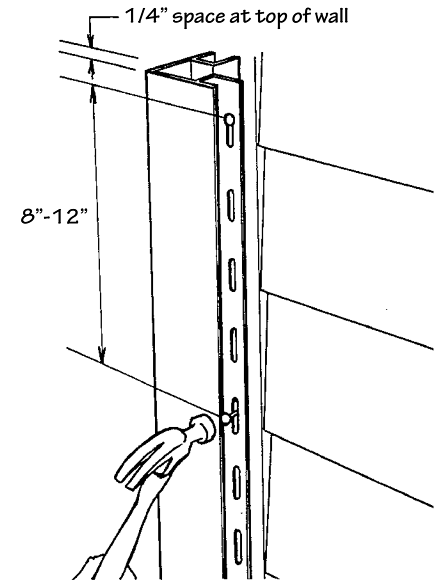



Figure 27.

- Inside corner posts can be a single or double J-channel, or a factory-formed inside corner.
- Place the corner post in position, allowing a 1/4" (6.4mm) gap between the top of the post and the eave or soffit. Position a nail at the top of the upper slot on both sides of the corner post, leaving a gap of approximately 1/32" (0.8mm) between the nail heads and the corner posts. The corner post hangs from these nails. The balance of the nailing should be in the center of the slot, 8" to 12" (203mm to 305mm) apart, again leaving 1/32" (0.8mm) between the nail head and the corner post. This allows for the expansion and contraction to occur at the bottom. The corner post should extend 3/4" (19mm) below the starter strip. Make sure the posts are plumb (i.e., vertically straight) and square to the wall (Fig. 27 and 28). Cut away any exposed nail hems.

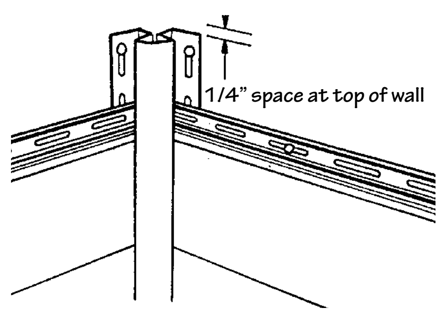



Figure 28.

- If more than one length of corner post is required, overlap the upper piece over the lower piece by cutting away 1" (25.4mm) of the nailing flange on the top piece. Overlap 3/4" (19mm), allowing 1/4" (6.4mm) for expansion. This method will produce a visible joint between the two posts, but will allow water to flow over the joint, reducing the chance of water infiltration.

## Capping a Corner Post

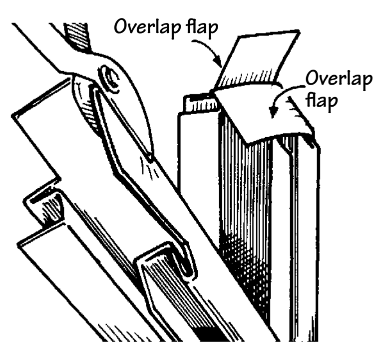



Figure 29.

- Corner posts on homes with a second-story overhang need to be capped by making the cuts shown (Fig. 29). Fold the flaps created over each other as indicated.
- Drill a 1/8" (3.2mm) hole in the center, through both layers of vinyl, and install a pop rivet to hold them in place. Cut a notch in both layers to allow clearance for the corner.

## Starter Strip

In order for the siding to be installed properly in a level fashion, the starter strip at the bottom of the wall must be level.

- Determine the lowest point of the wall that will be sided; from that point, measure up 1/4" (6.4mm) less than the width of the starter strip and partially drive a nail at one corner.
- Attach a chalkline; go to the next corner and pull the line taut.
- Make sure the line is level by using a line level or a 4' (1.2m) level.
- Snap the chalkline and repeat the procedure around the entire house.
- Optional method to determining the position of the starter strip in new construction and some re-siding applications: Measure down from the soffit at one corner of the house to the top of the foundation and subtract 1/4" (6.4mm) less than the width of the starter strip. Make a mark on the wall and record the measurement. Transfer the measurement to the other corner of the wall. Snap a chalk line in between the corners at the marks. Repeat the procedure around the entire house.

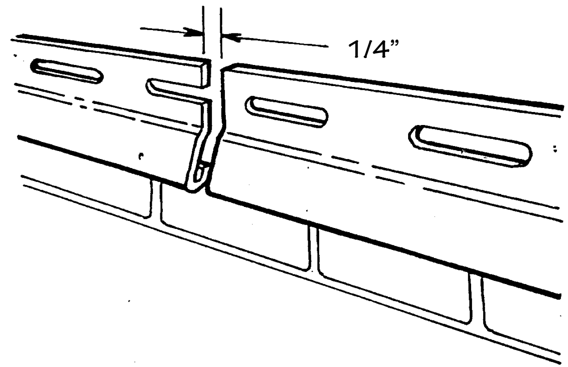



Figure 30.

**NOTE: When insulation or backerboard is used, fur the starter strip, if necessary, to accommodate the thickness of the siding. For a vertical siding starter methods, see the section on vertical siding.**

- Using the chalkline as a guide, install the top edge of the starter strip along the chalkline, nailing at 10" (254mm) intervals. Allow space for the corner posts, J-channels, etc.
- Keep the ends of starter strips at least 1/4" (6.4mm) apart to allow for expansion (Fig. 30).
- Nail in the center of the starter strip nailing slots.
- For insulated siding, the starter strip needs to be spaced away from the wall to accommodate the thickness of the backing on the siding. Consult the manufacturer's instructions for specific materials or techniques.

**NOTE: In certain situations, it may be necessary to use J-channel as a starter strip; remember to drill minimum 3/16" (4.8mm) diameter weep holes no more than 24" (610mm) apart.**

## Windows, Doors, and Roof Lines

### Flashing New Window Installations

If installing both a new window and flashing, refer to window manufacturer's instructions and ASTM E2112*, Standard Practice for Installation of Exterior Windows, Doors and Skylights* for the proper flashing installation method for the window type and wall configuration on the project.

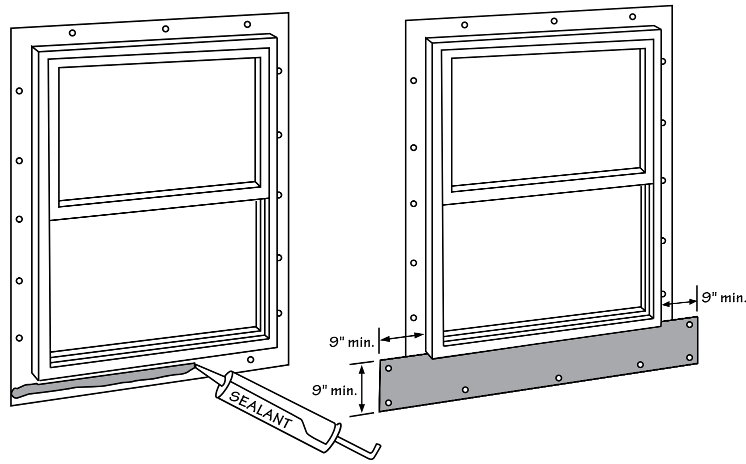



Figure 31.

### Flashing Previously Installed Nail Fin Windows

If a nail fin (in new construction) window has been previously installed without flashing, the following instructions should be followed:

- Apply a continuous bead of sealant to the nailing flange of the sill in a manner that covers the nails and nail slots. Apply a minimum of 9" (229mm) wide horizontal sill flashing level with the bottom edge of the existing window by pressing the flashing into the sealant bead at its top edge. Cut the sill flashing long enough to extend a minimum of 9" (229mm) beyond each jamb. Fasten the sill flashing at the bottom and side edges (Fig. 31).
- Apply a continuous bead of sealant to the nailing flange of the jambs in a manner that covers the nails and nail slots. Continue the bead of sealant at the jambs vertically a minimum of 8 1/2" (216mm) above the head of the window to allow for bedding the top portion of the jamb flashing into sealant in the next step. Install the jamb flashing by pressing the flashing into the sealant beads at the window jambs. Extend the bottom edge of the jamb flashing approximately 1/2" (12.7mm) short of the sill flashing edge, and extend the top edge approximately 8 1/2" (216mm) beyond the head of the window, where the head flashing will be placed next. Fasten the jamb flashing along the edges further most from the window (Fig. 32).

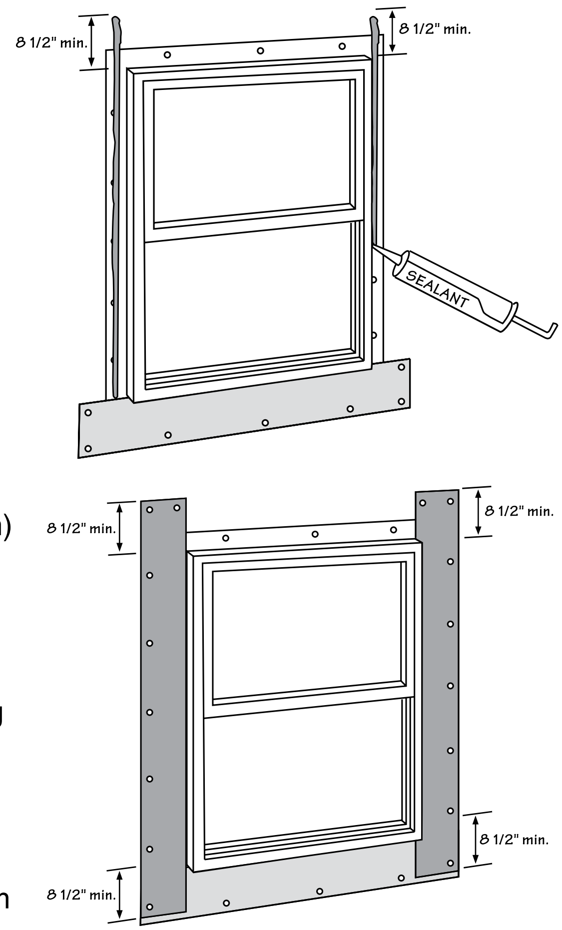



Figure 32.

**NOTE: Sealant should be compatible with window, flashing, and water-resistive barrier materials. Contact sealant manufacturer for job-specific recommendations.**

- Apply a continuous bead of sealant to the nailing flange of the head in a manner that covers the nails and nail slots. Add an additional bead of sealant horizontally, in line with the top of the head flashing. Install the head flashing by pressing the bottom edge of the flashing into the sealant bead previously applied across the mounting flange. Extend the ends of the head flashing approximately 1” (25.4mm) beyond the jamb flashing at each end. Fasten the head flashing into place along the top edge (Fig. 33).

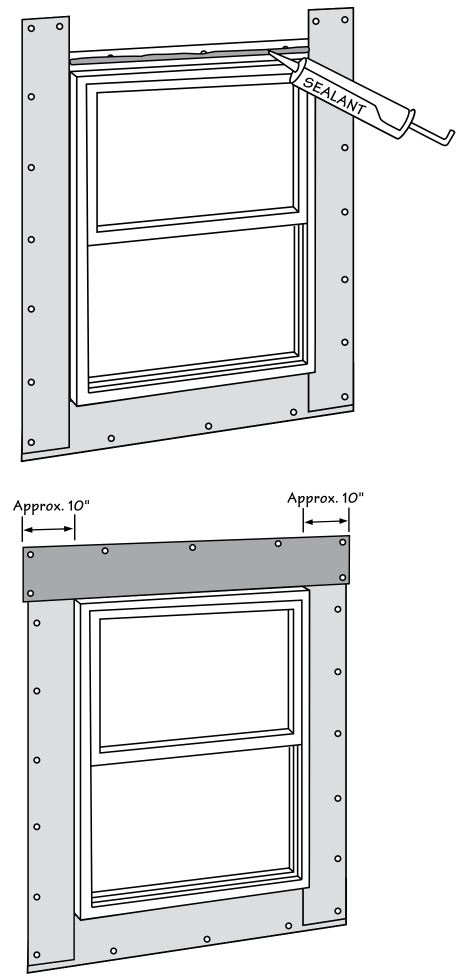



Figure 33.

**Flashing Previously Installed Window with Exterior Casing (Brick Mold)**

If a window with exterior casing (e.g., brick mold) has been previously installed without flashing, the following instructions should be followed:

- Ensure that exterior casing is sealed to the exterior sheathing or water-resistive barrier with a good quality sealant.
- Cover the exterior casing with aluminum or vinyl trim sheet. This can be accomplished by using a portable field brake and bending instructions from the brake manufacturer. The trim sheet should be installed in weatherboard fashion. The bottom piece should be installed first, and each piece should overlap the piece below wherever they join.
- Install rigid head flashing (i.e., drip cap) on top of the top piece of exterior casing, covering trim sheet installed in the previous step. The ends of the rigid head flashing must extend to the outer edges of the exposed legs of the side J-channels. Cut a notch on the ends of the rigid head flashing and bend them down over the sides of the exterior casing. The rigid head flashing must be sealed to the exterior sheathing and to the top of the exterior casing (Fig. 34).

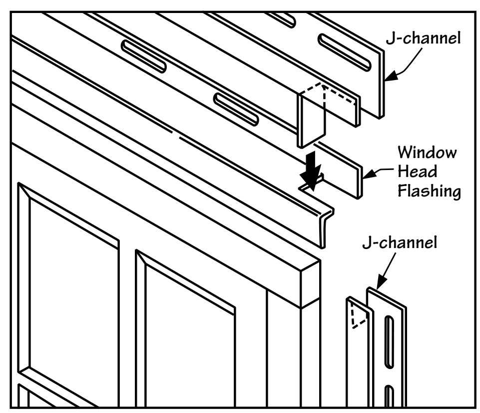



Figure 34.

**Trim**

J-channel is used around windows and doors to receive the siding. Follow the steps below when applying trim.

- Cut and bend the tab of the top piece of J-channel down to provide flashing over the side J-channel.
- Fold the bottom end of the side piece of J-channel inward at the bottom of the window, to fit over the existing J-channel to prevent water from entering under the sill.
- Cut the side J-channel members longer than the height of the window or door, and notch the channel at the top.

- Miter cut the free flange at a 45° angle and bend the tab down to provide flashing over the side members (Fig. 34). A similar miter and tab may be provided at the bottom of the window, depending on the sill's condition. The J-channel should fit snug to the window.

**J-Channel Over Roof Lines**

Install the flashing before the J-channel to prevent water infiltration along the intersection of a roof and wall.

- Keep the J-channel a minimum of 1/2" (12.7mm) from the roofing material. Chalk a straight line up the roof flashing to guide J-channel installation. Tip: You can use another J-channel laid over the shingles as a spacer to create the straight line desired.
- Overlap the J-channel (lapping the upper piece over the lower piece) if it is necessary to use more than one piece. See Fig. 54 on page 29.
- Extend the J-channel past the edge of the roof in order to ensure proper runoff. A diverter can be used; see Fig. 44 and 45 on page 26.
- With dark shingles, or a south or west exposure, it is recommended to either use a metal J-channel or to install the vinyl J-channel as far away from the roofing as is aesthetically acceptable, having first ensured that there is sufficient flashing behind the J-channel to prevent water infiltration.
- Fasten the nail, screw, or staple that is closest to the roof line at the far end of the nail hem slot, to ensure that siding will expand away from the J-channel (Fig. 35).

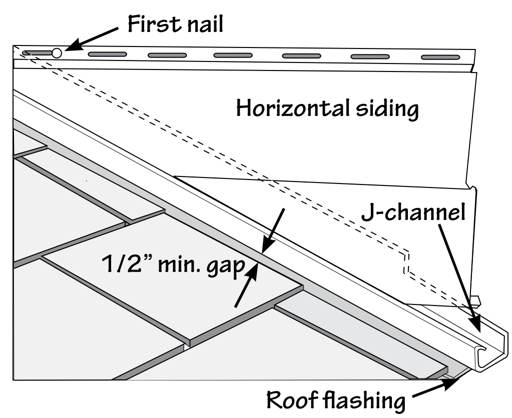


Figure 35.

**NOTE: *Vinyl J-channels should not be in direct contact with roofing shingles, since the shingles may transfer enough heat to the vinyl J-channel to cause its distortion.***

## Gable and Trim

Before applying siding to the gables, the J-channel should be installed to receive the siding at the gable ends (Fig. 36):

- Where the left and right sections meet at the gable peak, let one of the sections butt into the peak with the other section overlapping.
- A miter cut should be made on the face flange of this piece for better appearance.
- Fasten the J-channel every 8" to 12" (203mm to 305mm).
- If more than one length of J-channel is required to span a wall surface, be sure to overlap the channels by 3/4" (19mm). See Figure 54 on page 29.

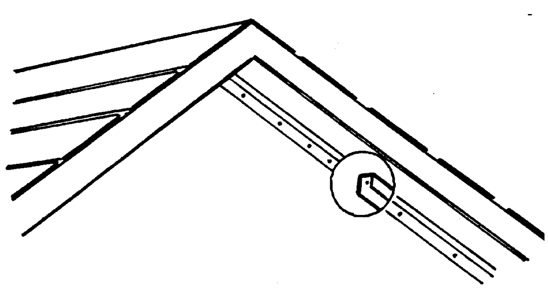


Figure 36.

# HORIZONTAL SIDING INSTALLATION

## Installing Panels

- The first course (row of panels) should be placed in the starter strip and securely locked along the entire length of the siding panel. Make sure the panel is securely locked before fastening.
- Fasten the panels in the center of the nailing slots (see pages 16 and 17 for specific information on fastening and fasteners). Be sure that nail length is sufficient to penetrate framing or framing plus nailable sheathing a total of 1 1/4" (32mm). If the sheathing is a material that won't hold a nail (e.g., foam plastic sheathing), the nail must penetrate 1 1/4" (32mm) into the framing regardless of the thickness of the sheathing.

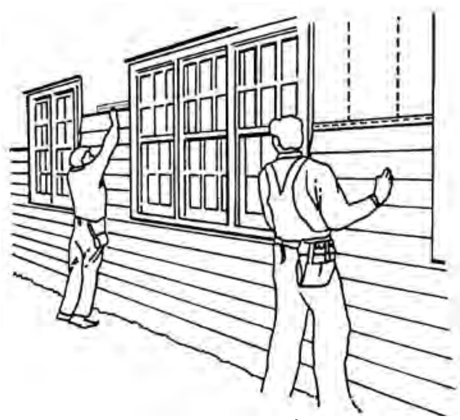


Figure 37.

- Allowance should be made for expansion and contraction by leaving a 1/4" (6.4mm) gap between the siding and all corner posts and channels. Increase to 3/8" (9.5mm) when installing in temperatures below 40° F (4.4° C). If the panels are 20 feet (6.1 meters) or longer, refer to the manufacturer's instructions for how to increase the gap.
- Do not drive the head of the fastener tightly against the nail slot. Leave approximately 1/32" (0.8mm) between the fastener head and the vinyl siding (about the thickness of a dime).
- Do not force the panels up or down when fastening. Panel locks should be fully engaged; however, the panels should not be under vertical tension or compression when they are fastened.
- Since vinyl siding moves as the temperature changes, make certain that the panels can move freely in a side-to-side direction once fastened.

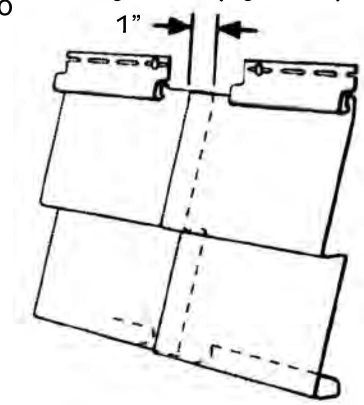



Figure 38.

- Check every fifth or sixth course for horizontal alignment (Fig. 37). Also check siding alignment with adjoining walls.
- When panels overlap, make sure they overlap by one-half the length of the notch at the end of the panel, or approximately 1" (25.4mm) (Fig. 38).
- When overlapping insulated siding, no gap is needed between the foam at the ends of the panels. Be sure to butt each piece of foam together (Fig. 39), unless installing in cold weather (then consult the manufacturer's instructions).
- Stagger the siding end laps so that no two courses (rows of panels) are aligned vertically, unless separated by at least three courses.

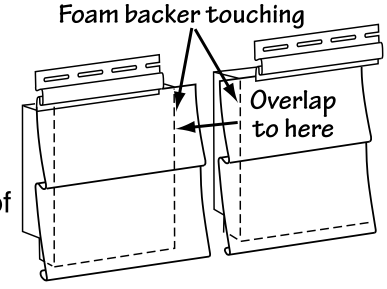



Figure 39.

- Always overlap joints away from entrances and/or away from the point of greatest traffic. This will improve the overall appearance of the installation (Fig. 37).
- Avoid using panels shorter than 24” (610mm).

## Fitting Siding Around Fixtures

Use a commercially available split or hinged trim ring (Fig. 40) to fit siding to a penetration such as a faucet or railing attachment, following the manufacturer’s installation instructions. If a commercial trim ring is not available for the application, refer to Fig. 41, which illustrates how to fit the siding to the penetration. In addition, the following tips are suggested:

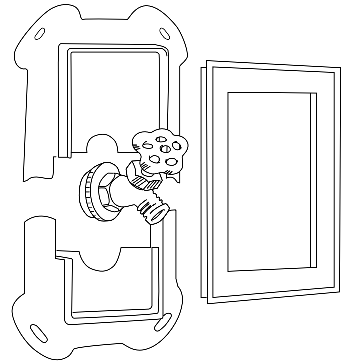


Figure 40.

- Install siding so that you have the factory end laps intersect at the fixture.
- Cut an opening 1/4” (6.4mm) bigger than the fixture or the trim ring.
- When cutting, match the shape and contour of the obstruction.
- For insulated siding, due to the thickness of the insulation, it may be necessary to build out the fixture or window and door trim to achieve the desired appearance.

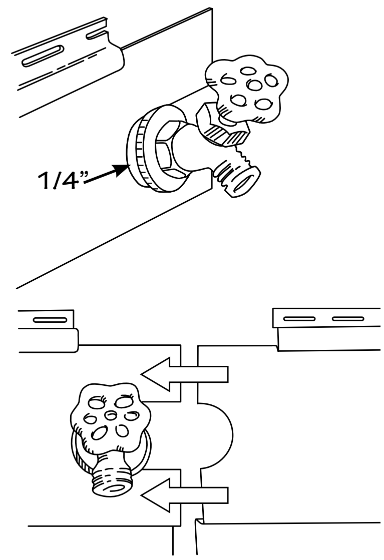



Figure 41.

## Fitting Under Windows

To mark the section to be cut, perform the following:

- Hold the panel under the window and mark the width of the window opening on the panel. Add approximately 1/4” (6.4mm) to both sides to allow for expansion and contraction of the siding. These marks represent the vertical cuts (Fig. 42).
- Lock a small piece of scrap siding into the lower panel next to the window. This will be used as a template for the horizontal cuts. Mark it 1/4” (6.4mm) below the sill height.
- Transfer the horizontal measurement to the panel, which will be installed under the window. Measurement may not be the same on both sides of the window.
- Cut the panel with tin snips and a utility knife.

The cut panel is now ready for installation under the window. Perform the following:

- Using a snap lock punch, punch the vinyl siding along the cut edge every 6” (152mm) so the raised lug is on the outside face.
- Install utility trim (or double utility trim) under the window, as a receiver for the cut siding. Utility trim is used any time the top lock has been removed from the siding. Furring may be needed to maintain the face of the panel at the desired angle.

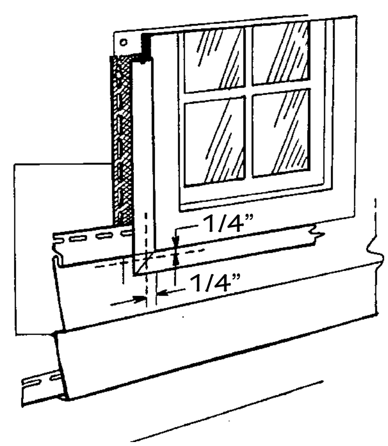



Figure 42.

- Install the siding panel, making sure the lugs (from the snap lock punch) lock into the utility trim (Fig. 43).

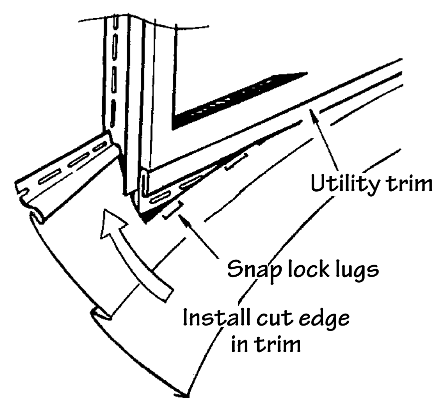



Figure 43.

## Sidewall Flashing at Roof Lines

- Run the siding until the last full course under the roof area.
- Cut a diverter from aluminum trim sheet, making sure it sits on the nail hem of the last full course (Fig. 44). Make sure the diverter is placed inside the receiving pocket of the vertical J-channel and is tucked behind the nail hem of the J-channel following the roofline for best drainage.
- If a water-resistive barrier is present, a cut should be made in that barrier to allow the diverter to slip behind the roof step flashing and the J-channels. That cut will need to be sealed with tape (approved by the housewrap manufacturer) once the diverter is installed.
- As an alternative to the diverter, create a “kickout” from metal flashing, as shown in Fig. 45.

**NOTE: “Kickout flashing” (Fig. 45) is an additional flashing strip that extends beyond the edge of the fascia that is required in some cold-climate localities.**

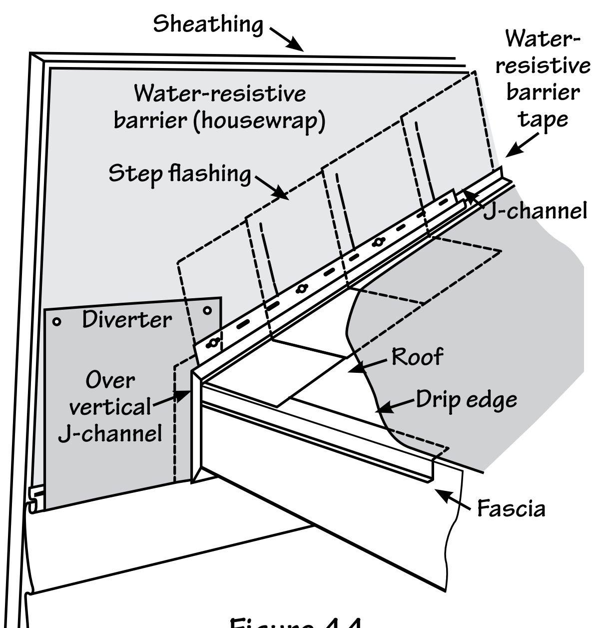



Figure 44.

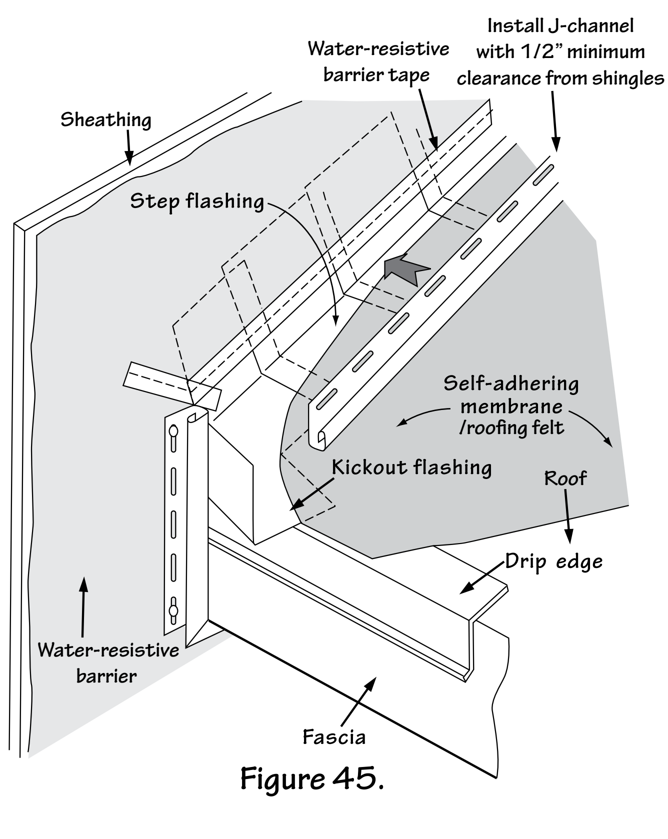



Figure 45.

# Finishing at the Top of Walls

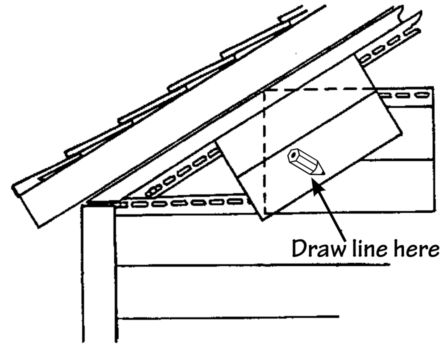



Figure 46.

Before the final course of siding is installed on the wall, any soffit accessories that will be used on the eaves must be installed. See the Soffit Installation section.

### Gable Ends

To install around gable ends, make a pattern that duplicates the slope of the gable (Fig. 46):

- Lock a short piece of siding into the gable starter course (i.e., the last course before the gable starts).
- Hold a second piece of siding against the J-channel at the slope of the gable. Mark the slope with a pencil on the short piece of siding.
- Remove the short piece and cut along the pencil line as a pattern for the gable angle cuts. Repeat the procedure on the opposite side of the gable. Check the angle template every few courses.
- It may be necessary to fasten the last panel at the gable peak with a trim nail. Use a 1 1/4" to 1 1/2" (32mm to 38mm) nail. This is one of the few times a nail should be placed in the face of the vinyl siding (Fig. 47).

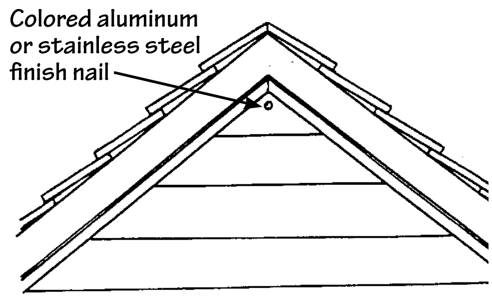



Figure 47.

### Eaves Treatment

The last course of siding may be cut to fit the eaves opening (Fig. 48).

- Measure from the soffit to the base of the upper lock on the previous course. Subtract 1/4" (6.4mm). Mark this dimension on the panel to be cut, measuring from the bottom edge of the panel. It is a good idea to check the dimension in several locations along the length of the wall.
- Using a snap lock punch, punch the vinyl siding along the cut edge every 6" (152mm), so the raised lug is on the outside face.
- Push the siding into the utility trim (or double utility trim) that has been nailed in place along the top of the wall. Furring may be needed to maintain the face of the panel at the desired angle. The raised lugs will catch and hold the siding firmly in place.

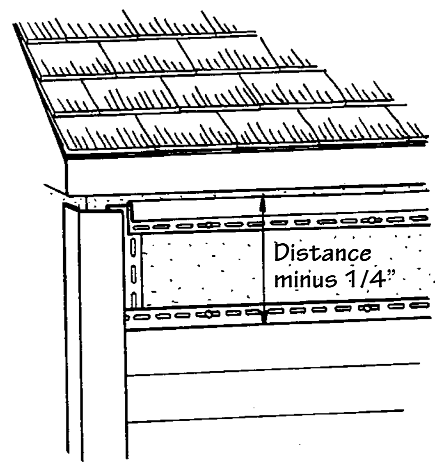



Figure 48.

## Optional Eave and Gable Treatment

Use a two-piece cover/receiver along the rake and eave (Fig. 49). Install the receiver flush with the top of the wall. Punch nail slots along the top edge of the panel every 16” (406mm). Use those nail slots to attach the panel to the wall. Snap the cover into place over the nails.

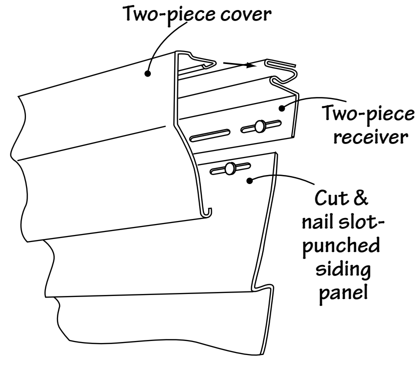



Figure 49.

## Transition from Horizontal to Vertical

- Finish the last course of horizontal siding with the J-channel and finish trim or double finish trim. Install head flashing and a J-channel.
- The top piece of J-channel must have minimum 3/16” (4.8mm) diameter weep holes drilled no more than 24” (610mm) apart to allow for water runoff, and the starter strip (J-channel) should not rest on head flashing because it will block weep holes. Leave a gap as shown (Fig. 50).

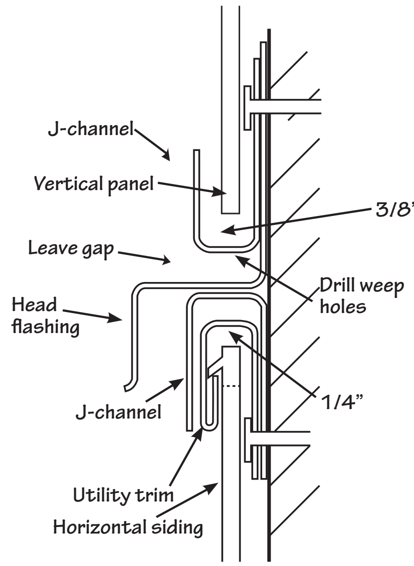



Figure 50.

## Transition from Brick to Vinyl Siding

- Caulk where the sheathing meets the brick sill. A head flashing (or drip cap) should be field formed and installed, then caulked where it meets the brick sill (Fig. 51).
- If horizontal siding is used, a J-channel or starter strip must be used. If starter strip is used, it is necessary to provide at least 3/8” (9.5mm) clearance for proper engagement of the siding.
- Use J-channel to receive vertical siding. Drill minimum 3/16” (4.8mm) diameter weep holes in the bottom of the J-channel no more than 24” (610mm) apart. Leave a gap between the J-channel and the flashing.

# VERTICAL SIDING AND ACCESSORIES INSTALLATION

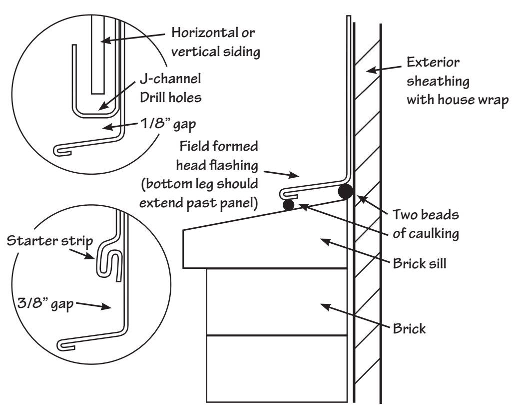



Figure 51.

## Preparation

See “Preparing the Walls” section on page 18. When installing vertical siding, however, follow these additional preparatory steps:

- Install horizontal furring strips, or a solid nailable sheathing prior to the siding, if needed, to level the surface or provide sufficient material for fastener penetration. If furring strips are used, install them 12” (305mm) on center or as specified in the siding manufacturer’s installation instructions. Be sure to use furring or sheathing material with the thickness specified in the manufacturer’s instructions. If the instructions specify the use of special nails (e.g., ring shank nails), be sure to use them and follow the instructions for nail spacing.

- Snap a level chalkline around the base of the sidewalls. Typically, the chalkline is positioned so that the bottom of the J-channel that will be installed like a starter strip is 1/4” (6.4mm) below the lowest point on the wall that will be sided. (See the Installing Accessories section for tips on snapping a chalkline.) Install J-channel along the chalkline as a receiver for the vertical siding.

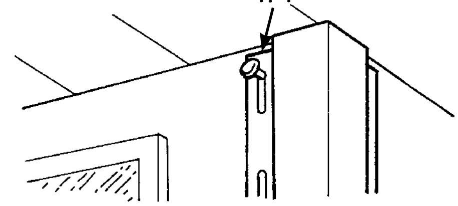


Figure 52.

## Accessories

As with horizontal siding, when installing vertical siding, it is necessary to install several accessories first, including corner posts and window, door, and roof trim.

**NOTE: Install vinyl soffit and fascia before installing outside and inside corner posts.**

### Outside and Inside Corner Posts

- Leave a 1/4” (6.4mm) gap at the top of corner posts.
- Place the first nails in the uppermost end of the top nail slots to hold them in position (Fig. 52). Place all other nails in the center of the slots. Nails should be 8” to 12” (203mm to 305mm) apart.
- Corner posts should extend 1/4” (6.4mm) below the siding. Do not nail tightly; the corner post should move.
- With insulated siding, use the manufacturer’s approved corner post to receive the additional thickness of the insulation. If one is not available, shim the post with foam or other shim material. Always consult the manufacturer’s instructions first.

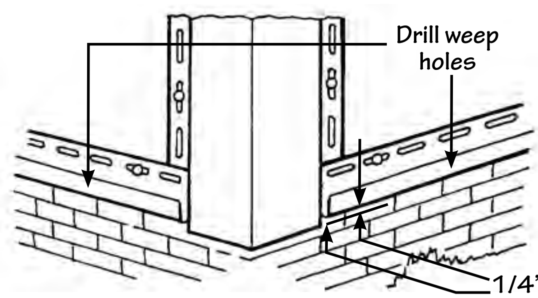


Figure 53.

### Bottom Receiver

- Position the top edge of a J-channel or vertical base along the previously snapped chalkline. Remember to drill minimum 3/16” (4.8mm) diameter weep holes no more than 24” (610mm) apart (Fig. 53).

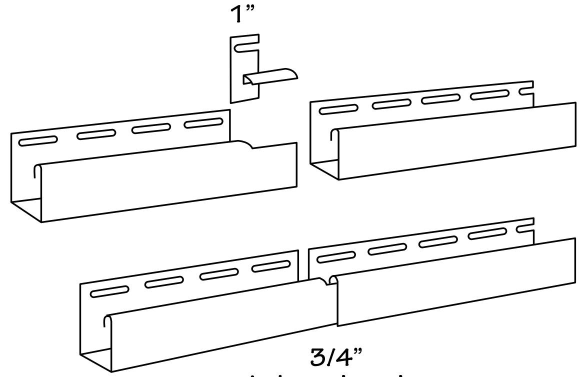


Figure 54.

- Fasten every 8” to 12” (203mm to 305mm). Use the center of the nail slots. All vinyl should be fastened securely but not tightly. Sideways movement should not be restricted. Leave 1/4” (6.4mm) gaps at the corner posts (Fig. 53). Where lengths adjoin, trim the nailing flange 1” (25.4mm) and overlap 3/4” (19mm) to produce a neat joint (Fig. 54).

### Window, Door, and Roof Trim

Install J-channel at the tops of the sidewalls (Fig. 55). At the gable ends, snap a level chalkline along the base of the gable and install J-channel. Overlap where necessary and allow for expansion (Fig. 54).

After installing flashing, trim around all windows and doors using J-channel. The following sequence is suggested:

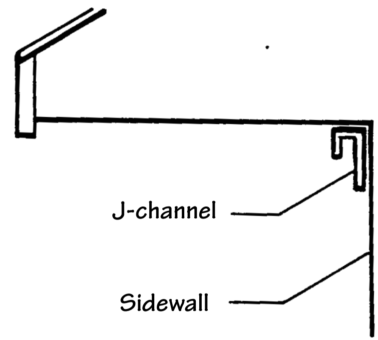


Figure 55.

- Cut a J-channel for the bottom of the window, the width of the frame plus the width of the side J-channels, and install it.
- Cut the side J-channels the length of the frame plus the width of the top and bottom J-channel. Cut notches in the top of the side J-channel. Cut and bend tabs (Fig. 56) into the bottom channel. Install the side channels.
- Cut the top J-channel the width of the frame plus the width of the side J-channels. Notch the top J-channel on each end, bend the tabs into the side J-channel, and fasten the top J-channel (Fig. 56).
- A miter cut and tab can be provided at the bottom of the window (Fig. 57), depending on the sill's condition.

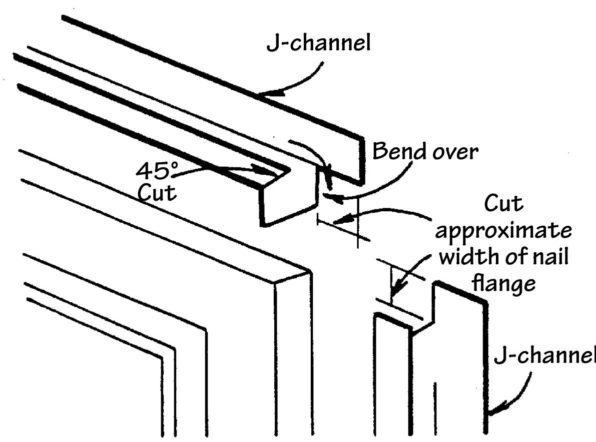


Figure 56.

## Sidewalls

- To create a balanced appearance (Fig. 58), divide the length of the wall by the exposure of the vertical panel to be used. For example, if the wall requires 20 full panels plus an additional 8" (203mm), then the first and last pieces installed would be cut to a new width of 4" (102mm). Make sure to allow for proper depth in the receiving channels of the accessories at both ends when measuring.
- To install the siding, if partial panels are required, mark the line to cut by measuring from the edge of the lock of the panel and cut the panel to the proper width. This will leave a panel with an intact nail hem and proper exposure.

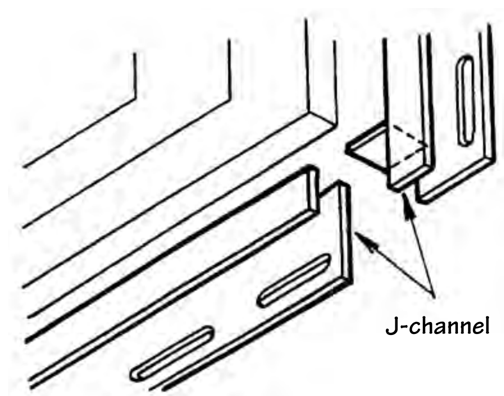


Figure 57.

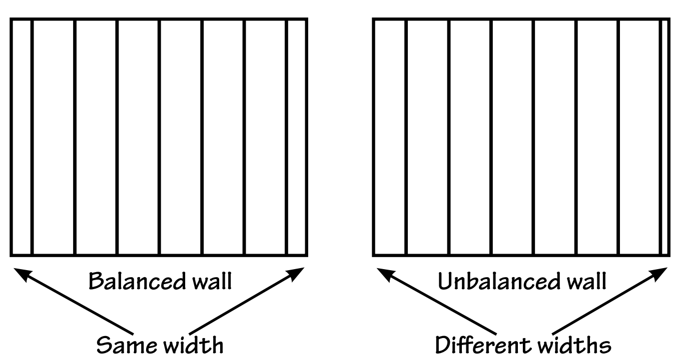


Figure 58.

To start or end panels that have been cut, and at all window jambs:

- If cut is on a flat area, use a snap lock punch, and install into utility trim.
- The utility trim will need to be shimmed to maintain the face of the panel (i.e., soffit panels).
- Shims should not be needed in most cases with board-and-batten panel.
- To complete this starting piece, snap the tabs into the utility trim, plumb the panel level, and begin securing by placing a fastener at the top of the topmost full nail slot, allowing for 1/4" (6.4mm) upward movement and 3/8" (9.5mm) downward. (Some manufacturers' vertical siding instructions are different; consult with the manufacturer for specific installation instructions). Continue securing with fasteners centered in the nail slots not more than 12" (305mm) apart.

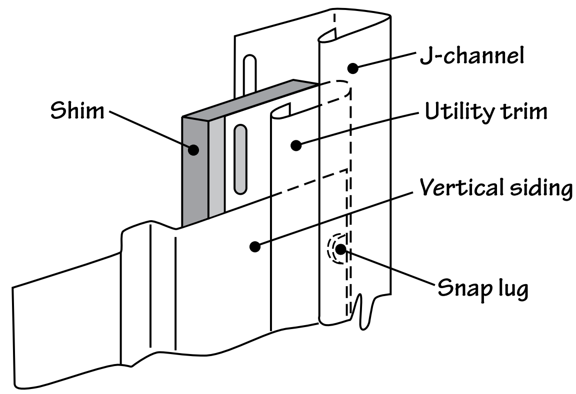


Figure 59.

- Install successive panels by securing from the topmost full nail slot downward, as described above, then 12" (305mm) on center for the rest of the panel. Around windows, doors, and fixtures, allow 1/4" (6.4mm) clearance in receiving channels (increase to 3/8" [9.5mm] if installing below 40° F [4.4° C]). When the panels are cut in the "V" groove or on the flat surface of the panel to accommodate an opening, install utility trim to properly secure panels, as described above (Fig. 59). Check the plumb of the installation every few panels to maintain the best appearance.
- If it will take more than one course to span the height of the house, terminate the first course into an inverted J-channel (Fig. 60), allowing 1/4" (6.4mm) for expansion. Install head flashing on top of the J-channel and install a second J-channel facing upward. Begin the second course leaving a 3/8" (9.5mm) gap from the bottom of the panel to the J-channel.

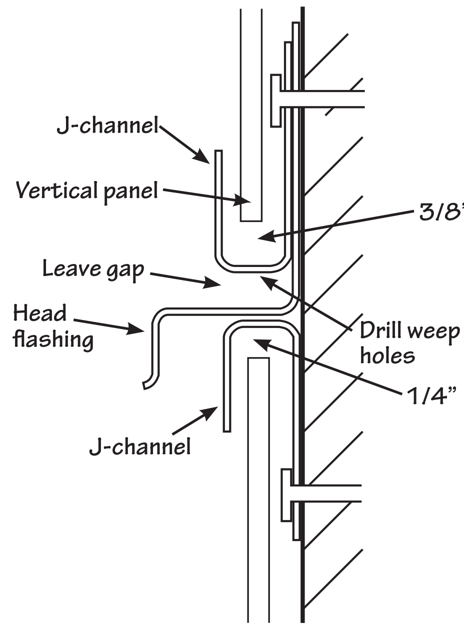


Figure 60.

**NOTE: It is necessary to drill weep holes in the upper J-channel that are a minimum 3/16" (4.8mm) in diameter no more than 24" (610mm) apart.**

- The final siding panel should be the same width as the starting course. Depending on where the cut occurs, it may be necessary to install utility trim inside the receiving pocket of the J-channel or corner post that receives the vertical siding (Fig. 59). It may also be necessary to shim the utility trim outward to a level equal that of the siding panel face, in order to keep a level appearance.

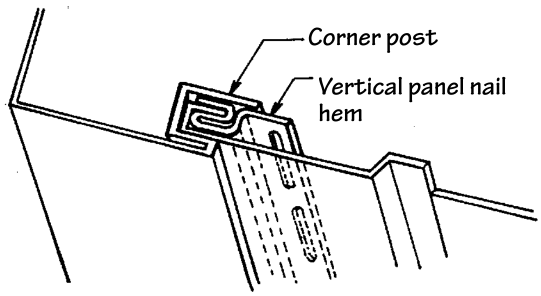


Figure 61.

- Cut the panel to the proper width and create tabs every 6" (152mm) using a snap lock punch. Finish the installation by inserting the tabs of the properly sized panel into the utility trim. It may be necessary to place a color-matched trim nail near the top of the panel and inside the J-channel or corner post to keep the partial panel from dropping.
- If you are starting with a full vertical siding panel, you can create a starter strip for vertical siding by cutting the nail hem and adjacent lock off a vertical siding panel. Fasten it inside the receiver channel of the corner post. Be sure this piece is plumb. Leave enough clearance in the pocket of the corner post to allow the siding panel to be attached (Fig. 61).

## Gable Ends

For application of vertical siding to gables, use the same method described on page 30 (Fig. 58) for a balanced appearance.

- Begin by fastening J-channel along the inside edge of the roof. Install an upward-facing J-channel as a vertical base on top of the previously installed J-channel at the base of the gable, as shown in Fig. 60. As an alternative, install back-to-back J-channels, centered with the peak of the gable. Install a cut nailing hem as a starter-strip in each J-channel, as described above (Fig. 61).
- Make a pattern for end cuts along the gable using two pieces of scrap siding (Fig. 62). Lock one piece into the vertical strip at the center of the wall. Hold the edge of the other piece against and in line with the roof line. Mark the slope on the vertical piece and cut along that line. Use it as a pattern to mark and cut the ends of all other panels required for this side of the gable end. Make another pattern for the other side of the gable.

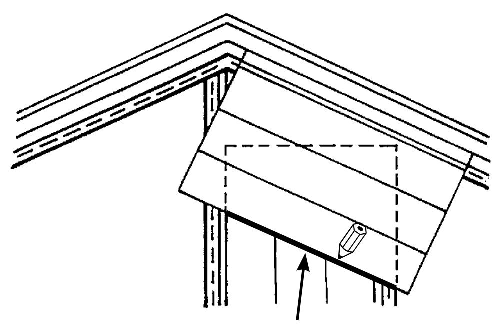


Figure 62.

# SOFFIT INSTALLATION

Soffit is used to enclose the underside of an eave. The installation of soffit will determine the positioning of the inside and outside corner posts. It also is necessary to complete the soffit before the final course of siding is installed on the wall.

Vinyl soffit is designed to be easily installed lengthwise from wall to fascia. Soffit panels are similar to vertical siding. Manufacturers produce both solid and vented panels, as well as combinations of the two.

**NOTE: Ventilation Requirements: Proper attic ventilation is important for any home. Consult local building codes for the appropriate requirements for a specific geographic area, and use vented soffit or other vented products as required.**

## Preparation

Inspect and plan the job in advance. For re-siding applications, nail down any loose panels, boards, or shingles. Check surfaces for straightness and fur when necessary. Surfaces should be uniform and straight from various viewing angles.

The procedure used to install soffit depends on the construction of the eave. There are two different types of eaves:

- Open eaves—eaves with exposed rafters or trusses—are typical of new construction. Open eave installation procedures are also used when removing damaged soffit during a re-siding project.
- Enclosed eaves—eaves with soffit in place—are typical of re-siding projects.

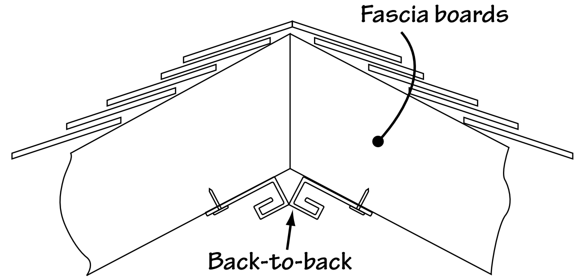



Figure 63.

When transitioning soffit at the peak of a gable (Fig. 63), secure two J-channels back to back to receive an individual piece of soffit on each accessory. Alternatively, bend a section of soffit, using a field brake, to match the angle of the peak of the gable.

## Installation Over Open Eaves

Follow this five-step procedure:

**1.** Install receiving channels (soffit receiver or J-channel).

- There are several ways to install receiving channels for soffit. You can use accessories such as J-channel or F-channel. The best approach is to select a method that works most effectively with the construction techniques used to create the eave.
- Examine the illustrations on the right side of page 34 and find one that most closely resembles the construction methods used on this particular project (Fig. 64-67).
- Install the receiving channels following the details shown in the illustrations on page 34. Nail channels every 8" to 12" (203mm to 305mm), positioning the nail in the center of the slot. Do not nail tightly.

**NOTE: Nailing strips must be installed as shown in Fig. 67 if the eave span is greater than 16" (406mm), unless otherwise specified in the soffit manufacturer's instructions. In areas with high wind restrictions, nailing should not exceed 12" (305mm) on center, unless otherwise specified by the manufacturer.**

- If no soffit receiver is available for a situation best suited for the product, the J-channel can be modified to create an F-receiver (Fig. 68).
- Simply cut slots in the nail flange area where it would be nailed to the wall (Fig. 68). After cutting the nail flange, bend the flange back and nail it to the wall.
- If the soffit will turn a corner, cut and install the channel so there is 1/4" (6.4mm) for expansion at each of the adjoining walls.

**2.** Measure from the wall to the fascia board. Then subtract 1/2" (12.7mm) to allow for expansion. Mark and cut this dimension on a soffit panel.

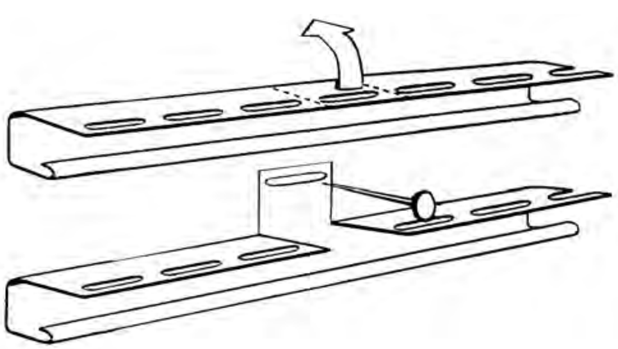


Figure 68.

**NOTE: These illustrations are based on common installation practices used in most areas of North America. Local environmental conditions (particularly high wind zones) and building codes may call for different installation techniques. Always consult the manufacturer's installation instructions and local building codes to determine the correct installation methods to use on any job.**

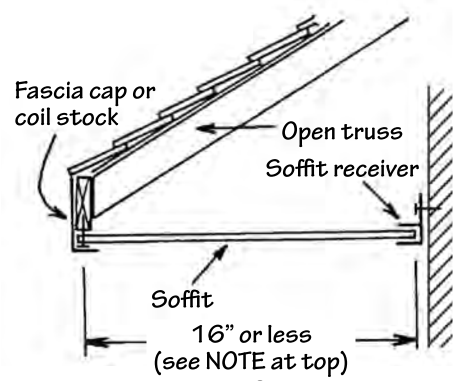



Figure 64.

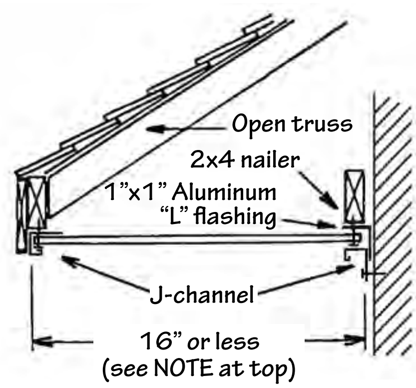



Figure 65.

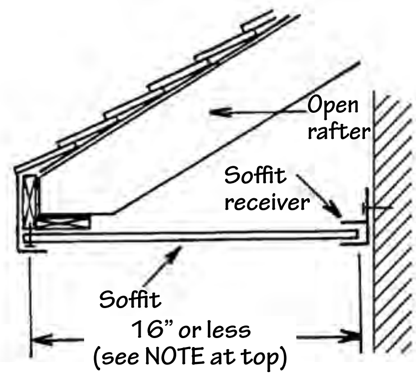



Figure 66.

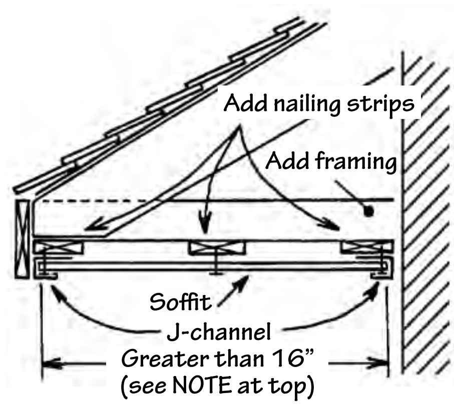



Figure 67.

**3.** In situations with two channels, (Fig. 67), flex the panel between the two channels installed. It is critical in this application that the installed nailing strips are wide enough (4" [102mm]) to allow a fastener to attach to the soffit. Make sure the panel is perpendicular to the wall when fastening.

In situations where the soffit panel will be attached at the wood fascia board and then covered with an aluminum fascia cover (Fig. 66), each soffit panel should be fastened through the nail hem and either into the wood fascia or into a wood shim using nails, screws, or staples.

**4.** To turn a corner, measure from the channel at the wall corner to the channel at the corner of the fascia board (Fig. 70). Subtract 1/4" (6.4mm) for expansion. Cut and install soffit double channel lineal or back-to-back J-channel. If necessary, install nailing strips to provide backing for the lineal. Miter cut the corner soffit panels and install as described in Step 3.

**5.** Once the soffit has been installed, apply the field- or factory-formed covers.

- The fascia covers can be installed into utility trim (either factory-formed or field-fabricated) (Fig. 69) or behind the existing drip edge. The fascia has to be fastened with aluminum or stainless steel painted trim nails into the bottom leg, no more than 24" (610mm) on center.
- When overlapping aluminum/vinyl fascia covers, make sure to overlap 3/4" (19mm).
- Drive these nails through the fascia and only into the "V" groove of the soffit.
- You may also need to face-nail the fascia. Always pre-drill holes into fascia and do not nail tight.

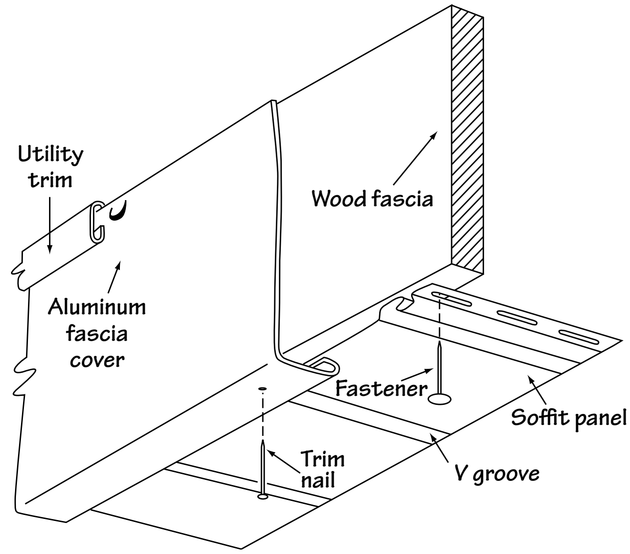



**Figure 69.**

**NOTE: According to the 2012 and later International Residential Codes, "Soffit panels shall be individually fastened to a supporting component such as a nailing strip, fascia, or subfascia component or as specified by the manufacturer's instructions."**

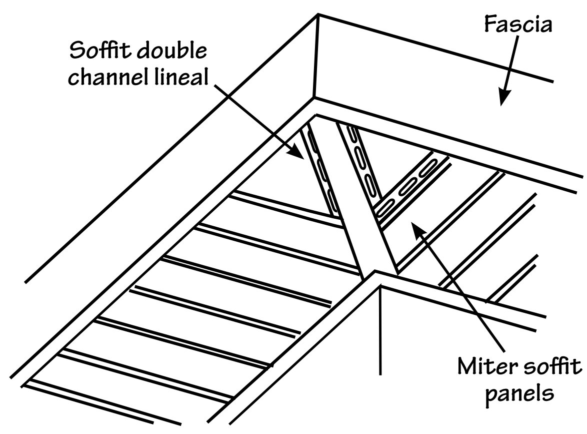



**Figure 70.**

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## Installation Over Enclosed Eaves

The procedure used to install soffit over an enclosed eave in a remodeling project is almost identical to that used for an open eave in new construction. The major difference is the installation of the J-channel (Fig. 71 and 72).

- Determine the preferred method of installing soffit at the fascia board.
- When installing J-channel at either wall of fascia board, nail every 8" to 12" (203mm to 305mm).
- If the soffit is to turn a corner, cut and install J-channel to allow 1/4" (6.4mm) for expansion at each of the adjoining walls and fascia boards.
- When installing vented soffit panels, if the existing soffit doesn't have openings for ventilation, cut an adequate number of openings.
- To complete the installation, follow Installation Over Open Eaves, Steps 3 through 5 on page 35.

**NOTE: If the existing soffit is rotted or damaged, remove it completely before installing vinyl soffit, then use the instructions for open eaves.**

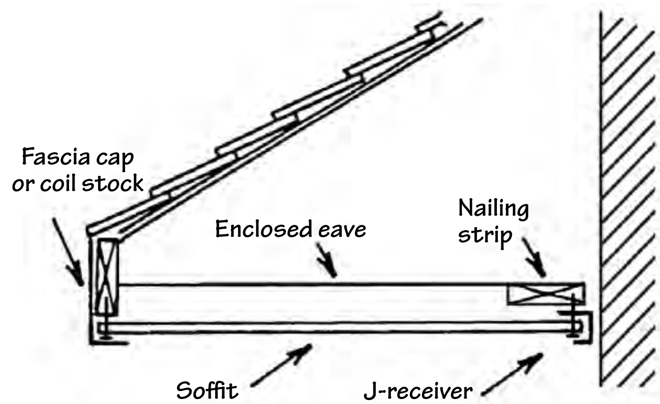


Figure 71.

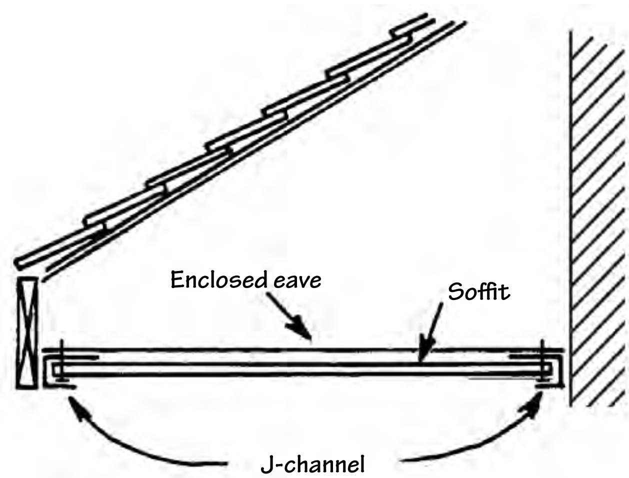


Figure 72.

## Porch Ceilings

The procedures used to install a porch ceiling are in many ways similar to those used to install soffit. These procedures vary slightly, depending on whether the installation is a new construction or a re-siding project.

### New Construction Projects

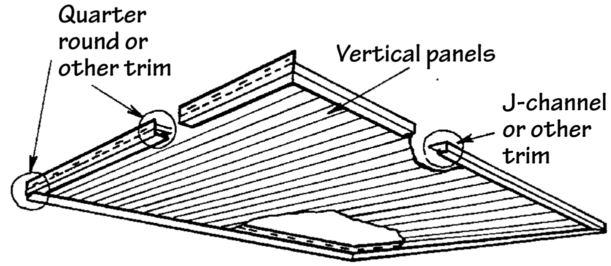


Figure 73.

1. Begin by installing receiving channels on all four sides of the porch (Fig. 73). If F-channels are being used, nail them to the existing walls. If J-channels are being used, a nailing base will have to be installed.
2. When using light blocks to attach external light fixtures, install them to adequate backing.
3. Plan the layout of the ceiling panels to achieve an even balance or to align with adjacent work. If the ceiling panels will run parallel to the ceiling joists, additional 1" x 3" (25.4mm x 76.2mm) wood furring nailing strips will have to be installed. Install these nailing strips perpendicular to the ceiling joists, placing a strip every 8" to 12" (203mm to 305mm).
4. Invert the J-channels and nail them to the underside of the wood strips along the perimeter of the ceiling area.
5. Install the first panel into the channels at one end of the porch. Be sure to leave room for expansion. Nail every 8" to 12" (203mm to 305mm), positioning nails in the centers of slots. Do not nail tightly. Install the remaining panels. When cutting the last panel of the first course, be sure to allow room for expansion.
6. For areas where more than one panel length is needed, use a double channel lineal or back-to-back J-channel.
7. If it is necessary to cut the nailing hem off the final panel, use a snap lock punch to create tabs every 6" (152mm) along the cut edge. Attach utility trim and insert the panel into the receiving channel.

### Re-siding Projects

1. Check to be sure the existing ceiling can serve as a solid nailing base.
2. If the existing ceiling is solid, remove all existing moldings and fixtures from the ceiling and begin by nailing inverted J-channels along the perimeter of the ceiling area. Then follow Steps 2 through 6 in the instructions under "New Construction Projects." With a solid ceiling, however, additional nailing strips are not necessary. Use the existing ceiling as the nailing base for the panels.
3. If the existing ceiling is not solid, install nailing strips to provide a secure nailing base, then install the J-channels. Additional nailing strips should be installed if the ceiling panels are to run parallel to the ceiling joists. Follow the instructions in Steps 2 through 6 for new construction.

# OTHER RECOMMENDATIONS

## Attaching Shutters and Other Specialty Products

To install shutters around windows:

- Pre-drill holes through the shutters for attachment screws and mark the location of these holes on the siding (Fig. 74).

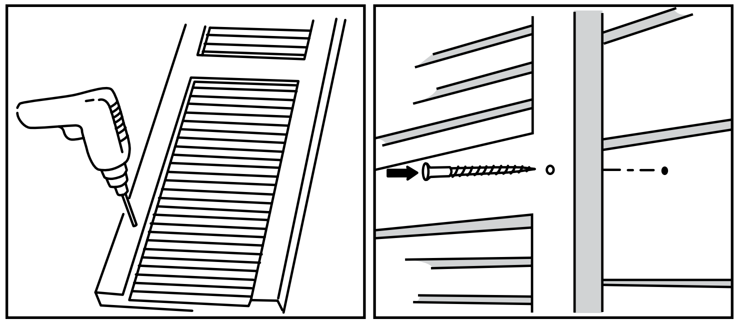

Figure 74.

- Using the hole marks as a guide, drill expansion holes through the siding where attachment screws will be located, a minimum 1/4" (6.4mm) larger than the diameter of the screw (Fig. 75).

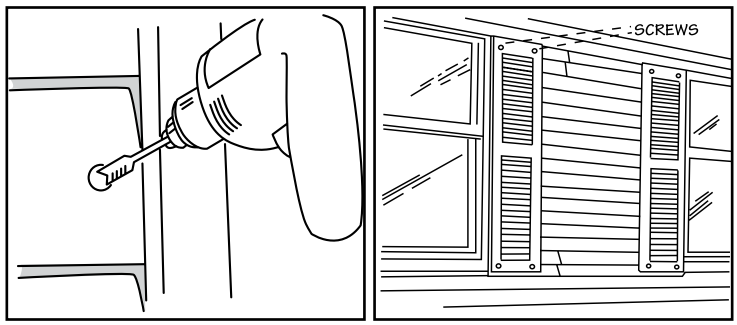


Figure 75.

- When attaching the shutters, do not fasten such that the shutter is tight against the siding, otherwise expansion of the siding will be restricted.
- When it is necessary to attach any specialty item, for example down spouts, drill a hole that is 1/4" (6.4mm) larger than the fastener shank diameter to allow the vinyl panel to move with temperature changes.

## Replacing a Damaged Panel

To remove a panel for any reason:

- Slip the zip lock or unlocking tool behind the bottom of the panel above the one to be replaced and unzip it from the lock on the damaged panel (Fig. 76).
- Gently bend out the upper panel. Take the nails out of the damaged panel and remove it (Fig. 77).
- Lock on the new panel and nail it up (Fig. 78).
- Use the unlocking tool again to zip the upper panel over the lock on the new panel (Fig. 79).

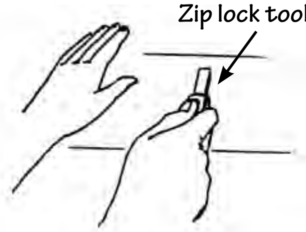


Figure 76.

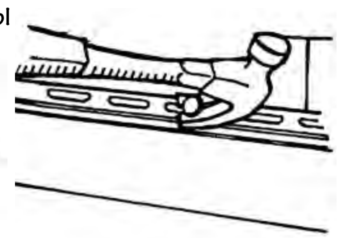

Figure 77.

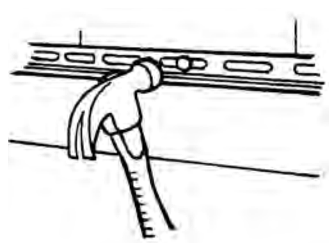

Figure 78.

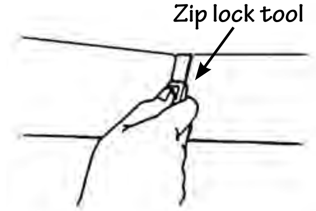


Figure 79.

## Repairing a Damaged Corner Post

Repair a damaged corner post with a series of cuts:

- Cut away the face of the damaged corner, leaving the nail hem and pocket intact.
- Remove the nailing hem from the replacement corner (Fig. 80).
- Place the new corner over the remaining portions of the old one and fasten it into position with one rivet on either side located at the top of the post.

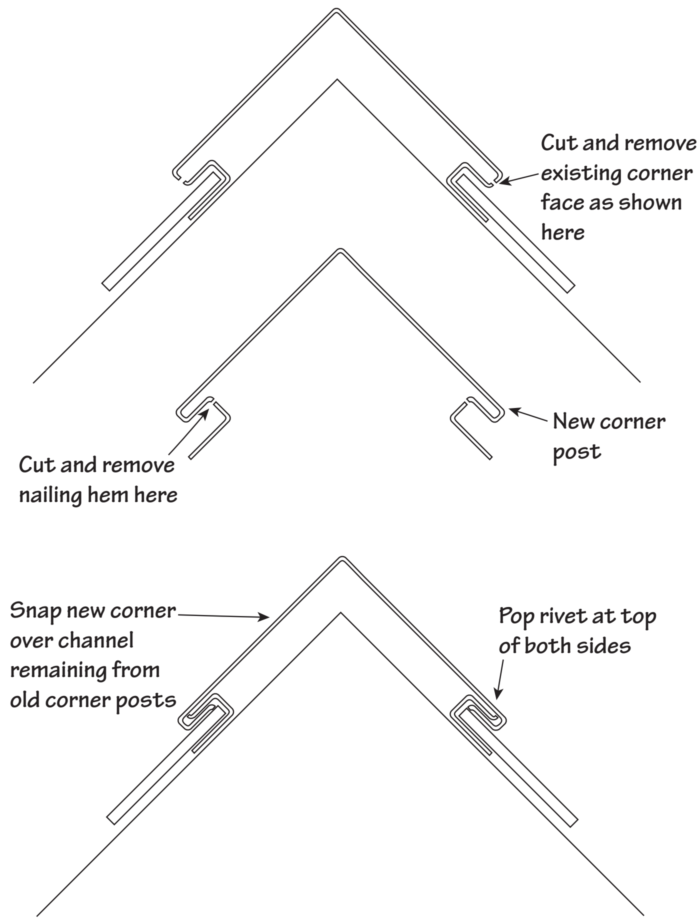


**Figure 80.**

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For more information,
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Designation: D 3679 – 06a

An American National Standard

# Standard Specification for Rigid Poly(Vinyl Chloride) (PVC) Siding[1]

This standard is issued under the fixed designation D 3679; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

## 1. Scope*

1.1 This specification establishes requirements and test methods for the materials, dimensions, warp, shrinkage, impact strength, expansion, appearance, and windload resistance of extruded single-wall siding manufactured from rigid (unplasticized) PVC compound. Methods of indicating compliance with this specification are also provided.

1.2 The use PVC recycled plastic in this product shall be in accordance with the requirements in Section 4.

1.3 Rigid (unplasticized) PVC soffit is covered in Specification D 4477.

1.4 Siding produced to this specification shall be installed in accordance with Practice D 4756. Reference shall also be made to the manufacturer's installation instructions for the specific product to be installed.

NOTE 1—Information with regard to siding maintenance shall be obtained from the manufacturer.

1.5 The values stated in inch-pound units are to be regarded as the standard. The SI units given in parentheses are for information purposes only.

1.6 The following precautionary caveat pertains to the test method portion only, Section 6, of this specification: *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

NOTE 2—There is no known ISO equivalent to this standard.

## 2. Referenced Documents

2.1 *ASTM Standards:* [2]

D 374 Test Methods for Thickness of Solid Electrical Insulation
D 618 Practice for Conditioning Plastics for Testing
D 635 Test Method for Rate of Burning and/or Extent and Time of Burning of Plastics in a Horizontal Position
D 696 Test Method for Coefficient of Linear Thermal Expansion of Plastics Between -30°C and 30°C with a Vitreous Silica Dilatometer
D 883 Terminology Relating to Plastics
D 1042 Test Method for Linear Dimensional Changes of Plastics Under Accelerated Service Conditions
D 1435 Practice for Outdoor Weathering of Plastics
D 1600 Terminology for Abbreviated Terms Relating to Plastics
D 2244 Practice for Calculation of Color Tolerances and Color Differences from Instrumentally Measured Color Coordinates
D 2457 Test Method for Specular Gloss of Plastic Films and Solid Plastics
D 3892 Practice for Packaging/Packing of Plastics
D 4226 Test Methods for Impact Resistance of Rigid Poly(Vinyl Chloride) (PVC) Building Products
D 4477 Specification for Rigid (Unplasticized) Poly(Vinyl Chloride) (PVC) Soffit
D 4756 Practice for Installation of Rigid Poly(Vinyl Chloride) (PVC) Siding and Soffit
D 5033 Guide for Development of ASTM Standards Relating to Recycling and Use of Recycled Plastics[3]

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[1] This specification is under the jurisdiction of ASTM Committee D20 on Plastics and is the direct responsibility of Subcommittee D20.24 on Plastic Building Products.

Current edition approved Sept. 1, 2006. Published October 2006. Originally approved in 1979. Last previous edition approved in 2006 as D 3679 – 06.

[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

[3] Withdrawn.

***A Summary of Changes section appears at the end of this standard.**

D 5206 Test Method for Windload Resistance of Rigid Plastic Siding
E 631 Terminology of Building Constructions
E 1753 Practice for Use of Qualitative Chemical Spot Test Kits for Detection of Lead in Dry Paint Films
G 147 Practice for Conditioning and Handling of Nonmetallic Materials for Natural and Artificial Weathering Tests
2.2 *ASCE Standard:*
ASCE 7-02 Minimum Design Loads for Buildings and Other Structures[4]

## 3. Terminology

3.1 Definitions are in accordance with Terminologies D 883, E 631, and D 1600, unless otherwise specified.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *center-pinning*—an installation technique in which the siding panel is fastened tightly through the nail slot at the center length of the panel, in order to cause thermal expansion and contraction to occur equally in both directions from the center.

3.2.2 *nominal*—the value that a manufacturer consistently uses to represent a specific property or dimension of a vinyl siding product in public claims including, but not limited to, product literature, advertisements, quotations, and certificates of conformance.

3.2.3 *process average thickness*—the rolling, arithmetic mean of average specimen thicknesses measured according to 6.5 for a specific product during all productions runs for the most recent six month period.

3.2.4 *temperate northern climate— in weather testing*, a North American metropolitan area testing site located within 73 to 100°W longitude and 37 to 45°N latitude.

3.2.5 *vinyl siding*—a shaped material, made principally from rigid poly(vinyl chloride) (PVC), that is used to clad exterior walls of buildings.

3.2.5.1 *Discussion*—Any exception to a homogeneous rigid PVC compound is present in a coextruded or laminated capstock.

## 4. Materials and Manufacture

4.1 The siding shall be made of one or more layers of poly(vinyl chloride) (PVC) compound. Any layers of materials other than poly (vinyl chloride) (PVC) compound shall be kept to less than 20% by volume.

4.2 Where rigid PVC recycled plastic as defined in Guide D 5033 is used, the siding containing the PVC recycled plastic shall meet all of the requirements of Section 3, Terminology; Section 4, Materials and Manufacture; and Section 5, Physical Requirements.

4.3 The poly(vinyl chloride) siding material, when tested in accordance with Test Method D 635, shall not exceed an average extent of burn of 4 in. (100 mm), with an average time of burn not to exceed 10 s. A minimum sample thickness of 0.035 in. (0.9 mm) is required. **Warning—** The flammability testing data, conclusions, and recommendations of Test Method D 635 related solely to the measurement and description of properties for classification of the poly(vinyl chloride) siding material in response to flame under controlled laboratory conditions and shall not be used for the description or appraisal of the fire hazard of vinyl siding under actual fire conditions.

4.4 The PVC compound when extruded into siding shall maintain uniform color and be free of any visual surface or structural changes, such as peeling, chipping, cracking, flaking, or pitting.

4.5 The PVC compound shall be compounded so as to provide the heat stability and weather exposure stability required for the siding market application.

4.6 PVC siding shall not contain elemental lead (Pb) or compounds of that material other than traces incidental to raw materials or the manufacturing process. This limitation applies to both PVC substrate and to any cap or film material. Compliance with this requirement shall be demonstrated by one of the methods in 6.16

## 5. Physical Requirements

5.1 *Length and Width*—The nominal length and width of the siding shall be as agreed upon between the purchaser and the seller. The actual length shall not be less than ¼ in. (6.4 mm) of the nominal length and the actual width shall be within ±1/16 in. (1.6 mm) of the nominal width when measured in accordance with 6.3 and 6.4.

5.2 *Thickness*—These requirements pertain only to measurements of the portions of the siding that are exposed after installation of the panel, measured in accordance with the procedure in 6.5. The average thickness of each specimen shall be no less than 0.035 in. No individual measurement shall be thinner than 0.003 in. below the nominal thickness. The process average thickness as defined in 3.2.3 shall be no thinner than 0.001 in. below the nominal thickness.

5.3 *Camber*—A full length of siding (typically 10 or 12 ft (3.05 or 3.61 m)) shall not have a camber greater than ⅛ in. (3.2 mm) when measured in accordance with 6.6.

5.4 *Heat Shrinkage*—The average heat shrinkage shall not exceed 3.0 % when determined by the method described in 6.7.

5.5 *Impact Resistance*—Siding shall have a minimum impact strength of 60 in.·lbf (6.78 J) when tested in accordance with 6.8.

5.6 *Coefficient of Linear Expansion*— The siding shall have a coefficient of linear expansion not greater than 4.5 by $10^{-5}$ in./in./°F (8.1 by $10^{-5}$ mm/mm/°C) when tested in accordance with 6.9.

5.7 *Gloss*—The gloss of smooth and embossed siding shall be uniform across the exposed surface. Variations in the glossmeter readings for smooth siding shall not be more than ±10 % or ±5.0 points (whichever is greater). Variations for embossed siding shall not be more than ±20 % or ±10.0 points (whichever is greater). Gloss of smooth and embossed siding shall be tested in accordance with 6.11.

5.8 *Surface Distortion*—The siding shall be free of bulges, waves, and ripples when tested to a minimum temperature of 120°F (49°C) in accordance with the procedure in 6.12. This distortion is called "oil-canning."

5.9 *Color*—The color of the siding shall be within the defined color space parameters for the specific color agreed

[4] Available from the American Society of Civil Engineers, 1801 Alexander Bell Dr., Reston, VA 20191-4400.

upon between the purchaser and the manufacturer. The color specified shall be uniform on the surface of the siding panels, except in the case of multicolored woodgrain panels.

5.9.1 *Uniformity of Color*—When tested in accordance with 6.13, the total color change, $\Delta E$, between a production specimen and the appropriate reference specimen or agreed-upon color coordinates shall not vary by more than 1.5, and the chromatic coordinates thereof shall not change by more than $\pm\Delta a_H = 1.0$ and $\pm\Delta b_H = 1.0$.

5.10 *Weathering*:

5.10.1 The siding shall maintain a uniform color and be free of any visual surface or structural changes such as peeling, chipping, cracking, flaking, and pitting when tested in accordance with 6.10.

NOTE 3—Weathering-conformance-testing requirements are to reflect performance of a "typical" extrusion siding profile representing a specific color of PVC compound and a specific extrusion technology. In no case is there an implied requirement for testing all the various shaped and sized siding profiles produced in this color. The lengthy outdoor weatherability testing for new products may be performed concurrently with market development and sales of siding to existing markets. Completion of weatherability testing prior to marketing of the product is not required.

5.11 *Windload Resistance*—The siding panel(s) shall be able to withstand a minimum static test pressure of 15.73 lbf/ft$^2$ (753 Pa) when tested in accordance with 6.14.

5.11.1 The static test pressure of 15.73 lbf/ft$^2$ (753 Pa) was established to withstand structural loading conditions that occur in 110 mph (177 km/h) wind-zone areas for elevations of 30 ft (9.1 m) and less in exposure category B, and is equivalent to 29.12 lbf/ft$^2$ (1394 Pa) negative design pressure.

5.11.1.1 The design-pressure values can be negative (suction loads) or positive. The negative values are the largest in magnitude and are the values used in this specification.

NOTE 4—In that the siding is being tested as a weather-resistant exterior product applied to an existing exterior structural wall, forces (negative) working to pull the siding off the wall, fasteners, or disengage locks will be the most important criteria for testing. Positive wind forces test the integrity of the total wall sections, and do not provide a measure of the performance of the siding.

5.11.2 Refer to Annex A1 for an explanation as to how the 29.12 lbf/ft$^2$ (1394 Pa) negative design pressure was established, and for applications where the effective negative design pressure as specified in ASCE 7-02 is greater than 29.12 lbf/ft$^2$ (1394 Pa) (for example, wind-zone areas greater than 110 mph (177 km/h) or elevations above 30 ft (9.1 m), or exposures other than exposure category B).

5.12 *Nail Slot Allowance for Thermal Expansion*—For siding panels utilizing nail slots to allow for thermal expansion and contraction, the nail slot shall be sized to allow for the expected range of expansion and contraction over a range of 100°F. Compliance with this requirement shall be demonstrated either by the test method in 6.15 or by sizing of the nail slots according to the specifications in the following sections. The instrument used shall be capable of measuring to the nearest 0.01 in. The manufacturing tolerance shall not exceed -0.030 in.

5.12.1 For panels shorter than 6 ft (1829 mm) in length, the minimum nail slot width shall be ⅜ in. (11.4 mm).

5.12.2 For panels 6 ft (1829 mm) in length or longer the minimum nail slot width shall be determined according to the following formula. The minimum width shall be the width resulting from application of the formula, rounded to the next lower quarter-inch. Regardless of the results of the calculation, the minimum nail slot width for panels 6 feet or longer shall be 1 in (25.4 mm).

$$WS = P_c \times (\alpha \times 100\ °F \times L) + T_c \tag{1}$$

Where:

$WS$ = Minimum width of nail slot, in.
$P_c$ = Center-pinning coefficient: 1 if manufacturer's instructions require panel to be center-pinned; 1.5 if center-pinning is not required
$\alpha$ = Coefficient of linear thermal expansion, $4.5 \times 10^{-5}$ in./in./°F or actual known coefficient for material used, as determined by 6.9
$L$ = Length of panel, inches
$T_c$ = Centering tolerance: 0.25 in.

## 6. Test Methods

6.1 *General*—The inspection and test procedures contained in this section are used to determine the conformance of products to the requirements of this specification. Each producer who represents its products as conforming to this specification shall be permitted to use statistically based sampling plans that are appropriate for each manufacturing process, but shall keep the essential records necessary to document, with a high degree of assurance, his claim that all of the requirements of this specification have been met. Additional sampling and testing of the product, as agreed upon between the purchaser and the manufacturer, are not precluded by this section.

6.2 *Conditioning and Test Conditions*— Condition the test specimen in accordance with Procedure A of Practice D 618 and test under those conditions, unless otherwise specified herein.

6.3 *Length*—Lay the specimen on a flat surface and measure with a steel tape. Measure the length of a siding panel to the nearest 1⁄16 in. (1.6 mm) at the center, the butt edge, and the bottom of the top lock. The average of the three measurements is the actual length.

6.4 *Width*—Interlock two 2-ft (610-mm) long specimens in the normal mode for installation. Lay the two specimens on a flat surface. Measure to the nearest 1⁄16 in. (1.6 mm), the distance between the lowest butt edge of the top specimen and the lowest butt edge of the bottom specimen. Make a measurement at one end of the specimens and at 6-in. (152.4-mm) intervals along the entire length, making sure that the measurement is made perpendicular to the butt edge. Average the measurements. The average constitutes the exposed width of siding.

6.5 *Thickness*—Thickness shall be measured using an outside micrometer calibrated in inches that gives readings to the nearest 0.0005 in. or smaller. The micrometer shall be equipped with a ratchet or friction thimble to control the force applied during measurement, and shall be tightened on the specimen using the ratchet knob or the friction thimble. The micrometer shall conform to the calibration requirements in Section 7 of Test Method D 374.

The thickness of the siding shall be measured at a minimum of 5 locations equally spaced across the entire portion of the siding that will be exposed after installation. All measurements shall be taken to the nearest 0.001 in. Calculate and report the average of these measurements. Also report the thinnest individual measurement.

6.6 *Camber*—Place a full length of siding (typically 10 or 12 ft (3.05 or 3.61 m)) on a flat surface alongside a straightedge at least as long as the siding specimen. Measure the maximum space between edge of the siding specimen and the straightedge for each edge to the nearest 1⁄16 in. (1.6 mm).

6.7 *Heat Shrinkage*:

6.7.1 *Apparatus*:

6.7.1.1 *Scriber*, similar to that described in Test Method D 1042, with the exception that the needle points shall be separated by 10 ± 0.01 in. (254 ± 0.254 mm).

6.7.1.2 *Test Media*, a controlled-temperature water bath of 5 gal (10 L) or more, equipped with an efficient stirrer that will maintain uniform temperature throughout. Heater and temperature-control devices must maintain the water at 160 ± 1°F (71 ± 0.5°C). Use a wire rack to raise and lower specimens into the water bath. As an alternative to the use of a water bath, the specimens may be heated for 30 min in a uniformly heated forced-air oven maintained at a temperature of 160 ± 1°F (71 ± 0.5°C).

6.7.1.3 Make measurements with any device capable of measuring the distance between two scribe marks to the nearest 0.01 in. (0.254 mm).

6.7.2 *Procedure*:

6.7.2.1 Cut three specimens from the siding panel, each 1 in. (25.4 mm) wide by 12 in. (305 mm) long. Cut one specimen from the center and one from each of the extreme edges of the flat surface. The long axis shall be parallel to the machine direction.

6.7.2.2 Condition specimens at 73.4 ± 3.6°F (23 ± 2°C) and 50 ± 5 % relative humidity for at least 24 h.

6.7.2.3 Make a slight mark with the scribe on each specimen so that a reference point will be clearly visible.

6.7.2.4 Place specimens in the test medium.

6.7.2.5 Remove specimens after 30 min and place on a flat surface until cool.

6.7.2.6 Repeat conditioning in accordance with 6.7.2.2.

6.7.2.7 Make a second mark with the scribe on each specimen, using the same center.

6.7.2.8 Measure the distance, $D$, between the scribe marks to the nearest 0.01 in. (0.254 mm).

6.7.2.9 Calculate the percent shrinkage as $(D/10) \times 100$.

6.7.2.10 Report the average shrinkage of the three specimens tested.

6.8 *Impact Resistance*—Test impact resistance of siding in accordance with Test Method D 4226, Procedure A, impactor head configuration H.25. 4 in.-lb increments (0.5 in. height increments with 8 lb falling weight) shall be used. Minimum sample dimensions shall be 1.5 by 1.5 in. Samples shall be tested with the normally exposed surface facing up. Conditioning time for quality-control tests shall be at least 1 h.

6.9 *Coefficient of Linear Expansion*— Conduct this test in accordance with Test Method D 696.

6.9.1 *Alternative Specimen Preparation*—Specimens prepared from strips cut from extruded siding are permitted to be used in testing under Test Method D 696. Where such specimens are used, they shall be cut with the long dimension parallel to the long axis of the siding panel. Guides shall be used in accordance with Test Method D 696 to prevent bending or twisting of the specimen in the dilatometer.

6.10 *Weatherability*:

6.10.1 A minimum of three samples shall be exposed at each of at least three test sites. Test sites shall be located in a northern temperate climate, represented by Cleveland, Ohio or Louisville, Kentucky; a hot, humid climate represented by Miami, Florida; and a hot, dry climate represented by Phoenix, Arizona. The samples shall be exposed for a minimum of 24 months.

6.10.2 Samples shall consist of a flat section of siding with minimum dimensions of 2 in. by 3 ¾ in. (25mm by 95mm).

6.10.3 Samples shall be representative of the product to be evaluated.

NOTE 5—Samples prepared in the laboratory in the same manner as commercial samples are permitted to be used as an alternative to a commercial part. If the commercial product is extruded, the laboratory specimen must be extruded; if the commercial product is injection molded, the laboratory specimen must be injection molded, and so forth.

6.10.4 Select a minimum of 4 specimens per sample per test site to allow for 3 test specimens and 1 file specimen for each sample evaluated.

6.10.5 Mark each specimen permanently to ensure retention of identity during and after exposure testing.

NOTE 6—Use of a vibratool leaves a permanent mark that satisfies this criterion.

6.10.6 All exposures shall be conducted at an angle of 45° South, plywood backed, in accordance with Practices D 1435 and G 147.

6.10.7 After a minimum of 24 months of exposure, remove the samples and inspect each exposed test specimen for appearance and surface condition. Record observations and inspection date in a permanent record.

6.11 *Gloss*:

6.11.1 *Apparatus*—Measure gloss using a 75° geometry glossmeter that meets the requirements of the Apparatus section of D 2457.

6.11.2 *Procedure*:

6.11.2.1 Gloss measurements shall be made in accordance with the procedure in Section 9 of D 2457, unless otherwise specified herein.

6.11.2.2 Measure gloss on one piece of siding on at least three widely separated sections across the width of the exposed surface of the panel. Care needs to be taken to ensure that a new surface area is used for each reading since instrument contact may leave scratches on the specimen surface. The area tested must be flat.

6.11.2.3 Measure gloss parallel to the direction of embossing. When the embossing pattern is not apparent, measure the gloss in the direction of extrusion.

6.11.2.4 Each reading shall be within the appropriate limit specified in 5.7.

6.11.2.5 The average reading of all readings shall be used to represent the gloss of the sample.

6.12 *Surface Distortion*:

6.12.1 *Test Specimen/Apparatus*:

6.12.1.1 The test specimen shall consist of three courses of siding, a minimum of 6 ft (1.83 m) in length, mounted on a flat rigid frame in accordance with the manufacturer's recommended installation instructions.

6.12.1.2 Heat-sensing elements shall be located at the midpoint of the backside of the second course of siding.

6.12.1.3 *Radiant-Heat Rod*, 600 W for each linear foot (0.31 m), mounted parallel to the middle course and approximately 32 in. (810 mm) away from the surface of the siding.

6.12.1.4 *Temperature-Control Device*, used to regulate the temperature of the radiant-heat rod, shall be able to maintain the conditions specified in 6.12.2.1.

6.12.2 *Procedure*:

6.12.2.1 Heat the test panel (second course of siding) at a rate of 3.0 to 6.0°F/min (1.7 to 3.3°C/min) until a minimum temperature of 120°F (49°C) is achieved as measured by the heat-sensing element on the midpoint of the backside of the second course. During this heating period, observe the test panel for surface distortion.

6.12.2.2 Failure is defined as the appearance of bulges, waves, or ripples before a temperature of 120°F (49°C) is reached.

6.13 *Color Uniformity*—Calculate the difference between the $L_H$, $a_H$, and $b_H$ color coordinates for a production specimen to those of either the appropriate reference specimen or the agreed upon color coordinates for that specific color product in accordance with Test Method D 2244. Calculate the total difference $\Delta E$ between the production specimen and the reference specimen in accordance with Test Method D 2244.

6.14 *Windload Resistance*—Conduct the test on windload resistance of finished siding in accordance with Test Method D 5206.

6.15 *Nail Slot Allowance for Thermal Expansion*—As an alternative to conformance with the nail slot width specification in 5.12.1 or 5.12.2, provision for thermal expansion and contraction shall be demonstrated through the following test procedure.

6.15.1 *Samples*—At least 3 samples of each profile in which the siding is produced shall be provided. The length of each sample shall be at least 50 % of the longest length in which the profile is produced, and not shorter than 12 ft. (3658 mm).

6.15.2 *Test Chamber*—The test chamber shall consist of an environmentally controlled room or compartment capable of providing an air temperature range of at least 0 °F to 100 °F (-18 °C to 38 °C) without exposure of the panel to radiant energy from heating or cooling elements. Air temperature shall be controlled such that a rate of temperature change of 2 °F (1.11 °C) per minute can be achieved over the full temperature range, and the minimum and maximum temperatures can be maintained for at least 15 minutes. Means for circulating air to provide a uniform air temperature throughout the chamber shall be provided. A vertical wall shall be provided for mounting of samples. The wall shall be insulated such that, with no panels mounted, the inner surface of the wall does not deviate more than 10 °F (5.5 °C) from the air temperature at the high and low temperature extremes after a holding period of 5 minutes. The test chamber shall be of sufficient size to accommodate the longest panel to be tested, including expected thermal expansion of the panel. Means shall be provided to measure the actual temperature of the surface of each panel at a minimum of 3 evenly-spaced locations along the length of the panel.

6.15.3 *Length Measurement*—A means for measuring the length of each sample throughout the temperature range shall be provided. The method utilized for length measurement shall not be influenced by the temperature of the chamber and shall have a minimum resolution of no greater than 0.0625 in. (1.59 mm).

6.15.4 *Procedure*—Install the sample panels on the wall inside the test chamber, following the manufacturer's instructions for fastener type, spacing, location and tightness. At ambient temperature measure and record the length of each panel and the temperature of the panel, averaged from a minimum of 3 locations along the length of the panel.

6.15.4.1 *Test Cycle*—Test cycles shall be performed by raising the air temperature to 100 °F ±5 °F (38 °C ±2.75 °C) at an average rate of 2 °F (1.11 °C) per minute, holding the air temperature at 100 °F (38 °C ±2.75 °C) for 15 minutes, lowering the air temperature to 0 °F ±5 °F (-18 °C ±2.75 °C) at an average rate of 2 °F (1.11 °C) per minute, holding at 0 °F (-18 °C ±2.75 °C) for 15 minutes, and returning to ambient temperature at an average rate of 2 °F per minute.

6.15.4.2 *Conditioning*—Close the test chamber and perform at least 2 conditioning cycles using the procedure in 6.15.4.1. No interruption is required between conditioning cycles.

6.15.4.3 *Test*—Following completion of the conditioning cycles, conduct 3 test cycles using the procedure in 6.15.4.1. It is acceptable for the test cycles to follow immediately upon completion of the final conditioning cycle, and no interruption is required between test cycles. After a minimum holding period of 15 minutes at the high and low extremes of each test cycle, measure and record the length of each panel and the temperature of the panel, averaged from a minimum of 3 locations along the length of the panel.

6.15.5 *Normalization*—From among the length measurements recorded for all three cycles, identify the shortest and longest length of each panel, and the average panel temperature at the time that length was recorded. Determine the maximum difference in length, ΔL, and the maximum difference in temperature, ΔT, by subtracting the smaller from the larger. Normalize the change in length to the full length of the panel over a 100 °F (38 °C) temperature range using the following formula:

$$E_t = \Delta L \, x \, (100 / \Delta T) \, x \, (L_f / L_t) \tag{2}$$

where:

$E_t$ = Total thermal expansion and contraction of a full length panel over a range of 100 °F (38 °C)
$\Delta L$ = Maximum change in length of the tested panel
$\Delta T$ = Maximum change in temperature of the tested panel

$L_f$ = Longest length in which the panel is produced
$L_t$ = Actual length of the panel as tested

6.15.6 *Acceptable Performance*—When tested according to this procedure, the result of ($E_t \times$ 2) + 0.25 in. for each of the 3 samples for each profile shall not be greater than the width of the nail slot. If the manufacturer's installation instructions require the panel to be center-pinned, the result of $E_t$+ 0.25 in. for each of the 3 samples for each profile shall not be greater than the width of the nail slot.

6.16 *Lead Content*:

6.16.1 Testing for lead content shall be conducted on extruded siding using a rhodizinate-type lead swab test kit conforming to Practice E 1753. Testing shall be performed in accordance with the test kit manufacturer's instructions. The siding shall be deemed to comply with 4.6 if the test shows a negative or not-detected result; that is, the test does not indicate the presence of lead. The test shall be conducted separately on the substrate and on any cap or film material.

6.16.2 As an alternative to the method in 6.16.1, and as a means of resolving any ambiguous results from that method, an analytical method capable of detecting lead at least as low as 0.02 percent by sample weight shall be employed. Under this alternative, neither the substrate nor any cap or film shall contain a concentration of lead in excess of 0.02 percent by weight.

## 7. Product Marking

7.1 In order that purchasers may identify siding conforming to all requirements of this specification, producers and distributors shall include a statement of compliance in conjunction with their name and address on product labels, invoices, sales literature, and the like. The following statement is suggested when sufficient space is available:

This PVC siding conforms to all the requirements established in ASTM Specification D 3679, developed cooperatively with the industry and published by ASTM.

Full responsibility for the conformance of this product to the specification is assumed by (name and address of producer or distributor).

7.2 The following abbreviated statement is suggested when available space on labels is insufficient for the full statement: Conforms to ASTM Specification D 3679 (name and address of producer or distributor).

## 8. Packing, Packaging, and Package Marking

8.1 The siding shall be packed in such a manner as to provide reasonable protection against damage in ordinary handling, transportation, and storage.

8.2 Provisions of Practice D 3892 shall apply to this specification.

## 9. Keywords

9.1 plastic building products; plastic weatherability; recycled plastic; rigid PVC siding; specification

# ANNEX

**(Mandatory Information)**

## A1. WINDLOAD RESISTANCE TEST DESIGN FACTORS

A1.1 *Windload Criteria:*

A1.1.1 ASCE 7-02 is the basis for determining the design pressures used in this test method. The velocity pressures, $q$, used in this test method have been computed using the following equation:

$$q = 0.00256\, K_z K_d V^2 I \ (lb/sq\,ft)$$
$$= 0.613\, K_z\, K_d\, V^2 I \ (N/m^2)$$

where:

$V$ = wind velocity, mph (km/h). The basic wind speed corresponds to a 3–s gust speed at 33 ft (10.1 m) above ground in exposure category C, as described in ASCE 7–02. A velocity of 110 mph (177 km/h) was used in this specification. (See Note A1.1)

$I$ = "importance factor" as described in ASCE 7-02. A value of 1.0 was used.

$K_z$ = "velocity pressure coefficient" as described in ASCE 7-02. A "$K_z$" of 0.70 was used in the wind pressure calculations, which is the value from ASCE 7-02 for an elevation of 30 ft (9.1 m) above ground level and Exposure Category B.

$K_d$ = "wind directionality factor" as described in ASCE 7–02. A "$K_d$" of 0.85 is used.

The velocity pressure = −18.43 lbf/ft$^2$ (882 Pa).

NOTE A1.1—In ASCE 7-02 the default wind speeds are given for exposure category C, and a table is provided to adjust this wind speed for other exposure categories. Since most vinyl siding is installed on buildings located in exposure category B, the velocity pressure coefficient, $K_z$ is included in the equation to make this adjustment

A1.1.2 ASCE 7-02 recommends various internal and external pressure coefficients, which include gust response factors. These coefficients vary with the effective area of the cladding component, the location of the cladding component relative to building corners, and the configuration of the building (open versus enclosed). The internal and external pressure coefficients are taken from Figure 6–5 and Figure 6–11A of ASCE 7–02. The effective area is taken as 10 square ft (the area of one piece of siding), an enclosed building is assumed, and factors for the building corners are used. The pressure coefficients are as follows:

$$\text{Internal Pressure Coefficient} = \pm 0.18$$

$$\text{External Pressure Coefficient} = +1.00 \text{ and } -1.40$$

The design pressure is calculated by multiplying the velocity pressures by the algebraic sum of the internal and external pressure coefficients.

A1.2 *Design Pressure:*

$$\text{Positive Design Pressure} = (18.43)(1.00 + 0.18) = 21.74 \text{ psf}$$

$$\text{Negative Design Pressure} = (18.43)(-1.40 - 0.18) = -29.12 \text{ psf}$$

A1.2.1 The negative values (suction loads) are the largest in magnitude and are the design values used in this test method. Based on research conducted by Architectural Testing, Inc. for the Vinyl Siding Institute[5] a certain amount of pressure equalization occurs through residential siding products installed with sheathing under high dynamic pressures. In light of this pressure equalization, the design pressure in the ASCE 7-02 windload standards is reduced by a factor of 0.36.

A1.2.2 Therefore, the required test pressures are calculated as follows:

$$P_t = D_P \times 0.36 \times 1.5$$

where:

$P_t$ = test pressure, lbf/ft$^2$ (Pa),
$D_P$ = design pressure, lbf/ft$^2$ (Pa),
$0.36$ = pressure equalization factor, and
$1.5$ = safety factor.

A1.2.3 In a 110 mph (177 km/h) wind zone area specifying a design pressure of −29.12 lbf/ft$^2$ (1394 Pa) for a building 30 ft (9.1m) in height or less, the required siding uniform load test pressure is 15.73 lbf/ft$^2$ (753 Pa). For applications where the effective design pressure is greater than -29.12 lbf/ft$^2$ (1394 Pa) (for example, wind zone areas greater than 110 mph (177 km/h), elevations over 30 ft (9.1 m), or exposure conditions other than Exposure B), refer to ASCE 7-02 for the effective design pressure. The product shall be subjected to a static test pressure determined by the formula in A1.2.2. These loading conditions apply only to siding installed to solid walls, with internal or external sheathing. For applications where the siding is installed over open studding, rapid pressure equalization does not occur. In these applications, the load the siding will see is equal to the total design pressure. The static test pressure required for products used under these conditions is as follows:

$$P_t = 1.5 \times DP$$

where:

$P_t$ = static test pressure, lbf/ft $^2$ (Pa),
$D_P$ = design pressure, lbf/ft$^2$ (Pa), and
$1.5$ = safety factor.

A1.3 *Wind Design Pressures:*

A1.3.1 The wind velocity maps in ASCE 7–02 provide one source of design wind pressures for particular geographic regions.

[5] Vinyl Siding Pressure Equalization Factor, Architectural Testing, Inc., Report No. 01-40776.01, September, 2002.

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Designation: D4756 – 15

An American National Standard

# Standard Practice for Installation of Rigid Poly(Vinyl Chloride) (PVC) Siding and Soffit[1]

This standard is issued under the fixed designation D4756; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

## 1. Scope*

1.1 This practice covers the basic requirements for and the methods of installation of rigid vinyl siding, soffits, and accessories on the exterior wall and soffit areas of buildings. In all applications, refer also to the specific manufacturer's installation instructions and the requirements of applicable building codes.

1.2 This practice covers aspects of installation relating to effectiveness and durability in service.

1.3 The various application systems are located in the following sections of this practice:

| | |
|---|---|
| Substrate, Surface Preparation | Section 8 |
| Application of Horizontal Siding | Section 9 |
| Application of Vertical Siding | Section 10 |
| Application of Soffits and Fascia | Section 11 |
| Special Details | Section 12 |

1.4 The values stated in inch-pound units are to be regarded as standard. The values given in parentheses are mathematical conversions to SI units that are provided for information only and are not considered standard.

1.5 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

NOTE 1—There is no known ISO equivalent to this standard.

## 2. Referenced Documents

2.1 *ASTM Standards:*[2]

D883 Terminology Relating to Plastics
D1600 Terminology for Abbreviated Terms Relating to Plastics
D3679 Specification for Rigid Poly(Vinyl Chloride) (PVC) Siding
D4477 Specification for Rigid (Unplasticized) Poly(Vinyl Chloride) (PVC) Soffit
E631 Terminology of Building Constructions
E2112 Practice for Installation of Exterior Windows, Doors and Skylights

## 3. Terminology

3.1 *General*—Definitions are in accordance with Terminologies D883 and E631 and abbreviations with Terminology D1600 unless otherwise indicated.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *backerboard*—a flat material used on the face of the house, applied between the studs and the siding (or over existing wall surface) to provide an even surface for the installation of the vinyl siding.

3.2.2 *buttlock*—the bottom of a siding or soffit panel, or accessory piece, opposite the nail hem, which locks onto the preceding panel.

3.2.3 *crimp*—small protrusions, typically approximately ½ in. (12.7 mm) long, ⅛ in. (3.2 mm) wide, and projecting ⅛ in. (3.2 mm) formed by a crimper (snaplock punch). (See Fig. 2.)

3.2.4 *crimper*—a special hand tool designed to form crimps (snaplock ears) intended to hold partial panels in place. (See Fig. 2.)

3.2.5 *face nail*—the action of fastening directly on to the "face," or exposed surface, of a panel (instead of using the nail slot).

3.2.6 *fascia*—the trim covering the ends of roof rafters. (See Fig. 1.)

3.2.6.1 *fascia board*—a board attached to the ends of the rafters between the roofing material and the soffit overhang.

3.2.6.2 *fascia cap or cover*—the covering around a fascia board.

3.2.7 *flashing*—special membrane pieces or manufactured trim pieces used to supplement siding panels in weather protection around joints, penetrations, and openings, such as windows, doors, mechanical penetrations, and roof-wall

[1] This practice is under the jurisdiction of ASTM Committee D20 on Plastics and is the direct responsibility of Subcommittee D20.24 on Plastic Building Products.

Current edition approved Feb. 1, 2015. Published February 2015. Originally approved in 1991. Last previous edition approved in 2013 as D4745 – 13. DOI: 10.1520/D4756-15.

[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

***A Summary of Changes section appears at the end of this standard**

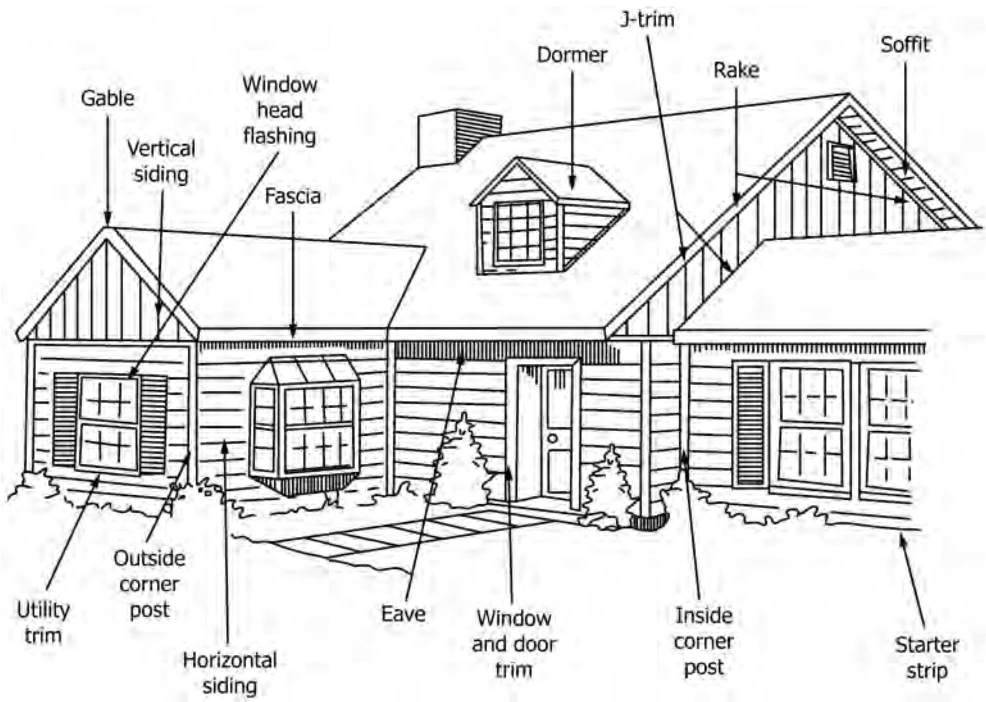



FIG. 1 Terminology for Buildings, Siding and Accessories

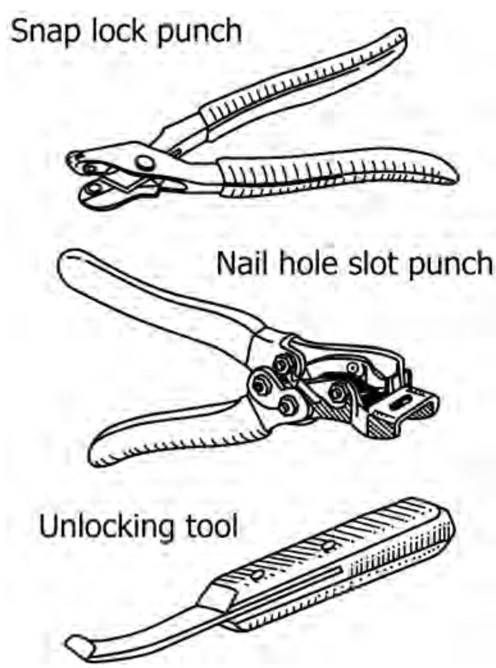



FIG. 2 Siding Installation Tools

intersections, designed and intended to move incidental water to the building exterior.

3.2.8 *furring/furring strip*—a wooden or steel framing material, usually a nominal 1 by 2 in. (25.4 by 50.8 mm) used to even the surface in preparation for installation of siding. To "fur" a surface means to apply these strips.

3.2.9 *nailslot punch*—a special hand tool used to create slots for attachment of field-modified siding or accessories. (See Fig. 3.)

3.2.10 *rake (roof)*—the inclined, usually projecting edge of a sloping roof.

3.2.11 *rake (wall)*—the board or molding placed along the sloping sides of a gable to cover the ends of the siding.

3.2.12 *snaplock ears*—see *crimp* and Fig. 2.

3.2.13 *snaplock punch*—see *crimper* and Fig. 2.

3.2.14 *soffit*—the underside surface (typically horizontal) of roof overhangs.

3.2.15 *starter strip*—an accessory applied directly to the surface of the building and used to secure the first course of siding to the home. Starter strips can either be a part manufactured for the specific purpose or created by cutting the nailing hem and adjacent lock from a siding panel.

3.2.16 *undersill trim (utility trim)*—an accessory strip used to receive and hold the crimped edge of horizontal or vertical siding that has had its normal lock removed.

3.2.17 *zip tool (unlocking tool)*—a special hand tool used to separate interlocked siding panels. (See Fig. 2.)

## 4. Delivery of Materials

4.1 All manufactured materials shall be delivered in the original packages, containers, or bundles bearing the size or type product, or both, brand name, and manufacturer (or supplier) identification, manufacturer's lot number, and the ASTM specification to which it conforms.

## 5. Protection of Materials

5.1 Do not store in any location or in any manner where the temperature of the siding, soffit or accessories is likely to exceed 130°F (54°C).

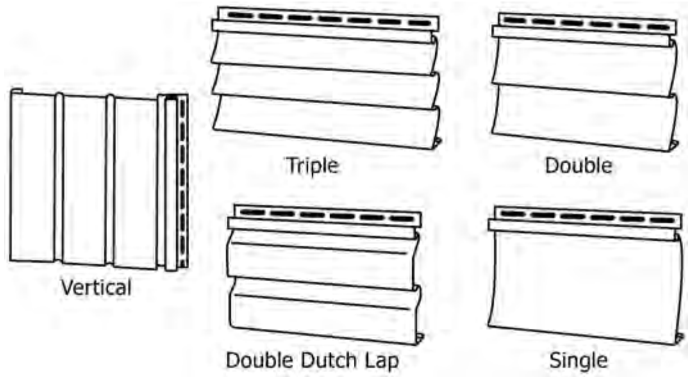



FIG. 3 Typical Siding Profiles

5.2 Store the cartons on a flat surface and support the entire length of the cartons.

5.3 Store the cartons away from areas where falling objects or other construction activity could impact the cartons. Keep the cartons dry.

5.4 Do not store the cartons in stacks more than 6 boxes high.

## 6. Environmental Conditions

6.1 Vinyl siding and accessories will expand when heated and contract when cooled. If siding is installed in hot weather and the siding is very warm it will be partially "expanded." Provide allowance for more future "contraction" than expansion.

6.2 Leave ¼ in. (6.4 mm) clearance between the ends of panels and trim and any receiver such as J-channels and corner posts to allow for thermal expansion. If installing during weather colder than 40°F (4.4°C), increase the minimum clearance to ⅜ in. (9.5 mm) to allow for additional expansion during warmer weather.

## 7. Materials

7.1 *Horizontal Wall Siding*—See Specification D3679.

7.2 *Vertical Wall Siding*—See Specification D3679

7.3 *Soffit Panels*—See Specification D4477.

7.4 *Accessories:*

7.4.1 *Starter Strip*—For horizontal siding made of poly(vinyl chloride) or corrosion-resistant metal.

7.4.2 *Corner Posts*—Of two types: for inside corners and for outside corners of poly(vinyl chloride).

7.4.3 *Trim Channels*—Produced of poly(vinyl chloride) in a variety of designs and sizes for use around openings and edges of wall and soffit surfaces. (See Fig. 5.)

7.5 *Fasteners:*

7.5.1 *Nails*—Corrosion-resistant with head diameter 5⁄16 in. (7.9 mm) minimum, shank diameter ⅛ in. (3.2 mm), length sufficient to penetrate not less than ¾ in. (19 mm) into framing or furring.

7.5.2 *Staples*—Corrosion-resistant, 16 gage minimum, with ⅜ to ½-in. (9.5 to 12.7-mm) crown, length sufficient to penetrate not less than ¾ in. (19 mm) into framing or furring.

7.5.3 *Screws*—Corrosion resistant, self-tapping type, No. 8 truss head or pan head length sufficient to penetrate wall thickness of steel stud or ¾ in. into framing or furring.

NOTE 2—To minimize the possibility of any color variation use material from a single manufacturer's lot number for application to one building.

## 8. Substrate, Surface Preparation

8.1 *Water-resistive Barrier*—Vinyl siding must be installed over a water-resistive barrier system that includes *(1)* a continuous water-resistive material, and *(2)* properly integrated flashing around all penetrations and where vinyl siding interfaces with other building products. Refer to the vinyl siding manufacturer's installation instructions and the minimum requirements of the local building code for specific product applications and requirements.

8.2 All caulking to prevent moisture penetration must be done before siding application. Do not use caulk where it could restrict the normal expansion of the vinyl siding.

8.3 Apply vinyl siding over sheathing or other rigid surface that provides a smooth, flat surface. Do not apply vinyl siding

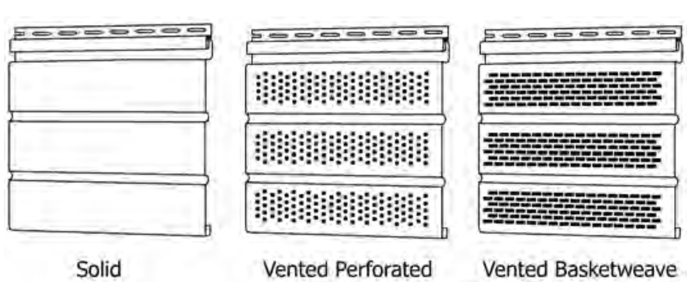



FIG. 4 Typical Soffit Profiles

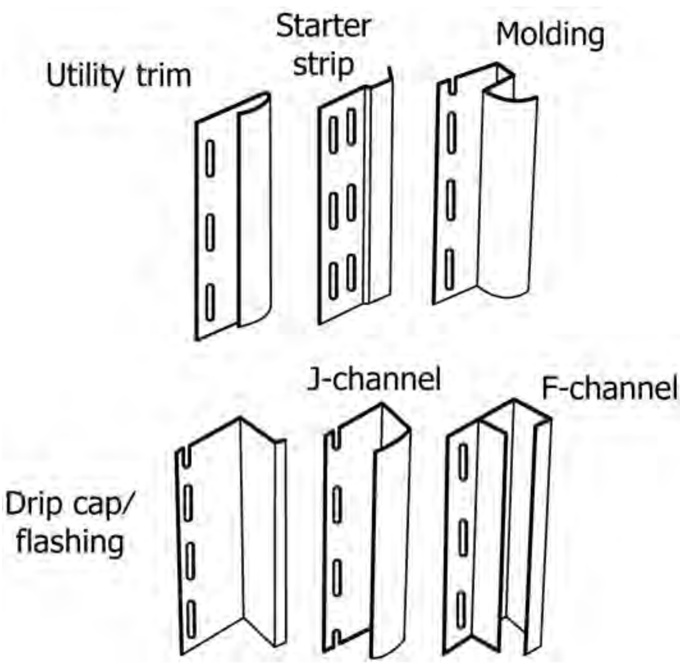



**FIG. 5 Typical Siding Accessories**

directly to studs without sheathing. If permitted by the vinyl siding manufacturer, a contoured foam underlayment fitted for the specific style of vinyl siding is permitted to be utilized. Apply over wood furring strips when the underlying surface is uneven.

8.4 Drive fasteners into framing or furring. Driving of fasteners directly into sheathing or existing siding is permitted in accordance with the siding manufacturer's instructions, where substantiated by windload testing conducted in accordance with Specification D3679.

8.5 On existing structures, secure any loose boards, replace any rotted ones, recaulk around windows, doors, and other areas as necessary to protect from moisture penetration prior to the installation of siding or accessories. Use furring as needed to create an even surface.

8.6 *Flashing*—Refer to Practice E2112 for installation of flashing around windows, doors, penetrations and points of interface between the vinyl siding and other building components. If available, also refer to the instructions provided by the manufacturer of the window, door, or other object that will penetrate the siding.

8.7 *Furring*—Masonry and uneven surfaces, as examples, require wood furring strips nominal 1 by 2 in. (25.4 by 50.8 mm) applied vertically and typically spaced 16 in. (406 mm) on center for horizontal siding and applied horizontally and typically spaced 12 in. (305 mm) on center for vertical siding.

## 9. Application of Horizontal Siding

9.1 *General Requirements*—Vinyl siding and accessories expand and contract as much as ½ in. (12.7 mm) over a 12 ft (3.65 m) length with changes in temperature. For this reason adhere to the following provisions:

9.1.1 When applied, vinyl siding products must be attached "loosely," leaving approximately a 1⁄32-in. (0.8-mm) space between the vinyl and the fastener head or crown to permit thermal movement. (See Fig. 6.)

9.1.2 Center fasteners in slots of siding and accessories to permit possible expansion and contraction. (See Fig. 7.) If a nail slot does not allow centering/securing into framing, furring, or other permitted nailable surface, use a nail hole slot punch to extend the slot and allow centering of the fastener.

9.1.3 Do not face nail siding panels. (See Fig. 8.)

9.1.4 Allow clearance at panel ends for thermal expansion between corner posts, J-channels, and other receivers in accordance with 6.2.

9.2 *Installation of Accessories*—Accessories, including starter strips, corner posts and door/window trim, are installed prior to application of the siding, adhering to the provisions of 9.1 and those which follow.

9.2.1 *Corner Posts*—Outside and inside corner posts will start ¼ in. (6.4 mm) below the top, and end ¾ in. (19.1 mm) below the bottom edge of the first course of siding which will be installed later. Attach each leg of the corner posts with fasteners, spaced not over 12 in (305 mm) apart centered in nailing slots except the top fastener that is located at the upper end of a nailing slot.

9.2.1.1 If more than one length of corner post is required, lap the upper piece over the lower piece by cutting away 1 in. (25.4 mm) of the nailing flange on the top piece. Lap ¾ in. (19 mm) allowing ¼ in. (6.4 mm) for expansion. (See Fig. 9.)

9.2.1.2 As an alternative for inside corners, install two J-channels with the web of one abutting the adjacent wall and the web of the other J-channel abutting the shorter outer flange of the first J-channel. Attach as specified in 9.1.1.

9.2.2 *Starter Strip*—Determine the lowest point along the area to receive siding and install starter strips located so that the bottom edge of the initial course of siding will be on a level line and typically approximately ¼ in. (6.4 mm) below that point. Allow space for corner posts, J-channels, etc., and keep ends of starter strips ¼ to ½ in. (6.4 to 12.7 mm) apart. Space fasteners not more than 10 in. (254 mm) apart, centered in nail slots.

9.2.3 *Door/Window Trim:*

9.2.3.1 Install flashing around windows and doors in accordance with 8.1 and 8.6 before installing trim.

9.2.3.2 J-channel is installed on each side and the top of door and window frames, and under window sills. Always install the bottom J-channel first, followed by the side channels, and then the top channel.

9.2.3.3 Extend the bottom and top J-channel the length of the window frame plus the width of the visible face of the side

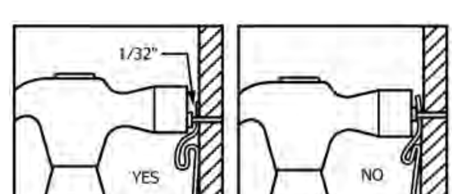



**FIG. 6 Attachment of Vinyl Siding**

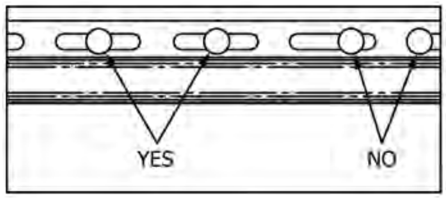



FIG. 7 Fastening Location in Siding Slots

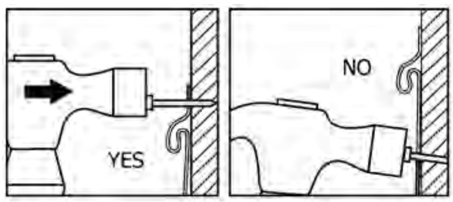



FIG. 8 Face Nailing of Vinyl Siding Prohibited

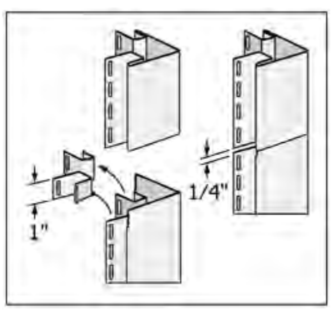



FIG. 9 Joining Corner Posts

J-channels (typically ¾ in. (19 mm)) on each side. Extend the side J-channels the height of the window or door frame plus the width of the visible face of the top and bottom J-channels.

9.2.3.4 In the bottom J-channel, cut a notch in the web at each end the width of the visible face of the side J-channel. In both side J-channels, cut a notch at the top end and a tab at the bottom end. Miter the bottom ends of the visible face of the side J-channels at a 45 degree angle. In the top J-channel cut along the bends at both ends of the J-channel to create a tab the same length as the exposed face of the side J-channel. Miter the end of the visible face of both ends of the top J-channel at a 45 degree angle.

9.2.3.5 Install the bottom J-channel. Install each of the side J-channels, with the mitered visible face over the face of the bottom J-channel. Bend the tabs in the side J-channels into the bottom J-channel. (See Fig. 10.)

9.2.3.6 Install optional head flashing across the top of the window or door frame. Install the top J-channel with the mitered face over the face of the side J-channels. Bend the tabs in the top J-channel into the side J-channels. (See Fig. 11.)

9.3 *Siding Panel Installation:*

9.3.1 *General Considerations*—To make overlapped siding joints less noticeable on the sides of a building, start at the rear corner and install toward the front. On the front and rear of buildings start at the corners and install toward the entrance door. Avoid use of short panel lengths under 24 in. (610 mm). (See Fig. 13.) When lapping, place factory-cut ends of panels on top of field-cut ends for best appearance.

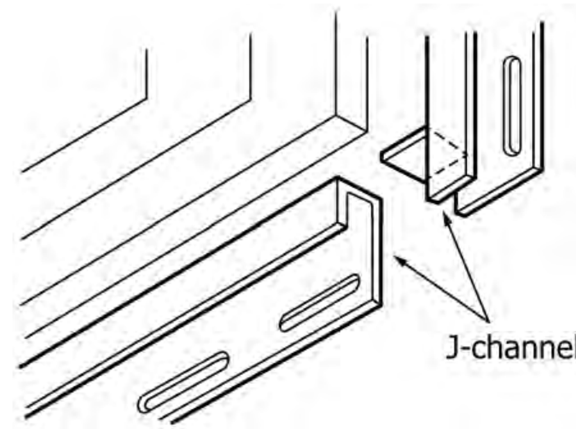



FIG. 10 Installation of Bottom and Side J-Channels under Window (for clarity, 45 degree miter of side J-channel is not shown)

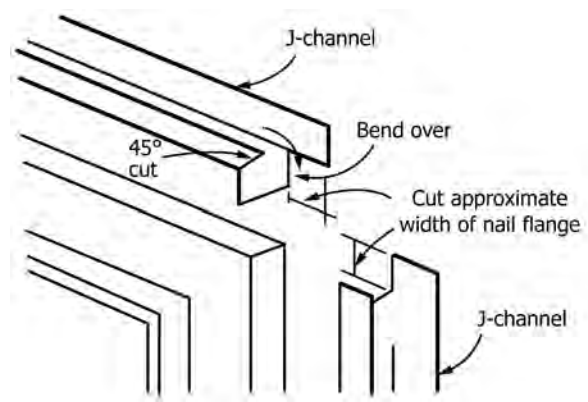



FIG. 11 Installation of Top and Side J-Channels Above Window or Door (note mitered face of top J-channel)

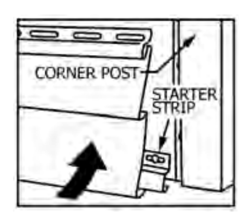



FIG. 12 Fastening of Initial Siding Panel

9.3.2 Engage the bottom of the first panel and the starter strip. If backerboard insulation is used, drop it in behind the panel now. Make sure the panel is locked, but not pulled tight, and fasten leaving ¼ to ⅜ in. (6.4 to 9.5 mm) gap at the corner posts, in accordance with 6.2. (See Fig. 12.) Space fasteners not over 16 in. (406 mm) on center. Greater spacing is permitted in accordance with the siding manufacturer's instructions, where substantiated by windload testing conducted in accordance with Specification D3679.

9.3.3 Lap the next panel over the first by approximately one-half of the factory cut notch, provided the overlap is at least ¾ in. (25.4 mm) but not greater than 1¼ in. (38.1 mm). (See Fig. 13.) Insert backerboard (if used) and fasten.

9.3.4 To field-notch a panel where the factory notch has been cut off, cut away 1½ in. (38 mm) of the nailing flange and

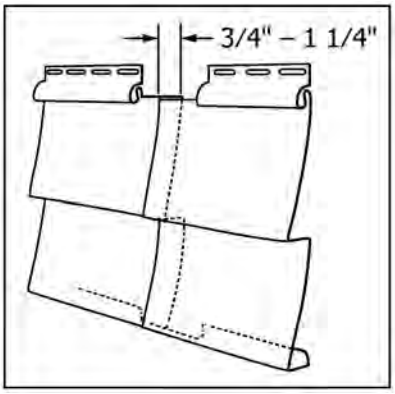



FIG. 13 Lapping Siding Panel

lock. Cut a ⅛ by 1½-in. (3.2 by 38-mm) notch from the bottom step of the panel, cutting away the hook on the back as well.

9.3.5 At the bottom of the window, snugly install between the side J-channels and against the underside of the sill, a piece of undersill trim cut to the exact width of the window. Use the proper thickness of furring behind it to keep the pitch of the panel consistent.

9.3.6 If the top of the siding panel will extend above the bottom of the window, cut a section out of the panel to fit under the opening. Be sure the uncut portion of this panel extends on both sides of the window. Measure the panel to fit. Hold the siding panel under the window and mark the width of the opening on it. Allow ¼ in. (6.4 mm) clearance at the edges for insertion into each side of the J-channel. Measure the space between the bottom edge of the S-lock on the previous panel and the top of the undersill trim, minus ¼ in. (6.4 mm) for insertion into the undersill trim receiver. Remove cut section. Punch snap locks every 6 in. (152 mm) along the horizontal cut edge. Slide the panel up into position so the bottom locks into the previous panel and the top snaps into the undersill trim and fasten. (See Figs. 14 and 15.)

9.3.7 Over a window or door, measure for the cuts. Mark the bottom portion of the panel and cut out the unwanted section. Install the panel. (See Fig. 16.) If necessary, place a piece of furring into the J-channel behind the cut edge of the siding to reduce wind movement and maintain the proper plane of this siding. Leave enough gap at the top of the cutout to permit locking onto the previous course.

9.3.8 At a gable, install J-channel along the rake boards, or at the top of the wall if there are no rake boards. (See Fig. 17.) Lap the channels if necessary by cutting 1 in. (25.4 mm) off the end leaving only the face and then lap ¾ in. (19 mm). Miter the ends that meet at the peak to make a neat joint.

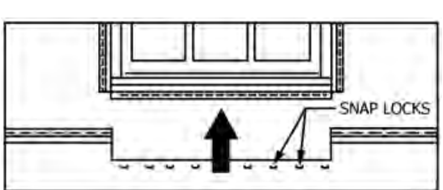



FIG. 14 Preparation of Siding Panel Under Window

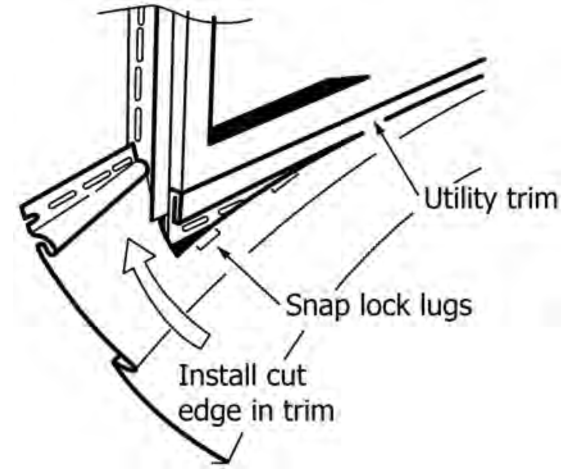



FIG. 15 Installation of Siding Under Window

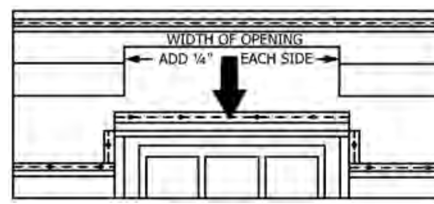



FIG. 16 Installation Over Window or Door

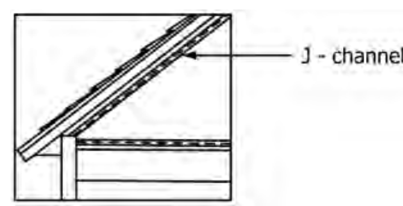
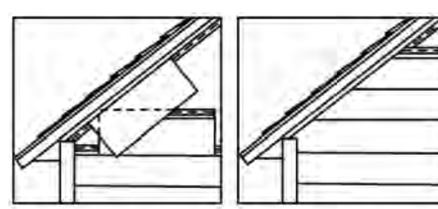



FIG. 17 Installation of J-channel on Gable



**(a)** *Pattern* **(b)** *Use*

FIG. 18 Using a Pattern to Match Panel End Cuts to Gable Angle

9.3.8.1 To ensure that the angle of the ends of the siding panels match the angle of the gable, make a pattern from two pieces of scrap siding. Hold one piece on the lock of the last installed panel, place the other piece against the gable and mark the horizontal piece. (See Fig. 18*(a)*.) Cut along the mark and use this piece as a pattern for the remaining siding panels on that side. Make another pattern for the other end of the panels. (See Fig. 18*(b)*.)

9.3.8.2 Lock each precut siding panel into the siding panel below and slide it into J-channel allowing ¼-in. (6.4-mm) expansion gap between the end of the siding and back of the J-channel.

9.3.8.3 Cut the panel for the top of the gable to match the angle of the gable. Use furring behind the top of this panel if necessary to maintain the proper plane of the siding.

9.3.8.4 If the nail hem of the panel for the top of the gable is cut off to fit the space, face nail the panel. Drill a hole slightly larger than the size of the nail shank in the center of this triangular panel. Lock the panel in place and drive one nail into the pre-drilled hole. Do not nail it tight. Nailing into the panel without a pre-drilled hole has the potential to crack or kink the vinyl. (See Fig. 19.)

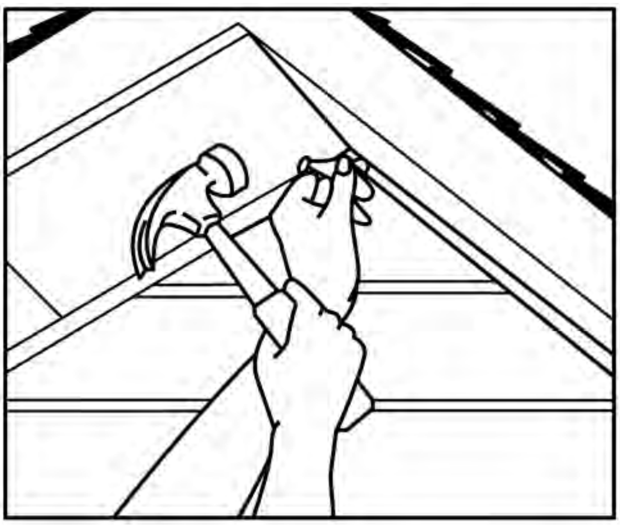


FIG. 19 Nailing of Panel at Top of Gable

9.3.9 The final panel under an eave is handled like the portion under a window. Nail undersill trim to the top of the sidewall (see Fig. 20), flush with the underside of the eave. If more than one length of undersill trim is needed, splice by cutting out 1¼ in. (31.7 mm) inch from the back and nailing flange of one piece of trim, then inserting the second strip inside the first, leaving ¼ in. (6.4 mm) for expansion. (See Fig. 21.) To determine the amount of the top panel to be cut off, measure from the bottom of the eave or soffit to the bottom of the preceding panel lock in several places along the full length of the panel and subtract ¼ in. (6.4 mm). (See Fig. 22.) Cut the panels to provide this width. Punch snap-locks every 6 in. (152 mm) along the cut edge and slide it up into position.

## 10. Application of Vertical Siding

10.1 For general requirements, see 9.1 and 9.2.

10.2 *Bottom Receiver*—Determine the lowest point along the area to be covered with siding and install J-channels located so that the lower edge of the J-channel is ¼ in. (6.4 mm) below

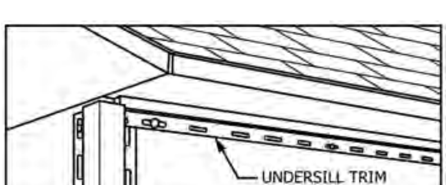



FIG. 20 Undersill Trim at Top of Sidewall

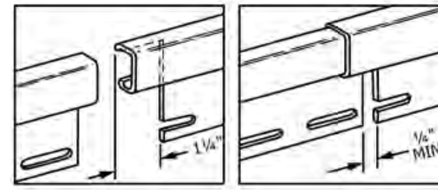



FIG. 21 Undersill Trim Splice

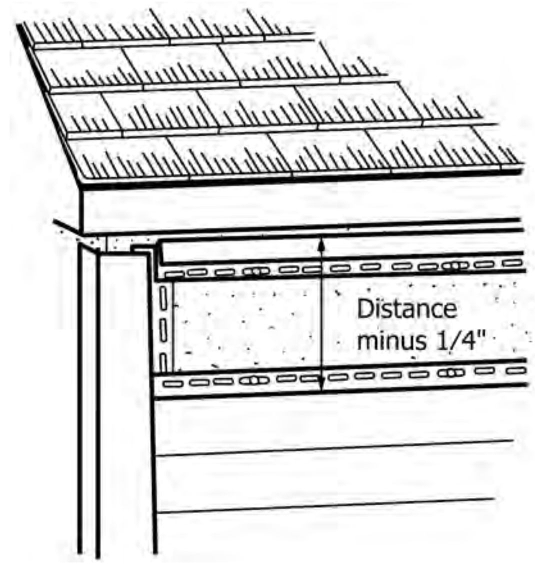



FIG. 22 Determining Width of Final Siding Panel under Eave

that point all along the area to be covered with siding. Leave ¼ in. (6.4 mm) gap at all corner posts and J-channels. To lap two pieces of J-channel, cut away 1 in. (25.4 mm) of the nailing flange of the overlapping piece and lap ¾ in. (19 mm). Drill minimum 3⁄16 in. (4.8 mm) diameter weep holes spaced no more than 24 in. (610 mm) apart in the bottom web of the J-channel.

10.3 *Corner Posts*—Install inside and outside corner posts. Leave a ¼ in. (6.4 mm) gap between the top of the corner post and eaves or soffits. Extend the corner post to ¼ in. (6.4 mm) below the lowest edge of the J-channel that serves as the bottom receiver. Fasten the corner posts by placing the uppermost fasteners at the top of the top nail slots, and placing other fasteners spaced not over 12 in. (305 mm) apart centered in nail slots.

10.4 *Top of Sidewalls*—If vinyl soffits are to be installed, install the soffits before installation of J-channels at the top of all sidewalls. For vinyl soffit installation see Section 11. Install J-channels along the top of all wall areas that will receive vertical siding. Lap where necessary, removing 1 in. (25.4 mm) of the nailing flange of the overlapping piece and lap ¾ in. (19 mm). (See Fig. 23.)

10.5 Trim around all windows and doors as described in 9.2.3, using J-channel at least as wide as the butt height of the vertical siding.

10.6 For most sidewall applications vertical siding is installed from one corner across the wall to the other corner. To produce a balanced appearance, measure the width of the wall

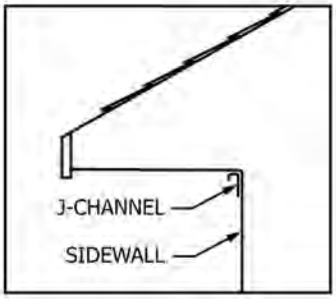



**FIG. 23 J-Channel Installation at Top of Sidewall**

and divide by the face exposure of the siding panels. Divide any fractional remainder by two and cut siding panels to that width to be used as the first and last panels.

NOTE 3—For instance, if a wall requires 20 full panels plus an additional 8 in., the first and last panel would be cut to a width of 4 inches. Be sure to allow for the depth of the receiving channels when measuring the wall width.

10.7 *Initial Siding Panel*—To start the first panel, install utility trim into the receiving pocket of a corner post. Shim the utility trim so that it matches the level of the siding panel face. Punch snap locks every 6 in. (152 mm) along to cut edge of the vertical siding, and insert into the utility trim. Where the first panel will be a full panel, including buttlock, cut the nail hem and top lock from a separate siding panel and install in the receiving pocket. Hook the buttlock of the first panel over the top lock to secure the panel.

10.7.1 Make sure that the first siding panel is plumb. Fasten the panel by installing the top fastener in the top of the uppermost nail slot, Place other fasteners spaced not over 12 in. (305 mm) apart centered in nail slots. Leave ¼ in. (6.4 mm) clearance at the top and ⅜ in. (9.5 mm) clearance to the bottom receiver.

10.7.2 For vertical siding under gables and other situations where the siding is to be visually centered, install back-to- back J-channels or an H-divider bar at the center of the wall. Install utility trim or the cut nail hem and top lock of a siding panel in each J-channel, as described in 10.7. Install the vertical siding from the center toward each corner. As an alternative for non-gabled walls, carefully measure the wall and install the siding starting at one side, trimming the first section so that a seam or center of a panel falls at the center of the wall.

10.8 Install the vertical siding panels by locking it into the previous panel, and nailing as described in 10.7.1.

10.9 The last panel at the corner opposite the starting corner is to be cut to the same width as the first panel. Install it into the receiving pocket of the corner post using utility trim or the cut nail hem and top lock of a siding panel, as described in 10.7. Drive a trim nail through the utility trim and edge of the siding panel, inside the receiving pocket, to prevent the panel from sliding down inside the trim.

10.10 For application of vertical siding to gables, make a pattern for end-cuts along the gables using two pieces of scrap siding. Lock one piece on the starter strip just under the eave. Hold the edge of the other piece against, and in line with, the roof line. Mark and cut the vertical piece. Use it as a pattern to mark and cut the ends of all other panels required for this side of the gable end. Make another pattern for the other side of the gable. (See Fig. 24.)

10.11 If it will take more than one course to span the height of the house, terminate the first course into an inverted J-channel, leaving a ¼ in. (6.4 mm) clearance. Install a head flashing on top of the J-channel. Then install an upward-facing J-channel on top of the head flashing. Install the second course of vertical panels, leaving a ⅜ in. (9.5 mm) clearance to the bottom J-channel. (See Fig. 25.)

10.12 At windows and doors, cut the panels to fit the opening allowing ¼ in. (6.4 mm) for expansion.

10.12.1 If the panel is cut down in the V-groove, fasten a wood furring stop as shown in Fig. 26, with fasteners that do not penetrate the legs of the J-channel or corner post, insert the cut side over the furring strip and into the J-channel, locking the other side into the last panel. (See Fig. 26.)

10.12.2 If the panel is cut on the flat surface, install undersill trim, backed by a furring strip, into the J-channel using fasteners that do not penetrate the leg of the J-channel. Punch snap locks along the edge of the panel at 6-in. (152-mm) intervals; snap it into the space below the return of the J-channel, locking the other side into the last panel. (See Fig. 27.)

10.13 At corners, insert a J-channel of height appropriate for the depth of the panel into the receiver of the corner post.

10.13.1 If panel is cut in the bottom of the V-groove, insert into the J-channel. Install a furring strip prior to panel insertion. This will prevent the panel from detaching. (See Fig. 28.)

10.13.2 If the panel is cut on the flat surface, place a piece of undersill trim, backed by furring, into the receiver of the corner post. Punch snap locks along the cut edge of the panel at 6-in. (152-mm) intervals and snap it into the undersill trim. (See Fig. 29.)

## 11. Application of Soffits and Fascia (See Fig. 30)

11.1 *Requirements for Proper Ventilation:*

11.1.1 Calculation of perforated soffit needed for ventilation.

11.1.1.1 Proper attic ventilation is important for any home or dwelling. Consult a local building official for the appropriate requirements for a specific geographical area, and use vented soffit or other vented products as necessary.

11.2 *Installation of Soffit on an Open Rafter* (See Fig. 31):

11.2.1 Provide two parallel slots to hold and support the soffit panels.

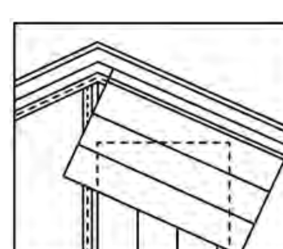


**FIG. 24 Pattern Preparation for Gable End-Cuts**

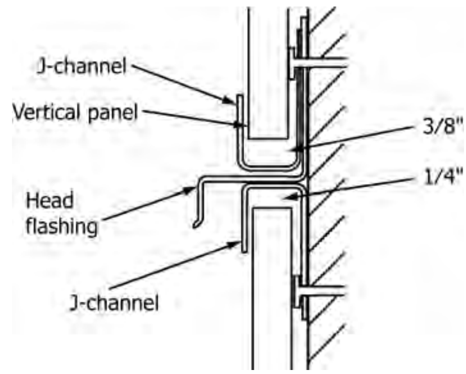


FIG. 25 Joining Area-Multicourse Installation

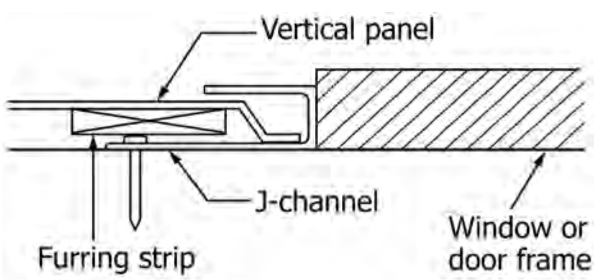


FIG. 26 Installation with Panel Cut in V-Groove

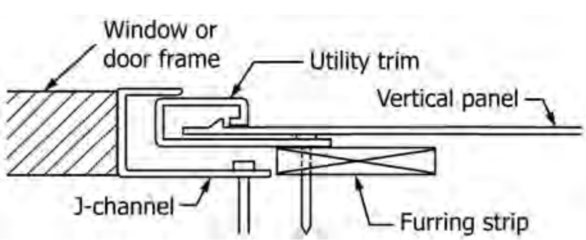


FIG. 27 Installation with Panel Cut on Flat Surface

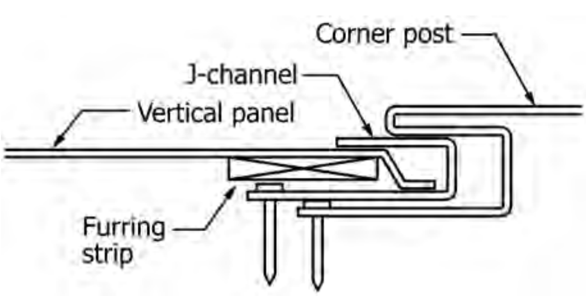


FIG. 28 Corner Installation with Panel Cut in V-Groove

11.2.1.1 Fasten an F-channel directly to wall at 6 to 12-in. (152 to 305-mm) intervals. Center the fasteners in the nail slot.

11.2.1.2 Fasten an F-channel on the outer bottom edge of the fascia board.

11.2.2 Cut a soffit panel to fit into the slots of the F-channels. Allow ¼ in. (6.4 mm) per side for expansion.

11.2.3 Slide the soffit panels into the F-channel slots. Panels are hooked together. On panel sections over 16 in. (406 mm) wide, intermediate nailing supports are required.

11.2.4 Secure each soffit panel with at least one fastener. If nailing strips are used, place fasteners through the soffit nail

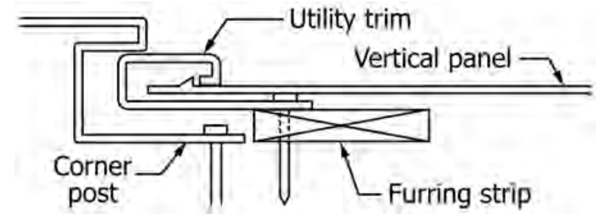


FIG. 29 Corner Installation with Panel Cut on Flat Surface

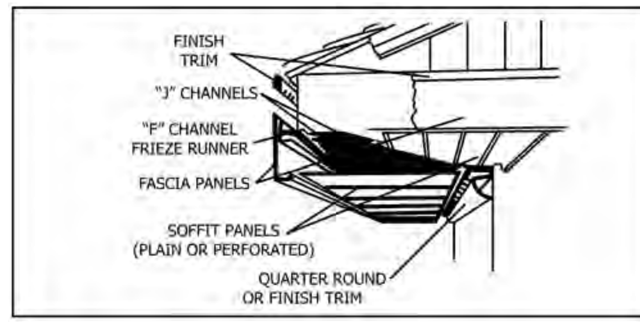


FIG. 30 Application of Soffit and Fascia

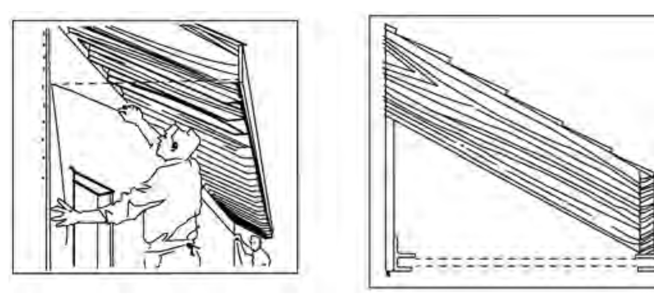


FIG. 31 Installation of Soffit on Open Rafter

hem into the nailing strip. If nailing strips are not used, drive a trim nail through the end of each V-groove in the soffit into the underside of the fascia board.

11.2.5 Where two soffit surfaces meet, a T-channel or two ½-in. (12.7-mm) J-channels properly supported and nailed back-to-back will provide support for the soffit panel.

11.2.6 At the ends, pieces of F-channel or ½-in. (12.7-mm) J-channel, are installed to finish the job.

11.3 *Installation of Soffit on an Enclosed Rafter* (See Fig. 32.):

11.3.1 Provide two parallel slots to hold and support the soffit panels.

11.3.1.1 Fasten an F-channel to the outer bottom edge of the fascia board.


FIG. 32 Installation of Soffit on Enclosed Rafter

11.3.1.2 Nail a quarter round Frieze moulding or a J-channel to the wooden soffit or an F-channel to the wall so that the slot to hold the soffit is parallel to the slot in the F-channel on the fascia board.

11.3.2 Cut a soffit panel to fit into the slots of the F-channels. Allow ¼ in. (6.4 mm) per side for expansion.

11.3.3 Slide the soffit panels into the F-channel slots. Panels are hooked together.

11.3.4 At the ends, pieces of F-channel or ½-in. (12.7-mm) J-channel are installed to finish the job.

11.4 *Installation of Fascia:*

11.4.1 Install undersill trim molding at the top of the fascia boards. (See Fig. 33.)

11.4.2 Measure the cover required and cut the fascia cover to proper width. Punch snaplock "ears" every 6 in. (152 mm) along the top of the fascia using a snaplock punch. (See Fig. 34.) Position the panel and secure the bottom lip of the fascia over the F-channel or J-channel, (see Fig. 35.), and snap into the undersill trim.

11.5 *Installation of Corner Cap:*

11.5.1 Trim the fascia cover ends at the corners as in Fig. 36.

11.5.2 Prefabricate or fashion corner caps from a piece of fascia cover. Cut a 5½-in. (140-mm) length of fascia cover and mark a vertical centerline on the back as shown in Fig. 37. Cut out a 90° section of bottom flange from the center, leaving 45° on each side. Using a hand seamer, fold along the centerline to form a right angle.

11.5.3 Punch the top edge of a corner cap with a snaplock punch. Hook the bottom ends of the cap over the fascia flange and push the top into the undersill trim slot to lock into place. (See Fig. 38.)

## 12. Special Details

12.1 *Fitting Siding Around Faucets or Railing*—Use a commercially-available trim ring to fit siding to a penetration such as a faucet, light fixture, or railing attachment, following manufacturer's instructions (See Fig. 39.) If a commercial trim ring is not available for the application, follow these steps to fit the siding to the penetration:

12.1.1 Always begin a course of siding at an obstruction such as a faucet or wrought iron railing to avoid excess lap joints.

12.1.2 Cut a slot ¼ in. (6.4 mm) bigger than the obstruction, matching the contour of the obstruction. Install the first piece of siding as shown in Fig. 40(*a*).

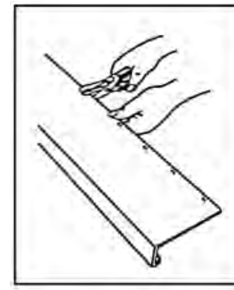


**FIG. 34 Punch Snaplock Ears on Fascia Cover**


**FIG. 35 Positioning of Fascia Cover**

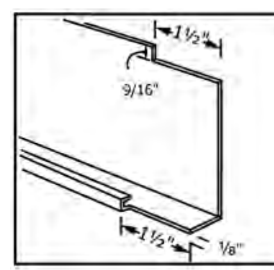



**FIG. 36 Trimming Fascia Corner Ends**

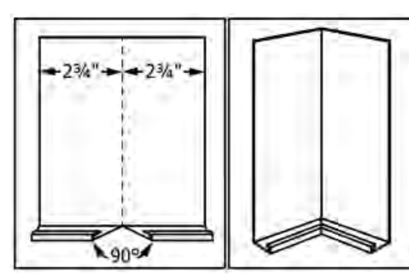



**FIG. 37 Prefabricating Corner Cap**

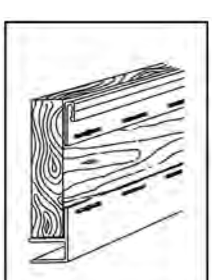


**FIG. 33 Installation of Undersill Trim**

12.1.3 Match the contour of the obstruction in the end of the next panel and lap it over the first one. (See Fig. 40(*b*).)

12.1.4 Apply flexible caulk around the obstruction to seal the penetration, but do not caulk the siding overlap.

12.2 *Installing Siding Around Electric Boxes*—Place J-channel around the service box, meter, or outlet cover in the same manner as for windows (see 9.2.3).

12.3 *Shutter Installation:*

12.3.1 Pre-drill holes through the shutters for attachment screws and mark their location on the siding. (See Fig. 41.)

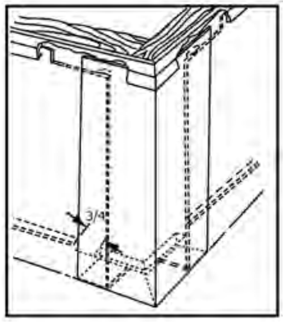



FIG. 38 Installation of Corner Cap

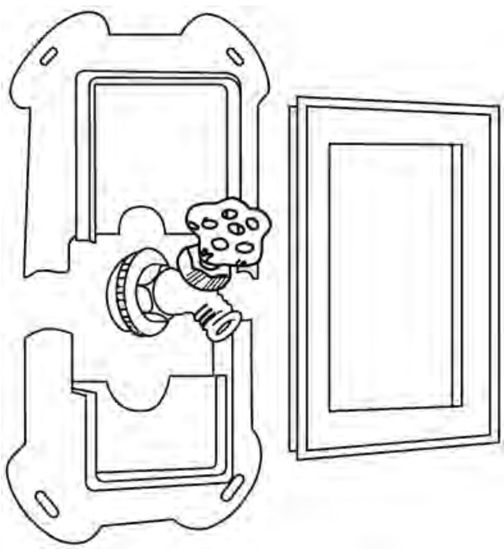
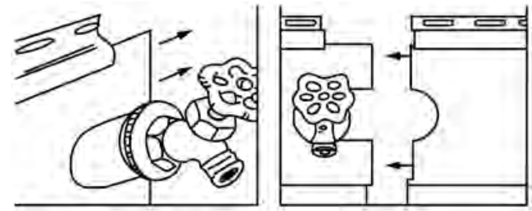


FIG. 39 Commercial Trim Ring



(a) Notch and install first (b) Notch and install second

FIG. 40 Fitting Siding

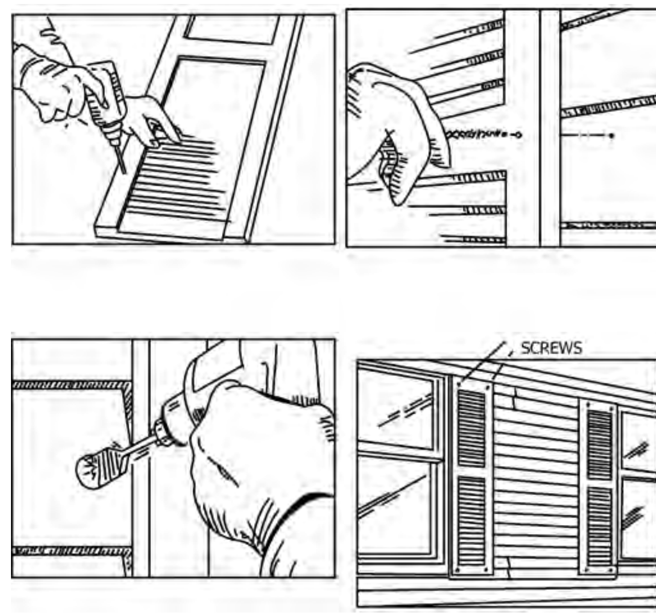



FIG. 41 Shutter Installation

12.3.2 Drill expansion holes through the siding (siding only) where attachment screws will be located, a minimum of ¼ in. (6.4 mm) larger than the diameter of the screw. (See Fig. 41.)

12.3.3 When attaching the shutters do not fasten such that the shutter bears tightly against the siding otherwise expansion of the siding will be restricted. (See Fig. 41.)

## 13. Keywords

13.1 crimp; horizontal siding; installation practice; poly(vinyl chloride) (PVC); vertical siding; vinyl siding; vinyl soffits

## SUMMARY OF CHANGES

Committee D20 has identified the location of selected changes to this standard since the last issue D4756 – 13 that may impact the use of this standard (February 1, 2015).

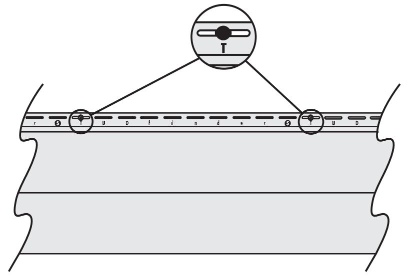
*(1)* Revised 1.1 to include a reference to applicable building codes.
*(2)* Revised 7.4.1 to remove reference to a vertical starter strip
*(3)* Revised Section 10 to describe proper installation without use of a vertical starter strip.

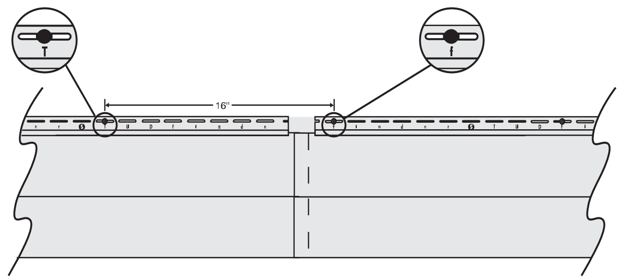
CertainTeed

# Installation Instructions
# CedarBoards™ Insulated Siding

These instructions describe and illustrate the steps involved in installing CertainTeed siding and trim. Their purpose is to provide detailed information and how-to tips that will simplify the installation process. CertainTeed shall not accept any liability or responsibility under its written warranty for failure caused by application that does not meet our minimum requirements for proper installation. These requirements are outlined throughout the *CertainTeed Installation Guide (CTS205)*. Any deviations from these requirements should be approved in writing by CertainTeed Corporation.

CedarBoards™ insulated siding will help even out wall surfaces. However, to minimize extremes in the peaks and valleys of uneven walls, you may have to repair the underlayment. Make sure the substrate is smooth and flat. If the surface is significantly uneven, apply 1/4" foam sheathing before installing CedarBoards siding.

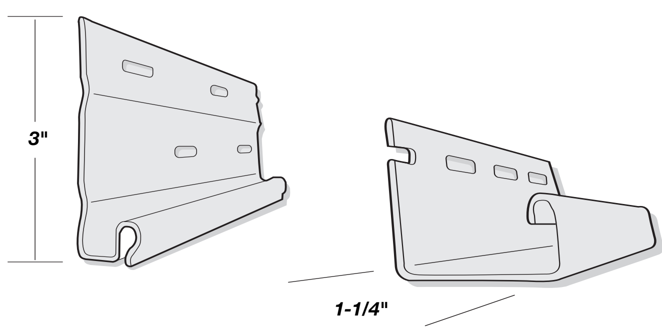





## Starter strips

Insulated siding is thicker than hollow vinyl siding. To accommodate the 1-1/4" thickness, we recommend that you use the CedarBoards starter strip.

When you can't use the CedarBoards starter strip, secure the siding panel with a combination of utility trim and J-channel. To do this, you will have to remove some of the foam backing and shim accessories to accommodate the thickness of the CedarBoards panel.




## Fastening

Use 2" corrosion-resistant nails, and penetrate the wood substrate by at least 3/4".

The nail flange on insulated siding is typically 3/4" thick. Drive the nails until there is 1/16" between the nail head and the nail flange.

Center the nail in the nail slot and drive the nail straight in. Do not drive nails at an angle. Space nails 16" o.c.

## STUDfinder™ Installation

The STUDfinder™ Installation System combines precisely engineered nail slot locations with graphics to create a siding panel that is designed to help ensure quick, accurate and secure installation.

The nail slots are positioned 16" on center to allow for alignment with studs, with STUDfinder graphics centered directly under each nail slot.

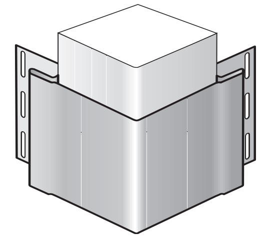
Locate the first stud and fasten in the center of the nail slot. Ensure that nail/staple penetration is at least 3/4". Notice which STUDfinder letter appears below the slot.

Go to the next repeat of the letter to find the next stud. For example, if your first stud is at "T," so will the succeeding studs in 16" o.c. applications (every 10th slot). When installing CedarBoards XL panels on 16" centers, the succeeding studs are at every 8th slot.

When you apply the next panel, adjust the overlap, as necessary, to line up with studs and repeat the steps above.

### Fitting into trim pieces

Around windows, doors, and other openings, use CedarBoards accessories. Insert the factory- or field-cut end of the siding panel into the accessories.



When the outside temperature is higher than 40° F, allow a 1/4" gap between the siding and the trim. When the temperature is less than 40° F, leave a 3/8" gap. For CedarBoards XL, allow a 3/8" gap between the siding and the trim when the outside temperature is above 40°F; 1/2" when the temperature is below 40°F.

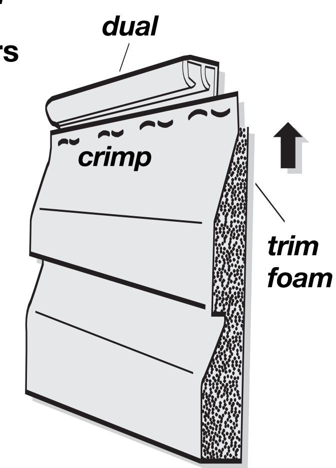
All other accessories should be fitted with foam shims and fillers. These shims will ensure that the accessories are on the same plane as the panels.

To fit panels into non-CedarBoards accessories, remove 1-1/4" of <u>additional</u> foam from the ends of factory-cut panels. Remove 2" of foam from the ends of field-cut panels. Fit all non-CedarBoards accessories with foam shims and fillers.

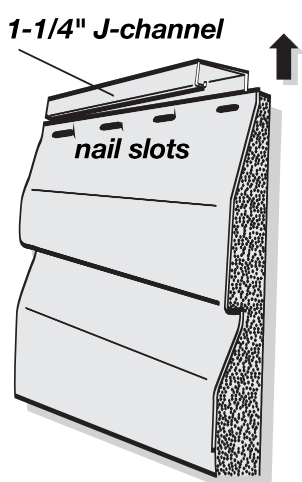
**NOTE:** ***If you use two 1-1/4" J-channels to form an inside cornerpost, you do not have to use shims or remove foam from the siding panels.***

### Around windows and doors

Because insulated siding is thicker than hollow vinyl siding, windows, doors, and other openings may have to be built out to avoid looking recessed. Use wood shims and either aluminum trim coil or vinyl lineals to build out openings. In some cases, the foam backing in CedarBoards siding will create enough stiffness to span over or under a window without additional support.



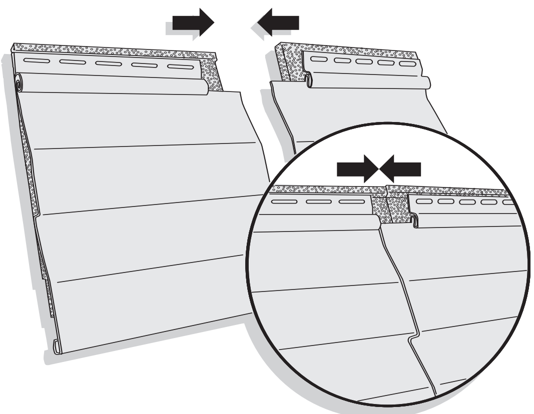

If you are using utility trim or dual undersill trim to secure the panel, shim the trim to accommodate the thickness of the siding panel. Remove the top 1" of the foam backing so the top of the panel fits into shimmed trim. Use a snap lock punch to raise tabs every 6" to lock the panels into the trim.




When you cut a siding panel to fit around an opening, use a nail slot punch to create additional nail slots. Fasten through these additional nail slots to secure the panel. Make sure the face of the J-channel or other trim will cover the nail slots.

### Under soffit

Secure the last course of siding under the soffit with utility trim, dual undersill trim, or cornice receiver with cornice molding. You will have to create tabs and nail slots as described above. You will also have to shim the trim and remove the top 1" of the foam so the top of the panel fits into the trim.



### Overlapping panels

On factory-cut panels, the foam is set back from both ends of the panel. The adhesive begins 2" back from the end of the foam. To correctly overlap the panels, slip the vinyl edge of the bottom portion of the seam between the foam and the vinyl panel. Slide the panels together until the foam ends touch.

For CedarBoards XL, overlap the panels 1-1/4" to 1-3/4" at temperatures above 40°F; 1" to 1-1/4" when the temperature is below 40°F.

If you have any questions about installing this product, please call us at 1-800-233-8990.

Known for its outstanding performance qualities, vinyl siding is increasingly the material of choice for homeowners, remodeling contractors, architects, and builders. Compared to other siding products, vinyl is attractive, durable, easy to maintain, and cost-effective. Siding is available in a variety of textures, ranging from matte surfaces to deeply embossed wood grain surfaces, which simulate wood clapboard siding.

For best results, it is recommended that vinyl siding meet the requirements of the Vinyl Siding Institute Sponsored Certification Program. See www.vinyl-siding.org for a current list of certified products.

This manual sets forth the basic guidelines for vinyl siding installation. The instructions herein are based, in part, on ASTM Specification D4756, the standard method for installation of vinyl siding and soffit. Updated information has been added as necessary. Additionally, it is recommended that installers review applicable building codes for variations that may apply to specific products or geographic areas.

The method of applying vinyl siding and soffit is essentially the same for new construction and residing. However, where required, special instructions for new construction and residing are included, as well as recommendations for historic restoration. In all applications, care should be exercised to properly prepare the structure. See the Basic Installation Rules and additional details throughout this document for proper installation techniques.

This publication is not intended to provide specific advice, legal or otherwise, on particular products or processes. Readers should consult with their own legal and technical advisors, building material suppliers, and other appropriate sources (including but not limited to product or package labels, technical bulletins or sales literature) that contain information about known and reasonably foreseeable health and safety risks of their proprietary products and processes. As the manufacturer of the vinyl siding we do not assume any responsibility for the users' compliance with applicable laws and regulations, nor for any persons relying on the information contained in this guide.

CONTENTS

The manufacturer has provided these suggested instructions as installation guidelines. The manufacturer, however, neither installs the panels nor has any control over the installation. It is the responsibility of the contractor and/or the installer to ensure panels are installed in accordance with these instructions and any applicable building codes. The manufacturer assumes no liability for either improper installation or personal injury resulting from improper use or installation.

### *Fire Safety Information*

Vinyl building materials require little maintenance for many years. Nevertheless, common sense dictates that builders and suppliers of vinyl products store, handle, and install vinyl materials in a manner that avoids damage to the product and/or the structure. Owners and installers should take a few simple steps to protect vinyl building materials from fire.

### *To Home and Building Owners:*

Vinyl siding is made from organic materials and will melt or burn when exposed to a significant source of flame or heat. Building owners, occupants, and outside maintenance personnel should always take normal precautions to keep sources of fire, such as grills, and combustible materials, such as dry leaves, mulch and trash, away from vinyl siding.

### *To the Building Trades, Specifiers, Professionals, and to Do-It Yourself Installers:*

When vinyl siding is exposed to significant heat or flame, the vinyl will soften, sag, melt, or burn, and may thereby expose materials underneath. Care must be exercised when selecting underlayment materials because many underlayment materials are made from organic materials that are combustible.

It is important to ascertain the fire properties of underlayment materials prior to installation. All building materials should be installed in accordance with local, state, and federal building code and fire regulations.

### *Storage and Transportation*

When transporting vinyl siding and accessories to the job site, make certain to keep the cartons flat and supported along their entire length. At the job site, take the following precautions when storing panels:

- Store the cartons on a flat surface and support the entire length of the cartons.
- Keep the cartons dry.
- Store the cartons away from areas where falling objects or other construction activity may cause damage.
- Do not store the cartons in stacks more than 6 boxes high.
- Do not store the cartons in any locations where temperatures may exceed 130º F (e.g., on blacktop pavement or under tarps or plastic wraps without air circulation).

### *Residing over Asbestos Siding*

Asbestos siding is a regulated material and the appropriate environmental agency should be contacted before residing over this product begins.

The manufacturer has provided these suggested instructions as installation guidelines. The manufacturer, however, neither installs the panels nor has any control over the installation. It is the responsibility of the contractor and/or the installer to ensure panels are installed in accordance with these instructions and any applicable building codes. The manufacturer assumes no liability for either improper installation or personal injury resulting from improper use or installation.

**1.** Installed panels must move freely from side to side.

**2.** Do not stretch horizontal siding panels upward when applying: instead, push upward on the bottom of the panel you are installing, until the locks fully engage. Nail in place. Panels should hang without strain after nailing. Stretching the panel upward pulls the natural radius out of the panel and increases the friction of the locks.

**3.** Always nail in the center of the slot. **WARNING: Do not nail at the end of a slot!** Doing so will cause the siding panel to be permanently damaged. If you must nail near the end of a slot to hit a stud, etc., extend the length of the slot with a nail slot punch tool.

**4.** Do not nail tightly. Allow a minimum of 1/32″ between the back of the nail head, screw or staple crown and the nailing strip. Nails or staples should be placed approximately 12″ to 16″ apart. Drive fasteners straight and level to prevent distortion and buckling of the panel. For fastening specs, see page 13.

5. Leave a minimum of 1/4″ clearance at all openings and stops to allow for normal expansion and contraction. When installing in temperatures below 40º F, increase minimum clearance to 3/8″.

**6.** Do not caulk the panels where they meet the receiver of inside corners, outside corners, or J-Channel Trim. Do not caulk the overlap joints.

**7.** Do not face-nail or staple through siding. Vinyl siding expands and contracts with outside temperature changes. Face-nailing can result in permanent ripples in the siding.

**8.** Panels should be overlapped approximately 1″. Fasten panels approximately 8″ or more from the overlap seam for best lap appearance.

**9.** Avoid the use of unstable or uneven underlayment. Keep in mind that siding can only be as straight and stable as what lies under it. See Section “Preparing the Walls” for more information.

**10.** When installing shutters, cable mounts, etc., make sure screw hole in the siding is 1/4″ larger than the attachment screw diameter. (Example: an 1/8″ screw requires a 3/8″ hole in the siding.) This will allow the panel to still expand and/ or contract.

**11**. Never attach fixtures directly to panels. When attaching fixtures, first drill a hole in the siding 1/4″ larger than the diameter of the fasteners, allowing for expansion and contraction. Note: Fasteners for fixtures must penetrate the solid substrate.

The beauty of vinyl siding is maintained with little effort. Although vinyl siding will get dirty, like anything exposed to the atmosphere, a heavy rain will do wonders in cleaning it. Or, it's possible to wash it down with a garden hose. If neither rain nor hosing does a satisfactory job, follow these simple instructions:

**1.** Use an ordinary, long-handled car washing brush. This brush has soft bristles, and the handle fastens onto the end of the hose. It allows the siding to be washed just like a car. Avoid using stiff bristle brushes or abrasive cleaners, which may change the gloss of the cleaned area and cause the siding to look splotchy.

**2.** When washing down your entire house, start at the bottom and work up to the top in order to prevent streaking. Rinse Cleaning Solution with water before it dries. If your house has brick facing, cover the brick so that it is not affected by the runoff.

**3.** Follow the precautionary labeling instructions on the cleaning agent container. Protect shrubs from direct contact with cleaning agents.

**4.** To remove soot and grime found in industrial areas, wipe down the siding with a solution made up of the following:

1/3 cup powdered detergent [(e.g. Fab®, Tide®, or equivalent powder detergent)]*

2/3 cup powdered household cleaner [(e.g., Soilax®, Spic & Span®, or equivalent)]*

1 gallon water

**5.** If mold and mildew are a problem, add one quart of liquid laundry bleach to the cleaning solution mentioned above.

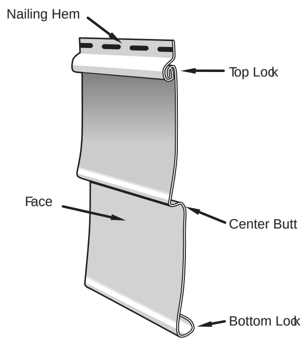
**6.** For stubborn stains, use the chart on the right. (page 6)

• Cleaning materials are listed in alphabetical order. The manufacturer does not endorse proprietary products or processes and makes no warranties for the products referenced herein. Reference to proprietary names is for illustrative purposes only and is not intended to imply that there are not equally effective alternatives.

| STAIN | CLEANERS* |
| --- | --- |
| *Bubble Gum* | Fantastik®, Murphy's Oil Soap®, or solution of vinegar [30 percent] and water [70 percent] |
| *Crayon* | Lestoil® |
| *DAP [Oil-based caulk]* | Fantastik® |
| *Felt-Tip Pen* | Fantastik® or water-based cleaners |
| *Grass* | Fantastik®, Lysol®, Murphy's Oil Soap®, or Windex® |
| *Lipstick* | Fantastik®, or Murphy's Oil Soap® |
| *Lithium Grease* | Fantastik®, Lysol®, Murphy's Oil Soap®, or Windex® |
| *Motor Oil* | Fantastik®, Lysol®, Murphy's Oil Soap®, or Windex® |
| *Paint* | Brillo® Pad or Soft Scrub® |
| *Pencil* | Soft Scrub® |
| *Rust* | Fantastik®, Murphy's Oil Soap®, or Windex® |
| *Tar* | Soft Scrub® |
| *Topsoil* | Fantastik®, Lysol®, or Murphy's Oil Soap® |

**CAUTION: Do not use or mix sodium hypochlorite with other household chemicals or products containing ammonia. To do so will release hazardous gasses.**

*Cleaning materials are listed in alphabetical order. The manufacturer does not endorse proprietary products or processes and makes no warranties for the products referenced herein. Reference to proprietary names is for illustrative purposes only and is not intended to imply that there are not equally effective alternatives.




***Backerboard/Underlayment***—a flat material used on the face of the house, between the studs and the siding, to provide a flat surface for the siding.

***Bottom Lock***—the bottom edge of a siding or a soffit panel, or accessory piece, opposite the nailing slots, which locks onto the preceding panel.

***Channel***—the area of the accessory trim or corner post where siding or soffit panel is inserted. Channel also refers to the trim itself, and are named for the letters of the alphabet they resemble (e.g., J-Channel, F-Channel, etc.).

***Course***—a row of panels, one panel wide, running the length of the house. Or, in the case of vertical siding, from top to bottom.

***Drip Cap / Head Flashing***—an accessory installed to channel water away from siding panels and sub-wall. Drip cap is often used on the tops of windows/doors and when transistioning from horizontal to vertical siding.

***Face***—refers to the side of a siding or soffit panel that is exposed once the panel has been installed.

***Fascia Board***— (sometimes referenced as a sub fascia) board attached to the ends of the rafters between the roofing material and the soffit overhang.

***Fascia Cap***—the covering installed on the fascia board.

***Flashing***—a thin, flat material, usually aluminum, positioned under or behind J-Channels, Corner Posts, Windows, etc., to keep draining water from penetrating the home.

***Furring/Furring Strip***—a wooden framing material, usually 1″ x 3″, used to provide an even nailing base. To "fur" a surface means to apply these strips.

***H-Mold (Double Channel Lineal)***—a siding accessory that joins the ends of vertical siding and soffit panels.

***Housewrap***—weather-resistant, breathable film used to cover wood underlayment prior to the installation of siding.

***Lap***—to overlap the ends of two siding panels or accessory pieces to join the panels/pieces and allow for expansion and contraction of the vinyl product.

***Lug/Crimp***—the raised "ears" or tabs on a siding panel, created by a snaplock punch, which can be used to lock a siding panel into undersill trim when the nailing hem has been removed.

***Miter***—to make a diagonal cut, beveled to a specific angle (usually 45º).

***Nailing Hem (or Flange)***—the section of siding or accessories where the nailing slots are located.

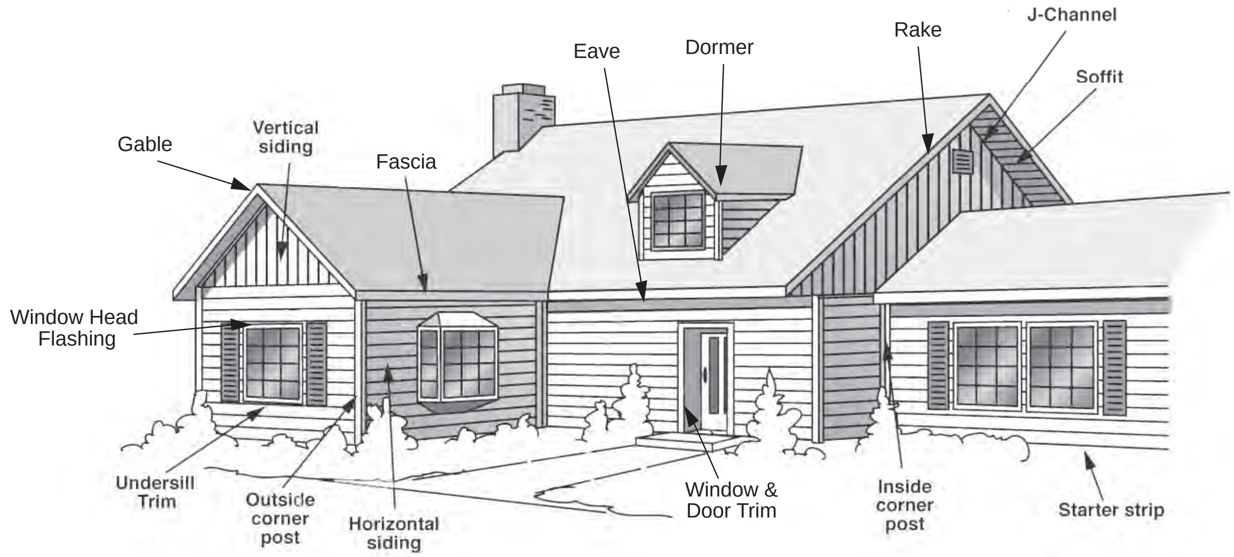
***Plumb***—a position or measurement that is truly and exactly vertical, 90º from a level surface.

***Scoring***—running a utility knife blade across a soffit or siding panel face without cutting all the way through the panel. This weakens the vinyl surface in a specific area and allows the panel to be bent and broken off cleanly.

***Soffit***—material used to enclose the horizontal underside of an eave, cornice or overhang.

***Starter Strip***—an accessory applied directly to the surface of the building and used to secure the first course of siding to the home.

***Weep Holes***—openings cut into the siding panel or accessories during the manufacturing process to allow for water runoff.




### *Outside and Inside Corner Post*

Corner posts are used to provide a finished edge at an inside or outside corner. The siding from adjoining walls fits neatly into the inside or outside corner post channels.

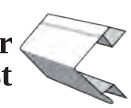
***NOTE: We produce various sizes of J-Channels and Corner Posts. Remember to order accessories of the proper size to accommodate the siding panels.***

### *Trim and Molding*

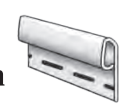
A complete line of accessories is used to give every installation a professional, weather-resistant appearance. Common accessories include Corner Posts, Starter Strips, F-Channels, Undersill Trim, and J-Channels (left). Each of these accessories will be addressed in more detail throughout this manual.

**Inside Corner Post**

**Outside Corner Post**



**Undersill Trim**



**J-channel**

**Starter Strip**

**F-channel**

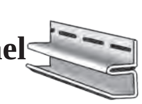


Fig. 1

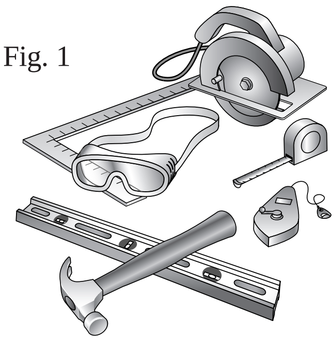


Fig. 2

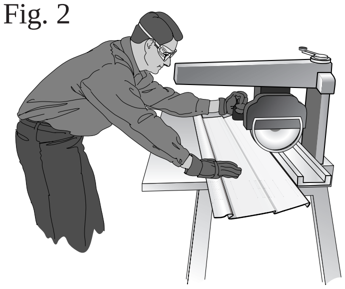
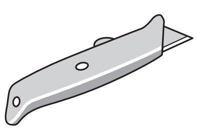


Fig. 3



***Hand Tools***
Common hand tools, such as a hammer, saw, square, chalkline, level, and tape measure are needed for proper installation (Fig. 1). Safety glasses are recommended for eye protection. Other basic tools include:

***Power Saw***
A bench or radial-arm power saw can speed the cutting of the siding. A finetooth blade (12 to 16 teeth per inch) should be used with the blade installed in the reverse direction. Some applicators prefer a hand-held power saw and a field-built cutting table. In extremely cold weather, move the saw through the material slowly to prevent chipping or cracking (Fig. 2).

***Utility Knife***
Vinyl is easy to cut, trim and score with a utility knife or scoring tool (Fig. 3).

**NOTE: A saw blade set up in reverse direction should be used only for cutting vinyl. DO NOT attempt to use it on other materials such as wood, plywood, etc.**

***Tin Snips***
Good quality tin snips and compound aviation-type snips will speed the cutting and shaping of the vinyl (Fig. 4).

***Snaplock Punch***
A snaplock punch is used to punch lugs in the cut edges of siding to be used for the top or finishing course at the top of a wall, or underneath a window (Fig. 5).

***Nail Hole Punch***
Occasionally, it may be necessary to elongate a nail slot. The hole is elongated to allow for expansion and contraction (Fig. 6).

***Unlocking Tool (Zip-Lock Tool)***
Remove or replace a siding panel with the unlocking tool. Insert the curved end of the tool under the end of the panel and hook onto the back lip of the buttlock. To disengage the lock, pull down and slide the tool along the length of the panel. Use the same procedure to relock a panel (Fig. 7).

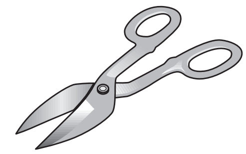


Fig. 4

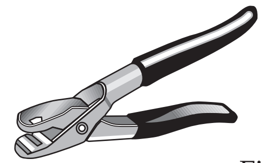


Fig. 5

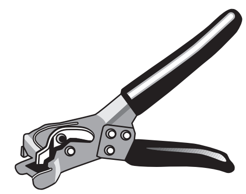


Fig. 6

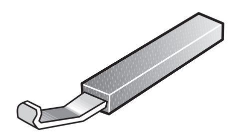
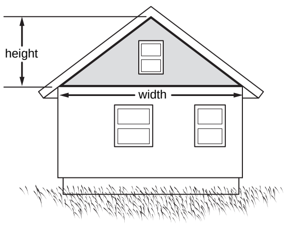
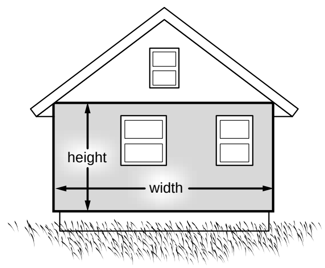


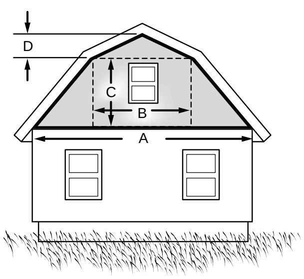
Fig. 7



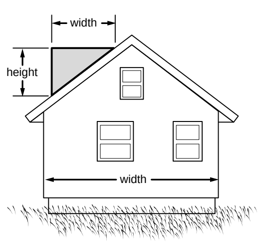

($1/2$ height)____feet x width____feet=____square feet




Height____feet x width____feet=____square feet




$1/2$ ( A + B ) x C + $1/2$ B x D = ___total area of gable (square feet)




($1/2$ height)____feet x width____feet =____total area of dormer (square feet)

**1.** All houses can be broken down into shapes of rectangles, triangles or a combination of both.

**2.** The area to be sided can be determined by measuring the height and width of the house, including windows (below).

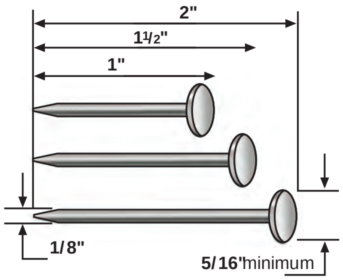
**3.** Total all of the measurements for the areas to be sided. Windows and doors are not usually deducted. Including them will provide an allowance factor for waste. If the windows and doors are extremely large (such as garage or sliding glass doors), some deductions can be made. Dormers and gables are prone to material waste due to cutting and fitting.

**4.** To estimate the amount of starter strip required, measure the linear feet around the entire base of the house. When measuring linear footage, add a factor of 10 percent to allow for waste.

***Use the following worksheet to estimate the required materials:***

| | | | |
|---|---|---|---|
| **Siding Walls** | | | ____square feet |
| | Gable ends | | ____square feet |
| | Upper gambrel walls | | ____square feet |
| | Total wall surface area | | ____square feet |
| | Large areas not covered | | ____square feet [A] |
| | [garage doors/sliding doors] | x0.50= | |
| | Uncovered area | | ____square feet [B] |
| | Subtract B from A for | | |
| | Total net surface area | | ____ square feet |
| **Soffit** | | | ____square feet |
| **Porch Ceiling** | | | ____square feet |
| **Accessories** | Starter Strip | | ____linear feet |
| | Utility trim | | ____linear feet |
| **Receiving channel** | J-Channel | | ____linear feet |
| | Flexible J-Channel | | ____linear feet |
| | F-trim | | ____linear feet |
| | 3 1/2″ and 5″ Window & Door Surround | | ____linear feet |
| **Outside corners** | Outside corner post | | ____linear feet |
| | Fluted corner trim | | ____linear feet |
| **Inside corners** | Inside corner post | | ____linear feet |
| | J-Channel | | ____linear feet |
| **Other** | Soffit cove trim | | ____linear feet |
| | H-molding | | ____linear feet |
| | Light blocks | | ____linear feet |
| | Width of accessory recess opening: | | |
| | [please circle one] 1/2″ 5/8″ 3/4″ 1 1/8″ | | |
| **Nails** | Pounds required | | |
| | Length [1 1/2″minimum] | | ____pounds |

| | | | |
|---|---|---|---|
| **Tools needed** | ___hammer | ___tin snips | ___chalkline |
| | ___utility knife | ___square | ___hacksaw |
| | ___nail hole punch | ___tape measure | ___level |
| | ___power saw | ___unlocking tool | |
| | ___snaplock punch | ___finetooth saw blade | |




Use aluminum, galvanized steel or other corrosion-resistant nails, staples or screws when installing vinyl siding. Aluminum trim pieces require aluminum or stainless steel fasteners.

### *Nails*

Nail heads should be 5/16″ minimum in diameter. Shank should be 1/8″ in diameter.

Minimum nail lengths are as follows:

- 1 1/2″ for general use
- 2″ for residing
- 1″ to 1 1/2″ for trim

### *Screw Fasteners*

Screw fasteners can be used if the screws do not restrict the normal expansion and contraction movement of the vinyl siding panel on the wall. Screws must be centered in the slot with a minimum 1/32″ space between the screw head and the vinyl.

Screws should be:

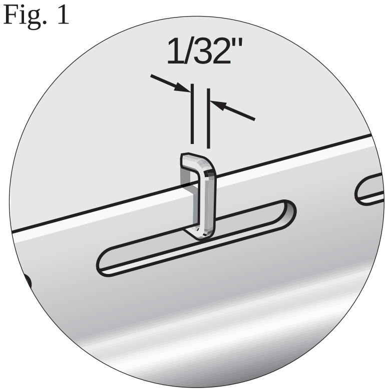
- Size #8, truss head or pan head.
- Corrosion-resistant, self-tapping sheet metal type.

### *Staples*

If staples are being used instead of nails or screws, they must be:

- Not less than 16-gauge semi-flattened to an elliptical cross-section (Fig. 1).
- Wide enough in the crown to allow free movement of the siding.
- 1/32″ clearance between staple crown and nailing hem of the siding panel. Make sure to adjust staple gap to allow for 1/32″ clearance.

Fig. 1




**** All fasteners must be long enough to penetrate into the framing 3/4 of an inch.***

Vinyl siding can expand and contract 1/2″ or more over a 12′ 6″ length with changes in temperature. Whether using a nail, screw or staple to fasten the siding, the following basic rules must be followed:

***Step 1***
Make sure the bottom lock of the panels are fully engaged along the entire length of the panel. WARNING: Push the panel up fully but do not stretch the panel by pulling it from the top.

***Step 2***
**Do not** drive the head of the fastener tightly against the siding nail hem. Leave a minimum of 1/32″ (the thickness of a nickel) between the fastener head and the vinyl. Tight nailing, screwing, or stapling will cause the vinyl siding to buckle with changes in temperature (Fig.1).
If the head or crown contacts the vinyl panel it may “pimple” or distort due to heat build-up.

***Step 3***
After locking the panel, fasten the panel in the center, work in, to both ends.This method helps keep panels running straight.

***Step 4***
Nail 8″ or more away from the end of a panel that will be overlapped with another panel. This will help the overlap appearance.

Center the fasteners in the slots to permit expansion and contraction of the siding (Fig. 2).

***Step 5***
Drive fasteners straight and level to prevent distortion and buckling of the panel (Fig. 3).

***Step 6***
Space the fasteners a maximum of 16″ apart for horizontal siding panels, 12″ apart for vertical siding panels, and 8″ to 10″ apart for the accessories.

***Step 7***
Start fastening vertical siding and corner posts in the top of the upper-most slots to hold them in position. Place all other fasteners in the center of the slots (Fig. 4).

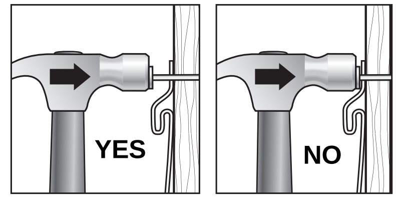


Fig. 1

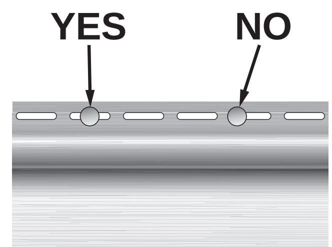


Fig. 2

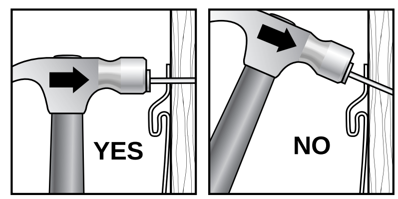


Fig. 3

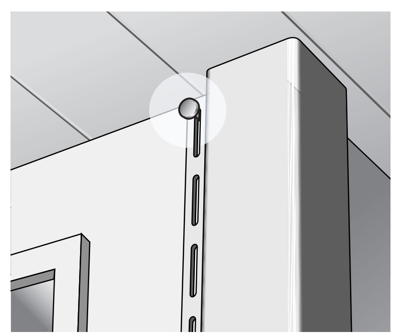


Fig. 4

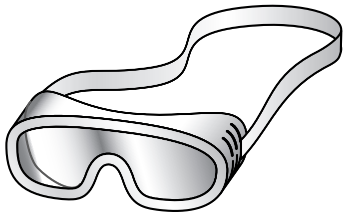


Fig. 1

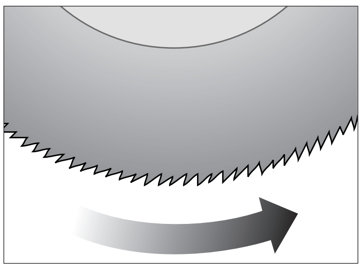


Fig. 2

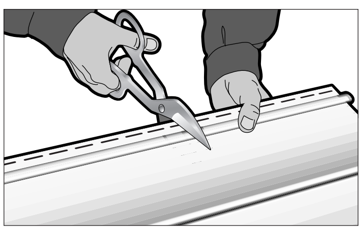


Fig. 3

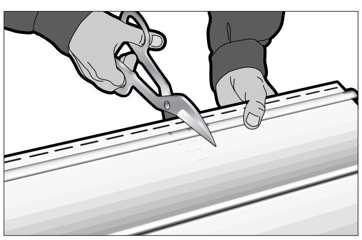


Fig. 4

When cutting vinyl siding, follow these guidelines:

***Step 1***
Safety goggles are always recommended for all cutting and nailing operations. As on any construction job, use proper safety equipment and follow safe construction practices (Fig. 1).

***Step 2***
With a circular saw, install the fine-toothed (plywood) blade backward on the saw for a smoother, cleaner cut. Cut slowly. Do not attempt to cut materials other than vinyl with a reversed direction saw blade (Fig. 2).

***Step 3***
With a utility knife or scoring tool, score the vinyl face up with medium pressure and snap it in half. It is not necessary to cut all the way through the vinyl (Fig. 3).

***Step 4***
With tin snips, avoid closing the blades completely at the end of a stroke for a neater, cleaner cut (Fig. 4).

***Sheathing/Backerboard***

Our vinyl siding should be applied over a sheathing that provides a smooth, flat, stable surface. Consult local building codes for sheathing requirements. Vinyl siding should never be applied directly to studs without sheathing. **We recommend that wood-based sheathings be protected utilizing moisture-resistant housewrap or building paper prior to the installation of the siding and accessories. Some building codes now require this protection.**

***Flashing***

Flashing, such as aluminum coil, roofing felt or house wrap, should be applied around windows, doors, other openings, inside and outside corners, and the intersection of walls and roofing to prevent water infiltration.

## *New Construction*

### *Step 1*

Make sure all studs are straight and true to avoid bulges or dips in the finished wall. Correct any bowed studs at this time.

### *Step 2*

Make sure all sheathing is properly fastened to the framing according to building code requirements and/or the sheathing manufacturer's recommendations.

*NOTE: Sheathing behind vinyl siding must be smooth, flat, stable and appropriate for use on the type of construction being erected. Increasing requirements in building codes, especially in the areas of fire and wind resistance, make the appropriate choice and fastening of wall sheathing an important area of consideration. Check local building codes for the allowable type and thickness of sheathing that can be utilized on the type of structure being sided.*

### *Step 3*

Make sure subwall assembly is weathertight before applying siding. Vinyl siding and vinyl siding accessories alone do not constitute a waterproof installation. The combination of proper subwall preparation and siding installation result in the desired protection of the structure.

Wall sheathing should be weather-resistant, or covered with a weather-resistant barrier such as fanfold insulation, housewrap, or building paper. **Independent VSI studies indicate that the combination of a weather resistant barrier plus a housewrap result in improved weather performance of the vinyl siding.** Some building code jurisdictions are currently requiring this protection.

A weather-resistant covering should be properly fastened according to the manufacturer's instructions, and be smooth and even. Flashing and caulking should be added as needed in areas such as windows, doors, and other openings to control moisture and to protect the subwall assembly.

*WARNING: A smooth, flat, stable wall surface is necessary for the proper installation of vinyl siding. Waviness in the finished siding resulting from uneven or inadequate backerboard sheathing constitutes misapplication under the terms of the warranty.*

*TIP: Place the drywall in the house, on the floor of the room where it is going to be applied, prior to the installation of the siding when possible. This will help load the floor system and the floor band prior to applying siding. This can help reduce panel bulging in the floor band areas where compression and shrinkage typically occur.*

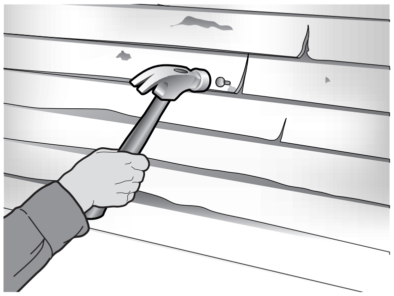


Fig. 1

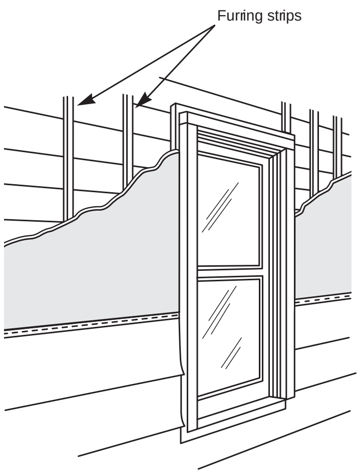



Fig. 2

## *Residing Existing Structures*

### *Step 1*

Nail down any loose boards on existing siding, and replace any rotten wood as needed. DO NOT INSTALL VINYL SIDING OVER ROTTEN WOOD. (See Fig. 1)

### *Step 2*

Scrape off loose caulk and any other buildup that may interfere with the siding installation. Remove all items such as gutters, downspouts, and light fixtures as needed.

### *Step 3*

Install suitable sheathing, as needed, to provide a smooth, flat, and stable surface for the installation of the vinyl siding. See information previously given in this segment for additional instructions on subwall protection and flashing.

### *Step 4*

Install furring in areas needing straightening and leveling. Apply rigid sheathing to cover and level the furring strips. Do not apply vinyl siding directly to furring strips without sheathing, because the siding may conform around the furred areas causing an uneven appearance. (See Fig 2)

### *Step 5*

Window and door casings may need additional attention or preparation. Depending on vinyl siding moldings being used, a window/door casing generally needs to extend out from the finished subwall sufficiently, to allow a J-Channel or similar molding to butt to it. In some situations, building out the casings, or using special purpose moldings such as Window and Door Surround may be necessary.

### *Over Masonry Sub-surface*

A minimum 1″ x 3″ wood strips are installed with masonry nails over the masonry area to be sided (Fig. 1). For increased decay resistance, use pressure treated furring strips.

### *Step 1*

For horizontal siding, strips should be installed vertically 16″ on center. They should be installed completely around doors, windows and other openings, at all corners, and at the top and bottom of the area to be sided.

### *Step 2*

For vertical siding, furring is essentially the same as for horizontal siding. Strips should be nailed horizontally 12″ centers.

*NOTE: Furring strips should be covered with insulated sheathing or the spaces between the furring strips should be filled in with insulated sheathing equal in thickness to the furring strips. This will provide an even wall surface for the siding and help avoid any waviness.*

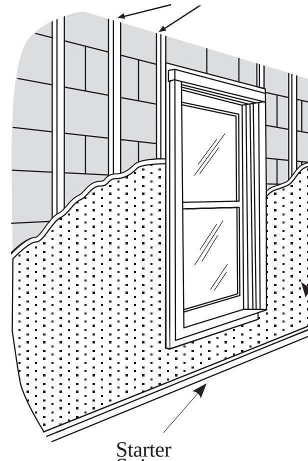



Fig. 1

STARTER STRIP

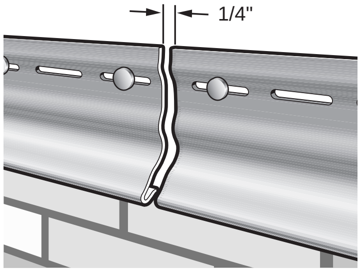



Fig. 1

Before the vinyl siding itself can be installed, a number of accessories must be installed first, including starter strips, corner posts, window flashing, trim and J-Channels.

***Step 1***
In order for the vinyl siding to be installed properly in a level fashion, the starter strip at the bottom of the wall must be level.

***Step 2***
The starting chalk line should be located so that it represents the top, not the bottom, of the starter strip.

Chalk lines are normally established from the lowest corner of the house. In situations where the ground at the corner of the house is not level, chalk lines must be measured from the soffit location to assure a uniform panel at the top of the walls.

***Step 3***
Attach a chalkline: go to the next corner and pull the line taut.

***Step 4***
Snap the chalkline and repeat the procedure around the entire house.

***Step 5***
Using the chalkline as a guide, install the top edge of the starter strip along the bottom of the chalkline, nailing at 10″ intervals. Allow space for accessories (corner posts, J-Channels, etc.)

***Step 6***
Keep the ends of starter strips at least 1/4″ apart to allow for expansion (Fig. 1).

***Step 7***
Nail in the center of the starter strip nailing slots.

***Step 8***
Starter strip fasteners should be driven just flush in the center of the slots to take out starter looseness, but should not be overdriven to where it indents the starter.

In most situations a typical starter strip is used to start the first course of siding. Special circumstances (panel application around decking, special roof lines and other unique applications) may require other techniques to secure the first panel locking leg. This can be accomplished in several manners (as illustrated in Figures 1 & 2).

Anytime a J-Channel is used as a starter strip it must have a 3/16″ diameter hole drilled no greater than 24″ on center to allow for water drainage.

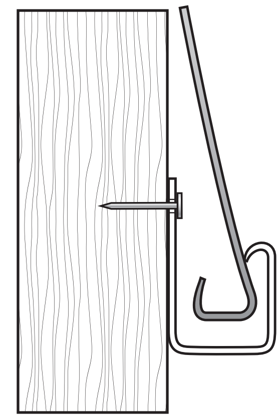


Fig. 1
Inside J-Channel

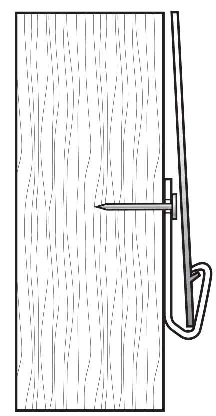


Fig. 2
Undersill with Snaplock

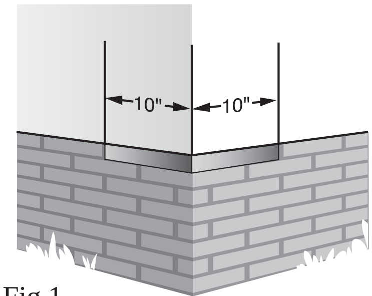



Fig.1

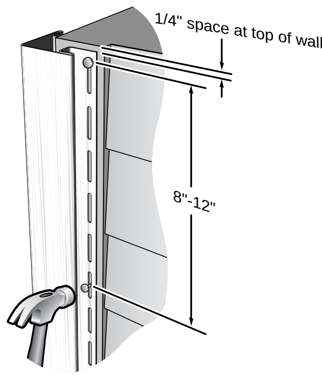



Fig. 2

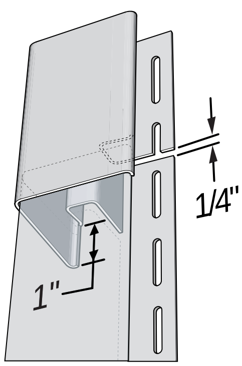



Fig.3

### *Step 1*

A water-resistant material should be used to flash the inside and outside wall corners a minimum of 10″ on each side before installation of the corner posts. A housewrap would be an adequate flashing (Fig. 1).

### *Step 2*

Place the corner post in position, allowing a 1/4″ gap between the top of the post and the eave or soffit (Fig. 2).

*NOTE: If vinyl or aluminum soffit will be installed, either install prior to corner post installation or allow for soffit and accessory thickness when positioning the height of the corner.*

Position a nail at the top of the upper slot on both sides of the corner post, leaving a 1/32″ gap between the nail heads and the corner post nailing hem. The corner post hangs from these nails. The balance of the nailing should be in the center of the slot, 8″ to 12″ apart, again leaving 1/32″ between the nail head and the corner post. This allows for the expansion and contraction to occur at the bottom. The corner post should extend 3/4″ below the starter strip. Make sure the posts are vertically straight and square.

**Do not nail corner post tight.**

### *Step 3*

If more than one length of corner post is required, overlap the upper corner post over the lower corner post.

### *Splicing Outside Corner Post*

Remove 1″ from the nail hem and receiving channel of the bottom end of the top piece. Position uncut top end of lower post under bottom edge of upper post allowing a 1/4″ gap at the nail for expansion and contraction. (Fig. 3).

### *Splicing Inside Corner Post*

Cut 1″ off all but the outer face of the upper portion of the bottom corner post. (Fig 4) Lap 3/4″ of the upper post over the lower post, allowing 1/4″ for expansion.

This method will produce a visible joint between the two posts, but will allow water to flow over the joint, reducing the chance of water infiltration.

### *Capping a Corner Post*

#### *Step 1*

Corner posts on homes with a second-story overhang need to be capped by making the cuts shown. Allow approximately 2″ extra length on the corner post. Trim away everything except the 2 faces. Fold the flaps created over each other as indicated (Fig. 5).

#### *Step 2*

Drill a 1/8″ hole in the center through both layers of vinyl, and install a pop rivet to hold them in place. Cut a notch in both layers to allow clearance for the corner (Fig. 5).

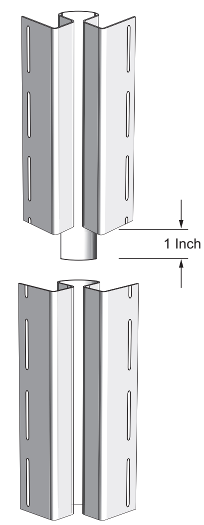



Fig. 4

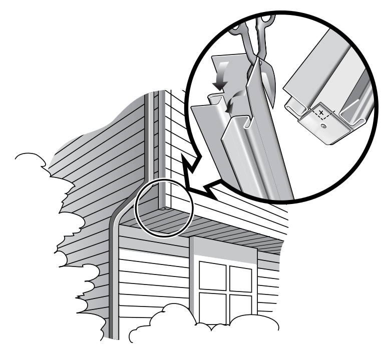


Fig. 5

DECORATIVE 3-PIECE CORNER SYSTEM

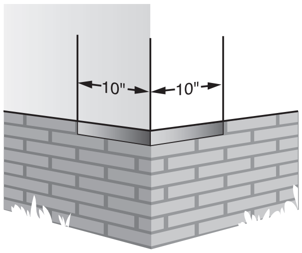



Fig.1

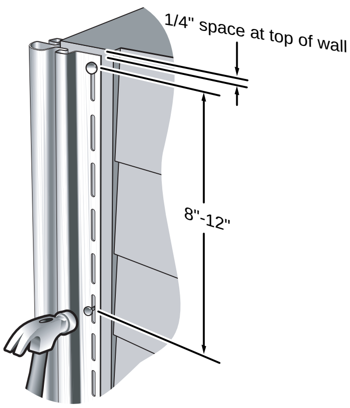



Fig. 2

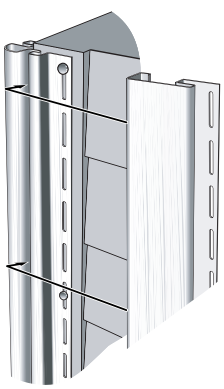


Fig. 3

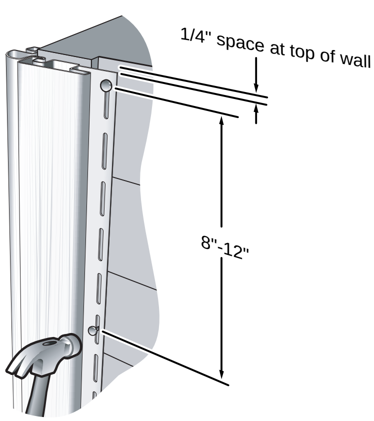



Fig. 4

### *Step 1*

A water-resistant material should be used to flash the inside and outside wall corners a minimum of 10″ on each side before installation of the 3-piece corner system (Fig. 1).

### *Step 2*

Place the Decorative Corner Starter on the outside wall corner, allowing a 1/4″ gap between the top of the post and the eave or soffit, and extending 3/4″ below the siding starter strip.
Cut to length (Fig. 2).

Position a nail at the top of the upper full slot on both sides of the Decorative Corner Starter, leaving a 1/32″ gap between the nail heads and the corner post nailing hem. The Decorative Corner Starter hangs from these nails. The balance of the nailing should be in the center of the slot, 8″ to 12″ apart, again leaving 1/32″ between the nail head and the Decorative Corner Starter. This allows for proper expansion and contraction clearance. Make sure the Decorative Corner Starter is installed vertically straight and true.

**Do not nail corner post tight.**

### *Step 3*

For typical installations, cut two 3-1/2″ or 5″ Window & Door Surround lineals to the same length as the Decorative Corner Starter. Snap the locking side of a Window & Door Surround into one side of the receiving lock section of the Decorative Corner Starter (Fig. 3). Repeat the procedure for installing the other Window and Door Surround.

### *Step 4*

Make sure that all 3 parts are fully locked and line up evenly at the top and bottom. Fasten the Window & Door Surround lineals to the wall following the same nailing procedures outlined in Step 2 (Fig. 4).

## *Lineals*

### *Step 1*
Create a watertight seal:

Apply a 1/8″ bead of caulk around the perimeter of the window or door frame before installation.

Apply caulk around the corner of the nail fin and where the window or door meets the sheathing.

Measure the width of the top of the frame and cut a piece of starter strip 1/8″ less than the frame. (Fig.1)

### *Step 2*
Butt the starter strip against the opening, center it and nail every 8″ to 12″ being sure to nail in the center of the nailing slots.

*(Starter strips are available for both new construction and remodeling applications.)*

Continue to measure and cut starter strips for the other sides of the frame. Be sure to cut starter strips 1/16″ less than each measurement. (Fig.2)

### *Step 3*
Install the starters. For vertical starter strips, nail the first nail in the upper most edge of the first slot. All other nails should be centered in the slots every 8″ to 12″. (Fig.3)

### *Step 4*
Measure and cut the lineals. For 3-1/2″ lineals add 7″ to your measurement in order to accommodate their widths at corners For 5″ lineals, add 10″.

Lineals should be installed in the following order: top, sides, bottom. (Fig. 4)

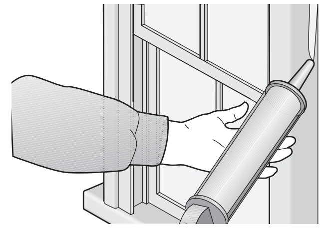


Fig.1

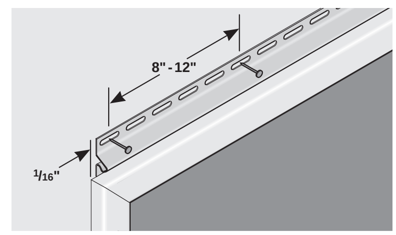



Fig. 2

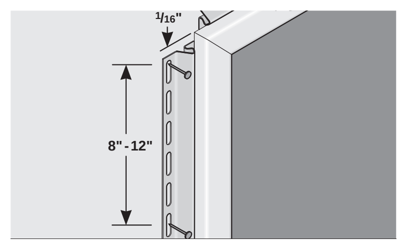



Fig. 3

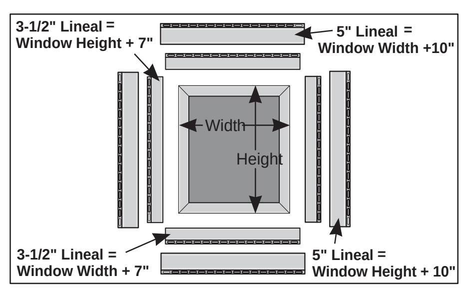



Fig. 4

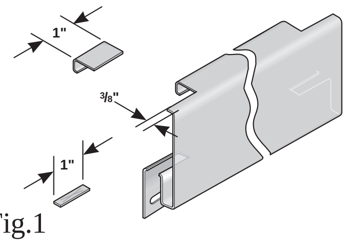



Fig.1

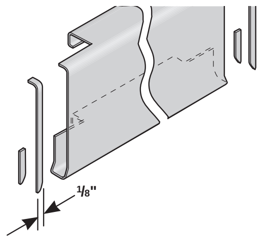
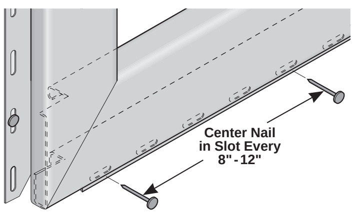



Fig.2

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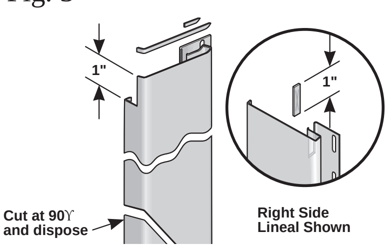



Fig. 4

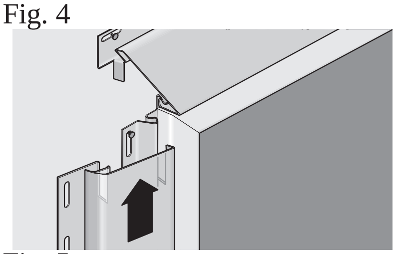


Fig. 5

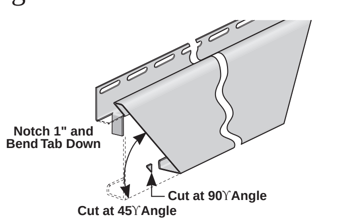



Fig.6

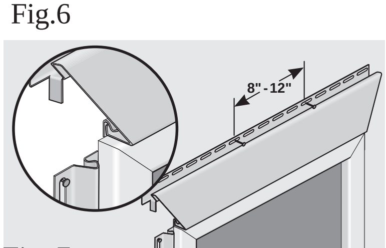



Fig. 7

*To install the bottom lineal*

Cut a notch on each side of the back of the lineal as shown. Cut a 1″ notch out of the nailing hem side. (Fig.1)

Make a 1/8″ curved sliver cut on the bottom front of the lineal. Push the locking leg of the lineal into the channel of the starter.

Nail the bottom lineal into place only after the side lineals are installed.

Work the bottom lineal into place by flexing the material to fit it together with the side lineals, lapping the side lineals over the bottom lineal.

Complete by nailing the bottom lineal every 8″ to 12″with nails centered in slots. (Fig.2 & Fig. 3)

*To install side lineals*

Cut a 1″ notch off the legs for the top of the lineal and a 45° miter cut for the bottom. Cut a 1″ notch out of the nailing hem side. Make curved sliver cuts on the top of the lineal. *NOTE: Right and left lineals should have opposite cuts. (*Fig. 4)

Push side lineals into the channel of the Starter about 2″ down from the header and slide the lineal into place.

Fit tabs of the header lineal down into the side lineals.

Nail top nail of the side vertical lineal into the top of the slot, then nail lineals into place every 8″ to 12″ with nails centered in slots. (Fig. 5)

*To install the top lineal...*

Miter each end of the lineal at a 45° angle. Notch the channel 1″ to form a flap and bend it down (do this on both ends) (Fig.6)

Push the locking leg of the lineal into the channel of the starter and center it above the frame. Nail every 8″ to 12″ with nails centered in slots of lineal. (Fig. 7)

## Window Mantels

### Standard Length Mantels

Locate the centerline of where the mantel will be installed. Measure to each side of the centerline as specified for each length mantel (see chart below).

| Mantel Length | Measurement |
|---|---|
| 36" | 16-5/8" |
| 40" | 18-5/8" |
| 44" | 20-5/8" |

Scribe a vertical line approximately 6″. These lines will correspond to the locking legs on the back of the mantels. Install 2 mounting clips to each line with the bottom of each clip at least 2″ above the bottom of the mantel, and the top of the other clip no higher than 4-3/4″ above the bottom of the mantel. (Fig.1)

Position the mantel over the clips and snap into place. (Fig.2)
*NOTE: When applying clips over beveled siding, you will have to shim and/or bend the top of the clips to keep the clip throats the same distance from the wall.*

### To Install End Caps

*(For non-standard window sizes.)*
Cut the window mantel to the required length minus 3/8″. NOTE: The cut on a mantel with dentil blocks must be 1/8″ to the right (facing the mantel) of a full dentil block. Clean any shavings or grit from the cut end(s). Insert the end cap into the mantel and mark the mantel on the inside. Remove the end cap and spread adhesive on both the lip of the end cap and the end of the mantel where marked.

Insert the end cap into the mantel and clamp each side. Allow 10 minutes for drying and then install the mantel into place as described above. (Fig.3)

### To Shorten a Mantel

Determine length and make two cuts to remove excess material from the center of the mantel. Be sure to cut through the center of the dentil blocks.

Turn the mantel sections face down. Drill a 3/16″ hole in the second indented hole marker 2-3/4″ from the cut edge of both mantel sections. Place mantel overlay face down under the cut and drilled mantel sections. The mantel overlay screw bosses will align with the 3/16″ drilled clearance holes. A paper pattern is included to locate screw location. Fasten together with #8x1/2″ self-tapping screws.

*NOTE: Mantels must be installed directly over brick or stucco siding. If vinyl siding is to then be applied, panels will have to be cut to fit around the end caps. Mantels can also be installed in remodeling applications over vinyl siding.*

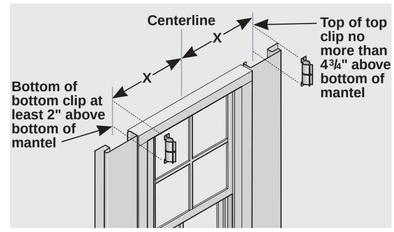



Fig.1

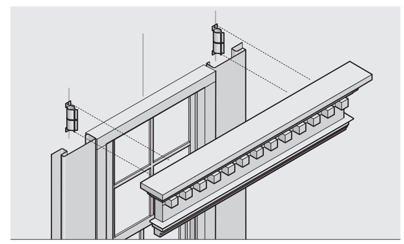


Fig.2

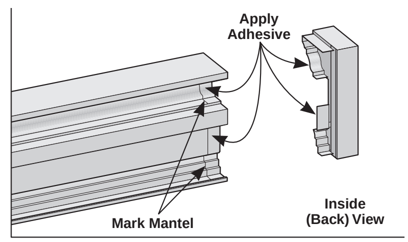



Fig.3

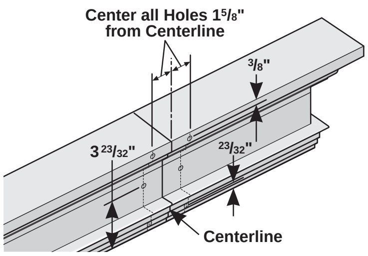



Fig.1

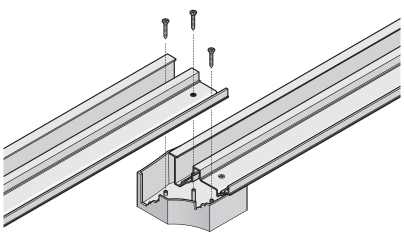
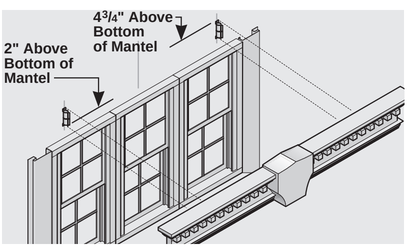


Fig. 2

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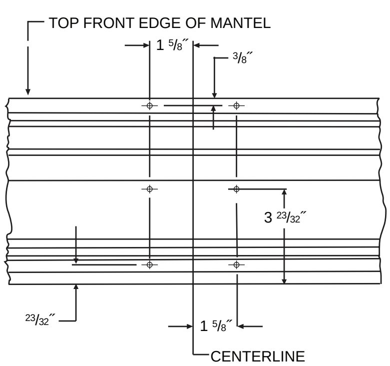



Fig. 4

## *To Install a Keystone*

(to shorten or lengthen a mantle)

*NOTE: Mantel keystones can be purely decorative, or can be used to modify mantels.*

Determine the length of mantel necessary. Using this measurement, cut two equal pieces of the mantel (each will be one-half the length of the required total length). (Fig.1)

Clean the cut ends.

Drill three holes 3/16″ in diameter into each mantel piece spacing holes 1-5/8″ from the centerline (along the cut ends of the mantels). (Fig. 4)

If placing mantel keystone over dentil blocks, you may need to cut away a thin section on both sides of mantel to accommodate keystone over dentil blocks.

Place keystone face down on clean work area. Insert one mantel section into keystone and align drilled holes with molded screw bosses in keystone and fasten with three screws. Insert and fasten second mantel section with three screws. (Fig.2)

To set clip locations when mantel has modified or cut, measure from new mantel cut centerline to the locking legs. Install clips as described.

Install clips to wall. You must determine the distance to place clips from the center of modified mantel. (Fig.3)

To stabilize the mantel system, it is recommended that a piece of fitted plywood be screwed into the back of the mantel system behind the keystone.

Install mantel as described in Standard Mantel installation.

## *Long Length Mantel System*

*NOTE: If installing mantel over existing siding or masonry surfaces, use brick end caps. If installing new siding, the mantel system should be installed using siding end caps with integrated J-Channels before the siding is applied.*

Determine the type of siding accessory to be used around opening. When using a standard J-Channel, cut the mantel to the width of the opening. (Fig.1)

When using a 3-1/2″ window and door casing lineal, determine the width of the opening and add 5″, then cut the mantel.

When using a 5″ corner lineal, determine the width of the opening and add 8″, then cut the mantel.

Clean the cut ends of the mantel. (Fig.2)

Insert the end cap into the mantel and mark the end cap with a pencil. Remove the end cap.

Spread a thin coat of styrene adhesive (included with caps) onto the end cap. ***CAUTION: Contact with styrene adhesive will cause painted surfaces to smear. (***Fig. 3)

Install mantel end caps to both sides of the mantel. Allow adhesive to set 10 minutes using clamps to hold end caps in place.

Before installing the mantel, apply a 1/4″ caulking bead along the back edge of the window/door framing, and on the backside perimeter of the mantel and end caps.

Center the mantel with attached end caps over the frame and fasten through the pre-drilled holes, using screws/washers provided. (Fig.4)

Install cover strip onto the mantel. (Plain & dentil cover strips are available.) (Fig.5)

*NOTE: When installing dentil cover strip, it may be necessary to trim cut from both ends to center the dentil blocks on the mantel.*

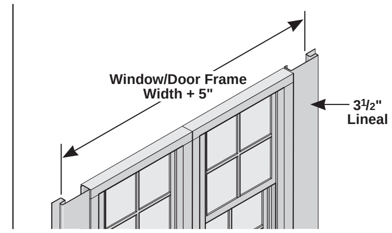



Fig.1

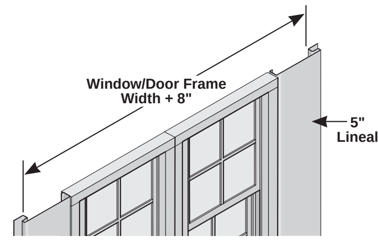



Fig. 2

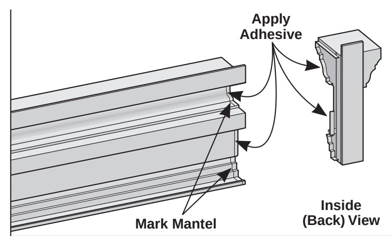



Fig. 3

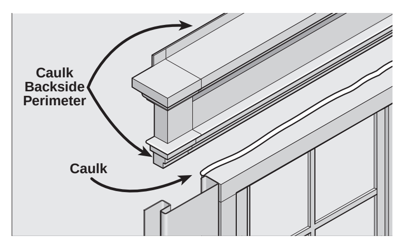



Fig. 4

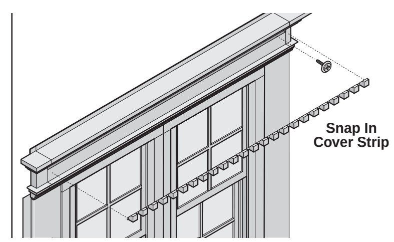



Fig. 5

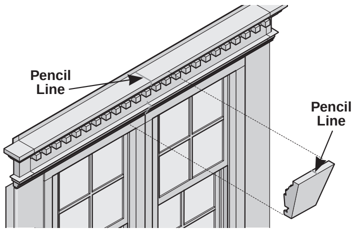



Fig.1

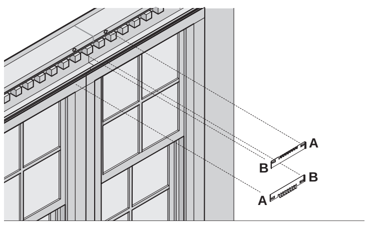



Fig. 2

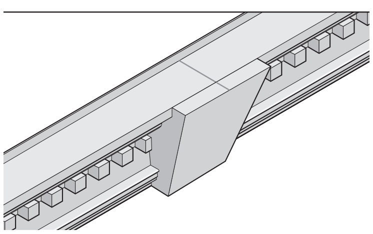


Fig. 3

*Installing Long Length Mantel System Keystones*

With the mantel already mounted to the wall, pencil a centerline on the top and bottom of both the mantel and keystone.

Using the drill jig provided with the keystone, place on the mantel's top edge and align slotted holes over the penciled centerline on the mantel.

Drill 1/4″ holes through hole pattern of drill jig. Repeat second set of holes on bottom edge of mantel. (Fig.1)

Install the keystone clips making sure end "A" is inserted first, then snap in end "B".

Slide clip back 1/16″ to ensure clamping legs are fully locked into place. (Fig.2)

Position the keystone using the centerline as the guide and snap it into place starting at one end of the top of the keystone. You may need to trim the sides of the keystone when using dentil cover strips. (Fig.3)
*NOTE: When installing keystone over two-piece mantel, make sure mantel pieces are cut to equal lengths. Use the cut ends to form the centerline for clips and keystone. Caulk bottom ends then install.*

### *Installing Over Brick or Existing Siding*

To apply on brick or over other existing siding materials, cut mantel to desired length, allowing for brick end caps.

Clean cut ends, insert with adhesive and allow to dry as described in "Long Length Mantel System."

Score the groove on back of mantel 3-5 times with utility knife and snap off mantel's top flange.

Secure mantel to wall with anchors, screws and washers provided.

Install cover strip or dentil cover strip as described in "Long Length Mantel System."

For keystone installation, see Installing Long Length Mantel System Keystones. (Fig.1)

### *Siding Applications*

### *Installing Accessories Over Top of Mantel*

1. Use J-Channel for vertical siding or horizontal panel applications.
2. Use dual utility trim for a Dutch lap applications.
3. Use finish trim for regular panels. (Fig. 2)

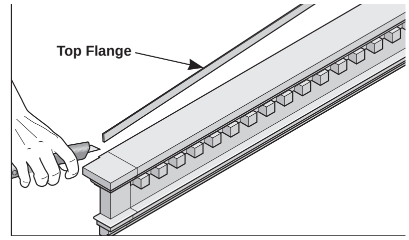



Fig.1

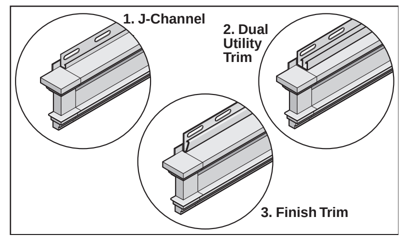



Fig. 2

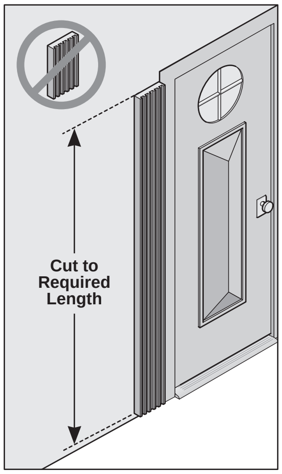



Fig.1

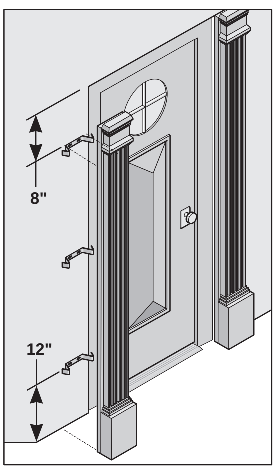



Fig. 2

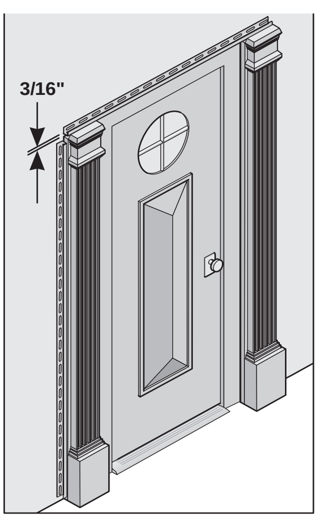



Fig. 3

## *Door Surrounds*

### *Installation of Pilasters on Brick, Stucco or before vinyl siding.*

Measure and cut pilasters to the required length. (Fig. 1)

To attach pilaster caps, use template enclosed in the carton. Mark and drill holes into back of pilasters (use 3/16″ drill bit). IMPORTANT: When installing during new construction before vinyl siding, use lower set of holes on the template. This will ensure that the caps will sit 3/4″ above the top of the pilasters. Attach caps to pilaster using 4 screws (enclosed).

To attach pilaster bases, use template enclosed in the carton. Mark and drill holes into back of pilasters (use 3/16″ drill bit).Attach caps to pilaster using 4 screws (enclosed). (Fig.1)

Attach mounting clips and pilasters (three sets for 96″ and four sets for 144″) by locating top clips 8″ from top and bottom clips 12″ from the ground. Space third set at mid-point for 96″ pilasters. Evenly space the other two sets for 144″ pilasters. If the clips are being applied to beveled wood or vinyl siding, bend the two tabs on the clips so that the clips are installed in a vertical position.

Locate clips 1/8″ from door trim. Attach the clips onto the substrate with two screws (enclosed).

Place pilasters over clips and snap into place. (Fig. 2)

### *Installation With Vinyl Siding*

Follow Installation of Pilasters and then install J-Channels around the pilasters.

Make sure to allow a small gap (3/16″) between the top of the pilasters and the top J-Channel to allow the pilaster to expand.

Install vinyl siding, completing the wall before installing the top mantel. (Fig.3)

### *Installation of Mantel Full Length-Mantel*

Develop a chalk line that represents the bottom of the mantel. Mark the center of the mantel on the chalk line.

Mark 17-11/16″ from both sides of centerline. Draw an 8″ vertical line at both marks.

Attach two clips on both lines. Make sure that both clip throats fall in the area that is 3-1/8″ to 7-3/8″ from the chalk line. When applying on beveled siding you will have to shim and or bend the top of the clips to keep the clip throats the same distance from the wall. (Fig.1)

Place locking legs over the four clips and snap into place. *NOTE: In new construction applications using vinyl siding, the mantel will sit on top of the cap. In all other situations the mantel will sit on the pilaster behind the cap. (*Fig.2)

### *Modified Length-Mantel*

To lengthen a mantel, cut the ends off two mantels. The mantels should be equal in length and must span the required distance. (Fig. 3)

To shorten a mantel, cut out a center piece to make two equal size mantels totaling the required length.

Place the two cut mantels face down and locate hole for mantel overlay. From centerline (cut edge) of mantels measure over 2-3/4″, and from top of mantels measure down 4-1/8″. At these locations, drill one 3/16″ hole into each mantel piece. Place mantel overlay face down located under the two mantel sections. Make sure to tightly butt the two mantel parts and then fasten the two mantels to the overlay with two #8x1/2″ screws (provided). (Fig. 4)

To stabilize the system (especially longer lengths) it is recommended that you screw a 6″ by 7-3/4″ piece of plywood centered into the back of the two mantels. This will eliminate sagging.

To install clips and mount the mantel system, use the distance from the center of modified mantel system to one of the locking legs to determine the location of your clips. *NOTE: Seal gaps at top of mantel if Pediment / Urn system is not used. (*Fig. 5)

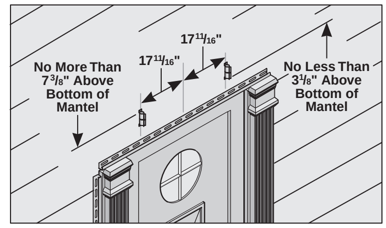



Fig.1

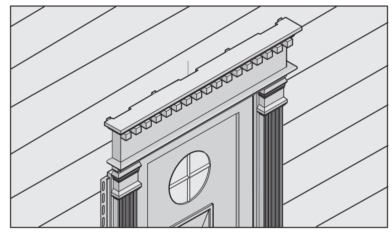


Fig. 2

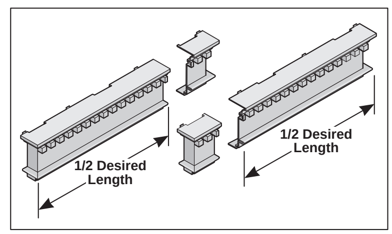



Fig. 3

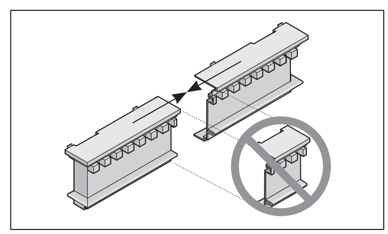


Fig. 4

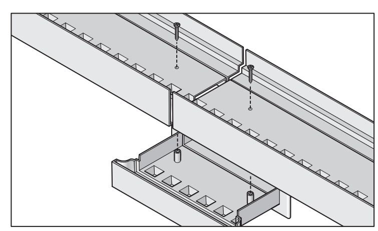


Fig. 5

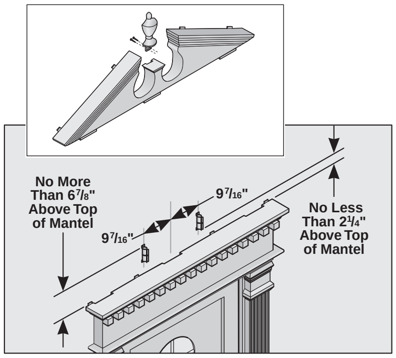


Fig.1

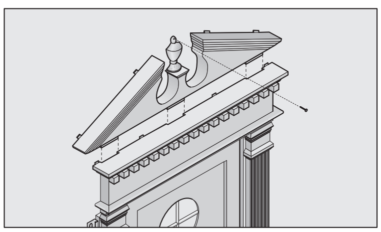


Fig. 2

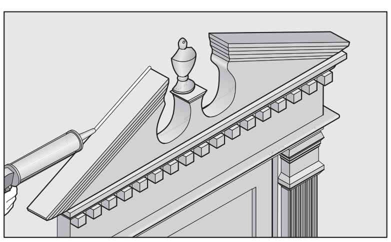


Fig. 3

*Pediment and Urn Installation (Fits Standard Size Mantel Only)*

Attach urn to pediment by sliding urn into place from back. Fasten with #8x1/2″ self-tapping screws.

Measure 9-7/16″ to each side of the mantelcenter line and scribe a vertical line approximately 8” long.

On each side of the lines, install two clips. Be sure the bottom of the bottom clip throats are located at least 2-1/4″ above the top of the mantel and the top of the top clip throat is no higher than 6-7/8″ above the top of the mantel. (Fig.1)

Position the pediment over the mantel by inserting the three male lugs on the bottom of the pediment into the matching slots in the top of the mantel.

Align the ribs over the clips and snap into place.

Secure the top of the urn to the wall by nailing through nail hole in urn. (Fig. 2)

With brick or stucco walls, caulk space between top of pediment and wall and other places where water seepage is possible. (Fig. 3)

## *Window Trim Capping*

Measure the required dimensions to cover window trim. Also, determine the required lengths of trims.

Cut trim sheet to the measurements and form each sheet on a bending break. (Fig.1)

Trim sheet should be installed in the following order: bottom, sides, top.

Place the trim sheet on the window frame and mark it for cutting.

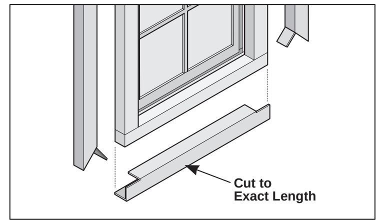
Create tabs into the trim sheet (both ends of bottom piece and tops of both side pieces) so that it covers the edge areas.

Miter the bottom of the side pieces and both ends of the top piece. (Fig. 2)

Nail into place using painted aluminum or stainless steel trim nails. Pre drill nail holes and do not nail tight. The top piece should be the last section to be nailed into place. (Fig. 3 )

*NOTE: Dissimilar Materials: Direct contact of aluminum products with certain dissimilar materials, or contact with water run-off from dissimilar materials, is likely to result in corrosion. Accordingly, care should be taken during installation to avoid such contact of aluminum with dissimilar materials including dissimilar metals (e.g. copper, zinc, steel, etc.), concrete, stucco, asbestos siding, pressure treated/pretreated lumber, masonry, roofing materials or roofing systems containing metallic granules or strips, or corrosive non-metallic materials.*

*A barrier must be used to separate trim from any pre-treated lumber. Optional barriers include: plastic, house wrap, roofing felt, foam, or a high quality primer or paint.*

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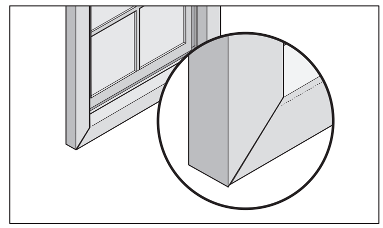

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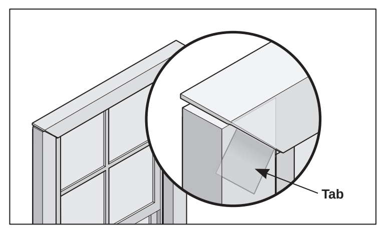


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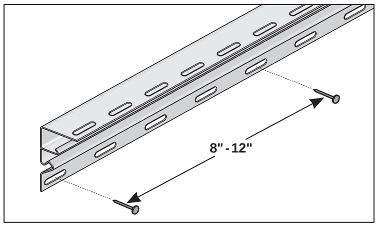


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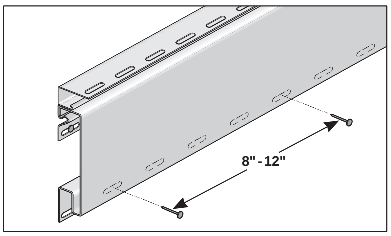



Fig. 2

## *Lineals*

*Choose either a 3.5″ or 5″ lineal, depending on the look you want to achieve.*

At Eave or Gable, butt the small leg of the starter against, but not under the J-Channel that was installed to receive the soffit.

Nail the starter in place every 8″ to 12″ with nails centered in nailing slots. (Fig.1)

Push the locking leg of the lineal into the starter channel.

Nail the Lineal in place every 8″ to 12″ with nails centered in nailing slots.

Install utility trim into the lineal receiving channel, making sure to align nail slots with lineal nail slots.

Install last course of siding. (Fig. 2)

In some situations you may have to shim the utility trim or you can use a Double utility trim.

## *Band Board Installation*

*Option 1: Choose either a 3.5″ or 5″ lineal, depending on the look you want to achieve.*

For easy installation (when possible), lock the lineal onto the last full course of siding.

Nail every 8″ to 12″ with nail centered in the nailing slots.

A drip cap must be installed along with a starter strip or J-Channel to recieve the 1st course of siding above the lineal. (Fig. 4, 5 & 6)

The drip cap should be formed so that it extends up the wall 4″ and extends over the face of the lineal by 3/4″. (Fig. 4)

Proceed with standard panel application by installing the siding into the lineal J-Channel.

*Option 2: (*Fig. 2) & ( Fig. 3)

Determine the location of the band board in relation to the siding making certain it does not interfere with the butt of the siding panel.

Strike a chalk line and install utility trim along the line nailing every 8″ to 12″ with nails centered in the nailing slots.

Lock the band board into the utility trim and nail every 36″. (Fig. 2)

Once the band board is in place, install another piece of utility trim by aligning the nails slots of the finish trim with the band board lineal. You may have to shim the utility trim. Nail every 8″ to 12″.

To install siding panels, use a snap-lock tool to create tabs in each panel and install them into the utility trim. (Fig. 3)

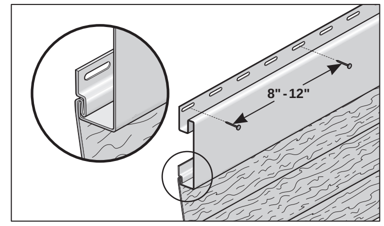
Once the siding is in place, install a drip cap (field or factory formed) on top of the band board lineal to prevent water intrusion. (Fig. 4)

Finally, for horizontal siding applications,
install a universal starter strip over the drip cap nailing every 8″ to 12″ centered in slots. Make sure to attach starter strip 1/4″ above drip cap to allow siding to lock. (Fig. 5)

For vertical siding applications, install a J-Channel over the drip cap and proceed with standard panel application.

Drill 1/8″ holes in base of J-Channel every 24″ to allow for water to run off. (Fig. 6)

*continued on next page*



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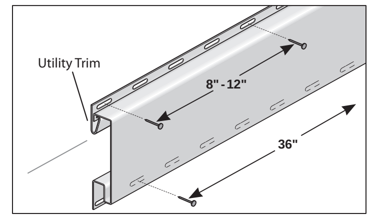
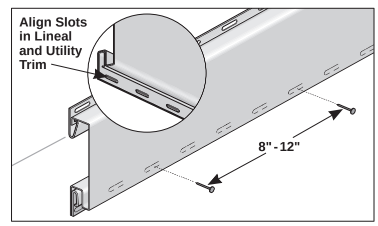
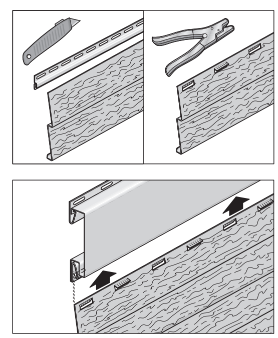


Fig. 2

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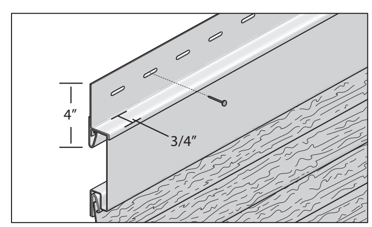

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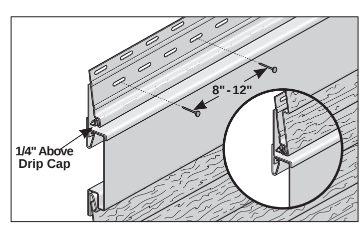

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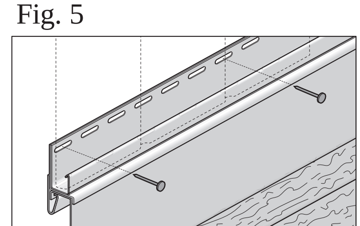
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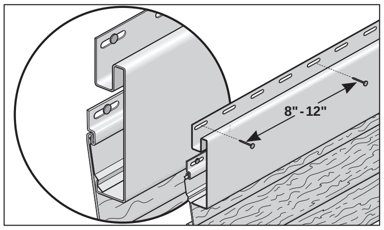
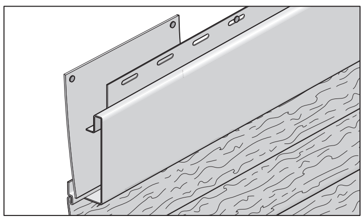



Fig.1



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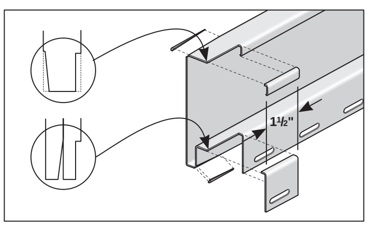



Fig. 3

*Option 3:*

Determine the band board location.

Install siding to that location and then install the band board. Nail every 8″ to 12″ with nails centered in slots.

Utilize field form aluminum to adjust the location of the lineal at the desired height.

Proceed with standard panel application for vertical or horizontal siding. (Fig.1)

## *Overlapping Lineals*

Notch the back legs of the lineal to be overlapped by making a series of cuts as indicated in the diagram.

Cut a tapered notch into the radius at the top and bottom of the lineal on the end to be overlapped.

Slip the un-notched lineal 1″ over the notched lineal, leaving 1/2″ for expansion. (Fig. 3)

*NOTE: For best appearance, be sure the overlaps are away from the direction that the house is most commonly viewed.*

## *Dentil Molding*

### *Vinyl Siding*

Snap a chalk line 6-1/2″ down from the soffit panel location (chalkline.) (Fig.1)

Prepare the dentil molding either by cutting the soffit flange to create a tab, or by removing a portion of the upper soffit flange and slotting. Center of slots should be spaced 16″ apart. (Fig. 2)

Butt the dentil molding to the chalk line and nail into place every 16″.

If siding panels are to be terminated with finish trim to complete sidewall application, dentil mold should be slotted and nailed prior to final course of siding. Cover slots with utility trim. (Fig. 3)

### *Brick, Stucco or Masonry Installation*

If a nailable, flat surface is not available, dentil mold can be applied as a decorative element by placing bottom edge of dentil mold into utility trim and nailing tabs to a 1″x6″ or 1″x8″ board. (Fig. 4)

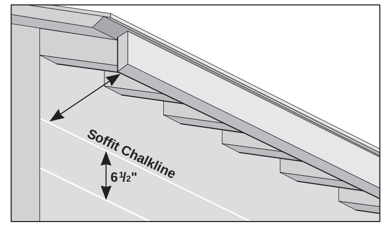


Fig.1

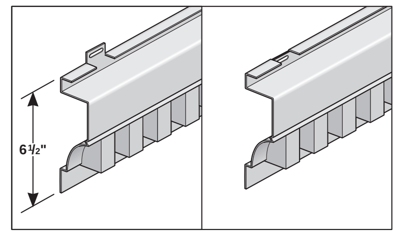
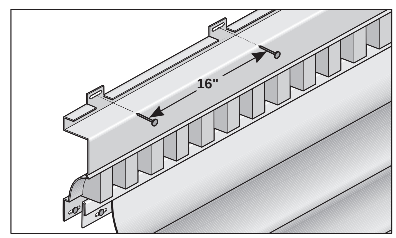


Fig. 2



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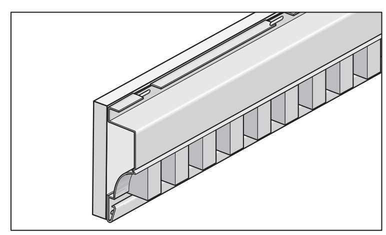
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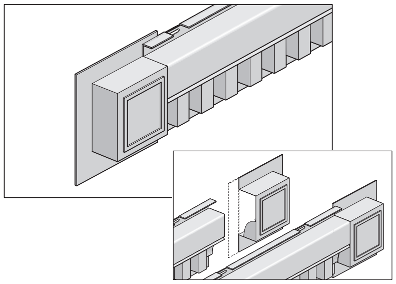

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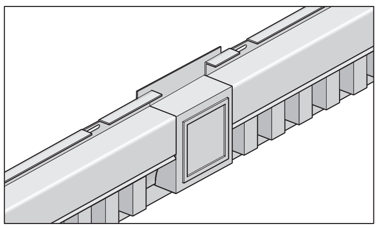

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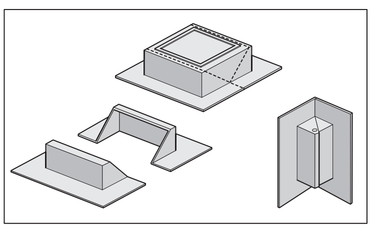

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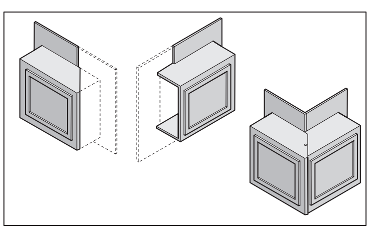


Fig. 4

## *Dentil Blocks*

Dentil blocks finish dentil molding and can be installed at the ends, center, corners or the outside.

To install at ends, position the dentil-molding flange behind the soffit flange and trim as indicated in the illustration. (An option to installing at the end position is to scribe a line onto the dentil block, remove that portion and then position the dentil block at the end of the dentil molding.) (Fig.1)

To install at the center, position the end block at the center of the opening and then butt the dentil molding ends into the end of the block. (Fig. 2)

To install inside corners, cut and remove sections as shown in the illustration. Once removed, pop rivet the two pieces together and then fasten it to the wall. (Fig. 3)

To install outside corners, cut and remove sections as shown. Once removed, pop rivet the two pieces together and then fasten it to the wall. (Fig. 4)

## *Gable Vents*

*For Vinyl and Aluminum Siding*

Using the inward edges of the vent base as a guide, mark the area to be cut in the exterior wall surface, then cut the hole.

Center the base of the vent over the opening and level the base.
*Note the word "TOP" on the base when positioning it.*

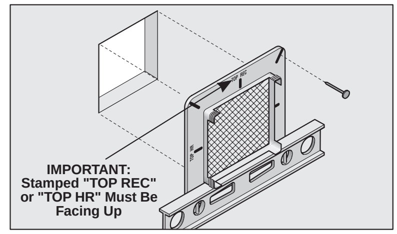
Nail the base onto the wall surface through the slotted nailing flange. A water diverter should be installed at the base. (Fig.1)

Siding can now be installed around the vent base. Be sure to leave a 1/4″ clearance between the cut siding and the base to allow for expansion and contraction. (Fig. 2)

Snap the face into the base by pressing firmly.

Should it be necessary to remove the face, firmly pull the face from the base. (Fig. 3)

Gable vents can be installed without cutting a hole if you want it to be decorative only.

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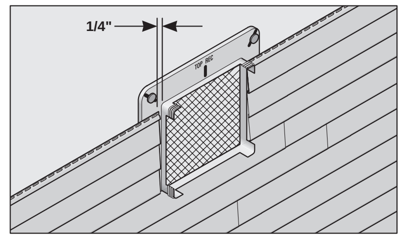



Fig. 2

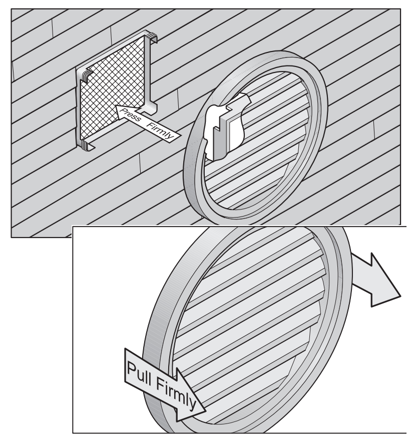
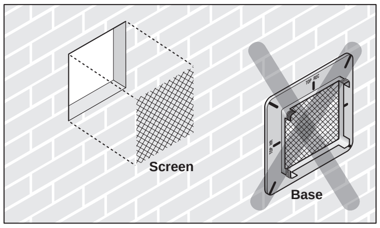



Fig. 3

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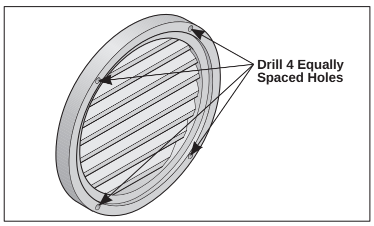


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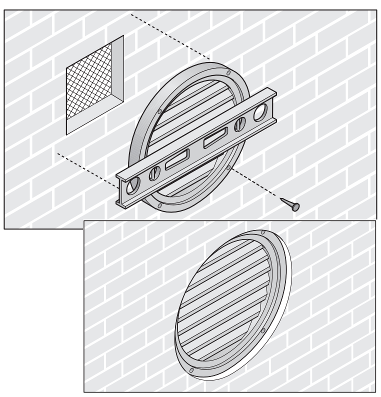


Fig. 3

### *For Installation onto Masonry Surfaces*

Fasten the screen to the inside or outside of the wall opening. Discard the base. (Fig.1)

Drill four equally spaced holes around the outer front surface of the vent face. (Fig. 2)

Place the vent face over the exterior wall opening, level it and fasten it to the wall using masonry fasteners. (Fig. 3)

*NOTE: On new homes, the vent face may be recessed into the brick.*

*Preparation*

*Determining proper ventilation*

For best results, vents must provide 1.5 sq. inches of net free area per sq. ft. of attic floor area, including enclosed overhang. (Fig.1)

*Placing proper ventilation*

Ideally 50% of the required free ventilating area should be placed at the ridge and 25% in each opposing soffit. Soffit ventilation area may be slightly larger than ridge ventilation area. Do not have more ventilation area in ridge than in the soffit.

The slope/pitch must not be less than 3:12 or greater than 6:12. Wood cant strips should be used for slopes outside this range. (Fig. 2)

*NOTE: Do not apply generic ridge vent part on roof hips.*

*Preparing an existing roof*

Remove ridge cap shingles along the roof ridge.

Snap chalk lines on both sides of the ridgeline to the dimensions shown in the illustration at left, depending on your specific roof construction.

Cut out ventilation opening along the ridge at chalk lines with ventilation opening end 12″ short of outside walls, chimneys, or roof protrusion.

Remove cutout portion of sheathing and shingles, leaving a clean open slot.

*For new construction*

Plywood can be set or cut back to the required dimension leaving a total opening of 1-1/2″. Shingles should then be installed up to the edge of the sheathing. *NOTE: Never cut ventilation opening in overhang.*

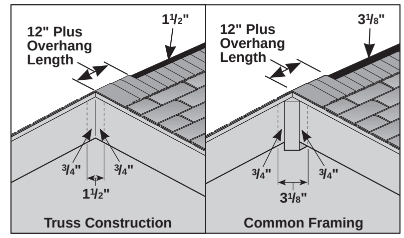
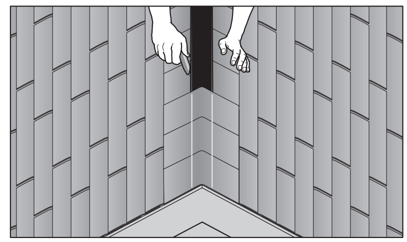



Fig.1



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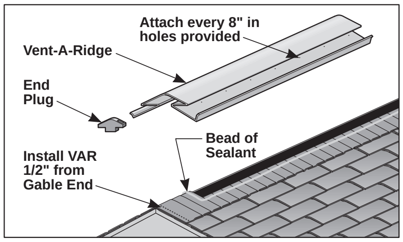


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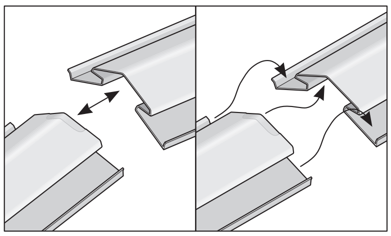


Fig. 2

*Insert ends on an angle.*

*Insert baffles and top angle over or under as indicated by the arrows.*

*Slide together, closing notch.*

*NOTE: Aluminum or stainless steel nails or screws should be used to attach ridge every 8″ (both sides). The fasteners should protrude at least 1/2″ through sheathing. Sealant is required on the underside of all end plugs and both baffle legs.*

## *Attaching the Vent*

Starting with the male end, place the first vent on the ridge, making sure the center of the vent aligns with the center of the ridge slot. (For best appearance, place the vent 1/2″ in from the end of the gable end.) A chalk line can be used to assist in the alignment.

Nail or screw one side of the vent to the roof every 8″ through nail holes. Attach the other side of the vent, making sure the vent lies flat on the roof.

Align the next piece, slide and lock into place, then nail. Make sure the vent aligns with the center of the ridge. Install additional pieces in the same manner.

Cut the final section of the vent to the required length. Make sure to position and seal an end plug as desired for a starter piece. Nail into place.

*NOTE: Ridge can be modified to be used in vertical and peak roof applications.*

## *J-Channel at roof line*

### *Step 1*

Install the flashing before the J-Channel to prevent water infiltration along the intersection of a roof and wall.

### *Step 2*

Keep the J-Channel at least 1/2″ from the roofline. Chalk a straight line up the roof flashing to guide J-Channel installation.

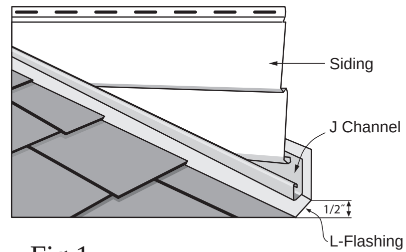
*NOTE: Vinyl J-Channels should not be in direct contact with roofing shingles, since the shingles may transfer enough heat to the vinyl J-Channel to cause distortion. With dark shingles, or a south or west exposure, it is recommended to either use a metal J-Channel or raise the vinyl J-Channel approximately 2″ off the shingles and install, having first ensured that there is sufficient flashing behind the J-Channel to prevent water infiltration.*

### *Step 3*

Overlap the J-Channel (lapping the upper piece over the lower piece) if it is necessary to use more than one piece.

### *Step 4*

Extend the J-Channel past the edge of the roof, channeling water into the gutter, in order to ensure proper runoff.

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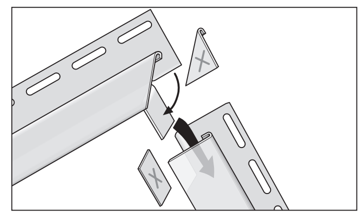

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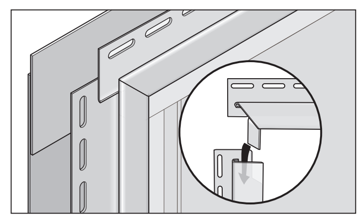

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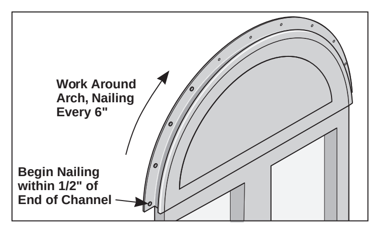



Fig. 4

## *J Channel*

J-Channels are designed to receive the siding panels and must be installed around all windows, doors, other large openings and in the gables where built-in J-channels are not present. J-Channels can be installed over old wood casing or placed next to the casing leaving the old window casing exposed.

Water runoff can also be accomplised by making a series of notches and tabs in the J-Channel. (Fig. 2)

Install J-Channel in this order: Bottom, Sides then top.

Miter J-Channels at corners to prevent gaps and allow for proper water drainage. (Fig. 3)

## *Flex-J*

Flexible J-Channels are designed for curved surfaces such as arched windows.

Begin nailing at one end of the arch one-half inch of the end of the channel. Nevver begin at the crown or middle of the arch.

Nail every six inches. (Fig. 4)

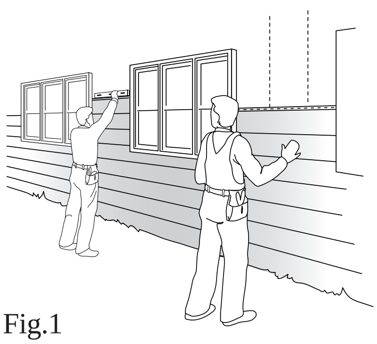


Fig.1

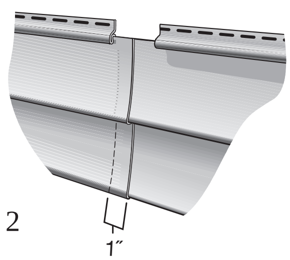



Fig. 2

***Step 1***

The first panel (or course) should be placed in the starter strip and securely locked along the entire length of the siding panel.

*NOTE: Always overlap joints away from entrances and away from the point of greatest traffic. This will improve the overall appearance of the installation.*

***Step 2***

Be sure to fasten the panels according to the instructions on page 14. Allowance should be made for expansion and contraction by leaving a 1/4″ gap between the siding and all corner posts and channels (increase to 3/8″ when installing in temperatures below 40ºF).

***Step 3***

Do not drive the head of the fastener tightly against the nail slot. Leave 1/32″ between the fastener head and the panel nailing strip.

***Step 4***

Do not stretch the panels up when fastening. Panel locks should be fully engaged; however, the panels should not be under vertical tension or compression when they are fastened.

***Step 5***

Since vinyl siding moves as the temperature changes, make certain that the vinyl panels can move freely in a side-to-side direction once fastened.

***Step 6***

Check every fifth or sixth course for horizontal alignment (Fig. 1). **[Check siding alignment with adjoining walls]**

***Step 7***

When panels overlap, make sure they overlap approximately 1″ (Fig. 2).

*NOTE: Overlap with factory ends whenever possible. If you must use cut ends, duplicate the factory notches before installing. Avoid stair-step lapping.*

***Step 8***

Stagger the siding end laps so that no two courses are aligned vertically, unless separated by three courses.

### *Beaded Horizontal Siding*

Beaded panels are factory notched in three places (Fig. 1). For best results, overlap panels using factory notched ends only. **This panel should be overlapped 1˝ due to the unique design of the locking and lapping system.** Overlapping more than 1˝ will result in less than optimal laps and increase the chances of panel restriction (Fig. 2). For easiest panel installation, start locking the panel at one end and tap the lock into place toward the other end. This panel will not lock by pushing straight up as in standard panel installation.

*TIP Always overlap joints away from entrances and away from the point of greatest traffic. This will improve the overall appearance of the installation.*

### *Fitting Siding around Fixtures*

For handling protrusions around the wall, refer to the figure (Fig. 3) for hand fabricating, or use manufacturers' accessories specifically designed for this purpose. In addition, the following tips are suggested:

- Always begin a new course of siding at the fixture to avoid excess lap joints.
- Cut a slot 1/4˝ bigger than the fixture. (Fig. 3)
- When cutting, match the shape and contour of the obstruction. (Fig. 4)

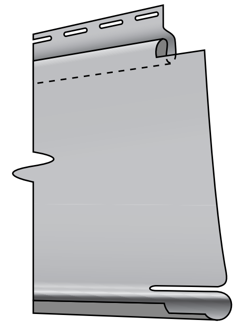


Fig. 1

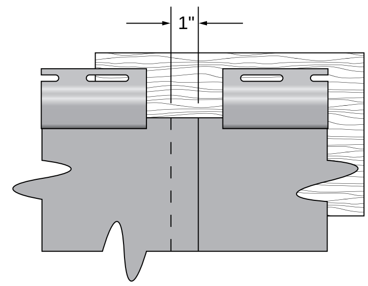



Fig.2

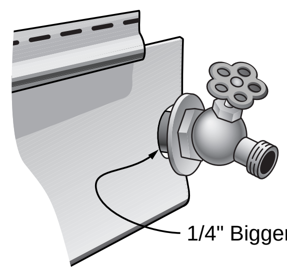



Fig. 3

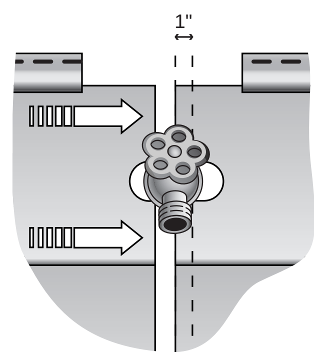



Fig. 4

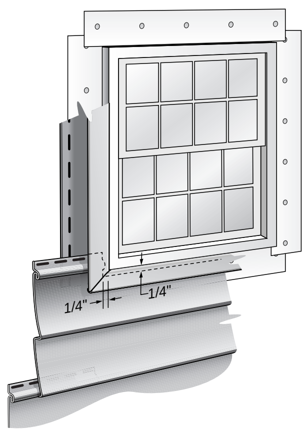
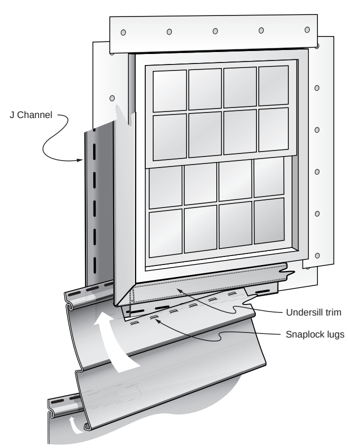



Fig. 1




### *Fitting under Windows*

To mark the section to be cut, perform the following:

### *Step 1*

Hold the panel under the window and mark the width of the window opening on the panel. Add 1/4″ to both sides to allow for expansion and contraction of the siding. These marks represent the vertical cuts (Fig. 1).

### *Step 2*

Lock a small piece of scrap siding into the lower panel next to the window. This will be used as a template for the horizontal cuts. Mark it 1/4″ below the sill height (Fig. 1).

### *Step 3*

Transfer the horizontal measurement to the panel, which will be installed under the window (Fig. 1).

### *Step 4*

Cut the panel with tin snips and/or a utility knife.

The cut panel is now ready for installation under the window. Perform the following:

### *Step 5*

Install undersill trim under the window, inside previously installed J-channel as a receiver for the cut siding. Undersill trim is used any time the nail hem has been removed from the siding. Furring may be needed to maintain the face of the panel at the desired angle.

### *Step 6*

Use a snaplock punch to place lugs facing out in the cut edge of the panel every 6″-10″.

### *Step 7*

Install the siding panel, making sure the lugs (from the snaplock punch) lock into the undersill trim (Fig. 2).

### *Finishing at the Top*

Before the final course of siding is installed on the wall, any soffit accessories that will be used on the eaves must be installed.

### *Gable Ends*

To install into gable ends, make a pattern that duplicates the slope of the gable (Fig. 1).

### *Step 1*

Lock a short piece of siding into the gable starter course (i.e., the last course before the gable starts).

### *Step 2*

Hold a second piece of siding against the J-Channel at the slope of the gable. Mark the slope with a pencil on the short piece of siding.

### *Step 3*

Remove the short piece and cut along the pencil line as a pattern for the gable angle cuts. Repeat the procedure on the opposite side of the gable.

### *Step 4*

It may be necessary to fasten the last panel at the gable peak with a trim nail. Use a 1 1/4″ to 1 1/2″ nail. **[This is the only time a nail should be placed in the face of the vinyl siding (Fig. 2).]**

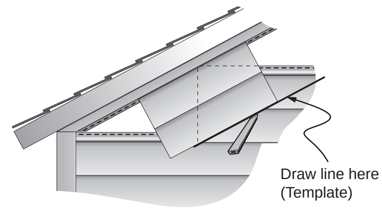



Fig.1

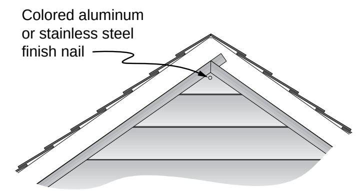



Fig. 2

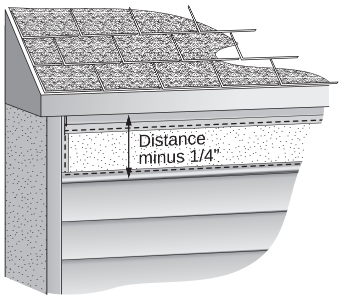


Fig.1

### *Eave Treatment*
The last course of siding will generally need to be cut to fit the eave opening (Fig.1).

### *Step 1*
Install undersill trim under the eave or overhang as a receiver for the cut siding. Undersill trim is used anytime the top or bottom lock has been removed from the siding. Furring may be needed to maintain face of the panel at the desired angle.

### *Step 2*
Measure from the top of the undersill trim to the bottom of the upper lock on the previous course of panels. Subtract 1/4˝. Mark this dimension on the panel to be cut, measuring from the bottom edge of the panel.

### *Step 3*
Using a snaplock punch, punch the vinyl siding along the cut edge every 6˝ to 10˝, so the raised lug is on the outside face.

### *Step 4*
Install the siding panel, making sure the lugs (from snaplock punch) lock into the undersill trim.

### *Starter Strip*

You must use the required starter strip (with 1/2″ step). (Fig. 2)

Chalk lines are normally established from the lowest corner of the house. In situations where the ground at the corner of the house is not level, chalk lines must be measured from the soffit location to assure a uniform panel at the top of the walls.

The starting chalk line should be located so that it represents the top, not the bottom, of the starter strip (Fig.1)

*Note: Make sure starter strip works with insulated siding.*
Align the top of the starter strip with the chalk line.

Nail the starter strips 8″ on center and in the middle of each nail slot Do not drive nails tight. Always nail in the lowest row of the nail slots allowable. (Fig. 2)

Allow at least 1/4″ separation between pieces of starter strips for expansion and contraction. (Fig. 3)

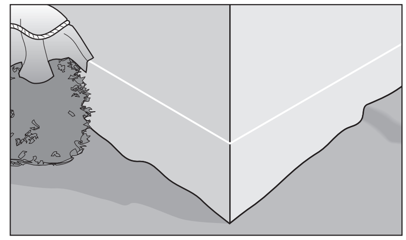


Fig.1

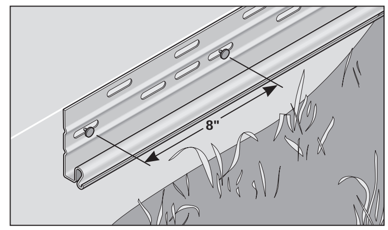



Fig. 2

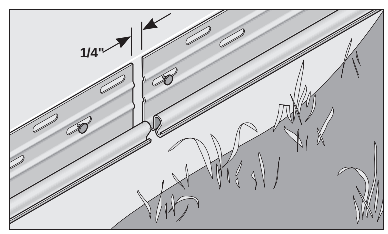



Fig. 3

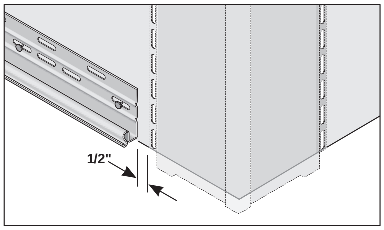



Fig.1

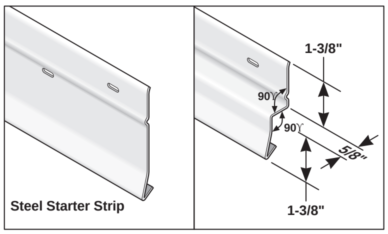



Fig.2

*Starter Strip and Accessories*

Cut the starter strip back from each corner so the corner post nailing hem may be installed without touching the starter strip. Leave a 1/2″ gap from all corner post nail hems.

Cut the corner post so that it hangs 3/4″ below the bottom of the starter strip. (Fig.1)

When installing panels above exposed overhang areas, the 3-1/2″ steel starter strip can be modified by bending the starter in two locations as shown. (Fig.2)

*Corner Post Options*

The preferred corner post is the foam-filled corner. This corner post has a1-1/4″ opening to receive the Insulated panel. (Fig.1)

*NOTE: Nail all corner posts as described in Basic Accessory Installation, “Installing Corner Posts.”*

*NOTE: For the best appearance do not start any course with factory ends. Remove the factory notch by cutting the first 2″ of the panel. This is important in high altitude, high heat applications.*

If other corner posts are used, follow the steps below:

1. Attach 1/2″ thick shims under the nail hems of the corner.
2. 2″ of foam must be cut to allow the panel to be installed into the corner. (Fig. 2)

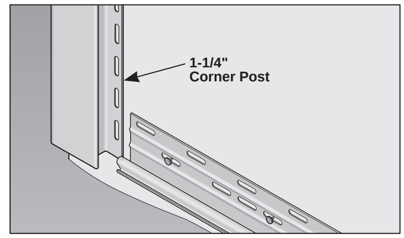



Fig.1

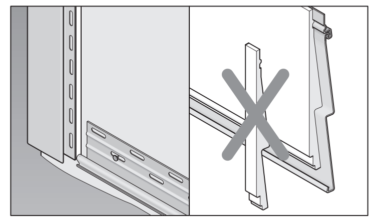


Fig. 2

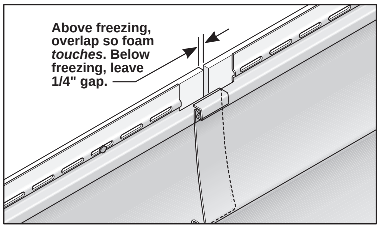



Fig.1

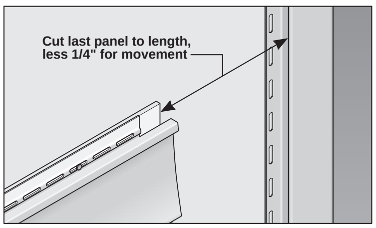



Fig.2

## *Panel Installation*

When installing at overlaps, the vinyl of one panel should slide between the foam and the vinyl of the adjacent panel. With panel overlaps at temperatures above freezing, the Structure foam should touch. At applications below freezing, leave a 1/4″ gap at the foam area. (Fig.1)

When determining the length of the final panel of a course, measure from the edge of the foam on the installed panel to the corner, less 1/4″. Apply this measurement to the final panel, measuring the foam instead of the panel. This will insure foam to foam contact with the necessary amount of room for expansion of the siding. (Fig.2)

*Installing Around Openings*

The preferred J-Channels are 1-1/4″ or 2-1/2″. They should be installed as described in Basic Accessory Installation, “J-Channel, Flex-J, and Flashing.”

Utilize a flexible water diverter at the bottom of all openings (see General Siding Installation). A flexible water diverter should be housewrap, plastic, or roofing felt. (Fig.2)

To measure for a window or other opening:

a. Set the panel below the opening.

b. Mark the J-Channel location, allowing for a 1/4″ gap on all sides of the opening for expansion and contraction.

(Fig.3)

Cut the panel as marked using either a utility knife or tin snips. Cut back foam 2″ for 1-1/4″ or 3-1/2″ for 2-1/2″. (Fig.4)

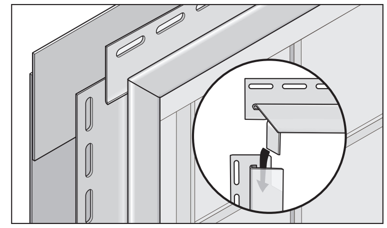


Fig.1

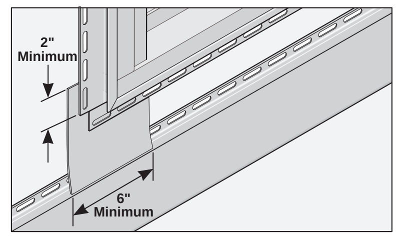



Fig.2

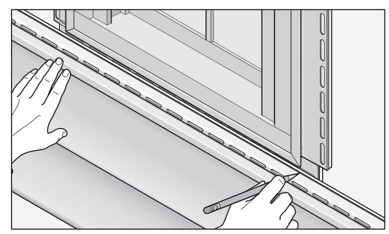


Fig.3

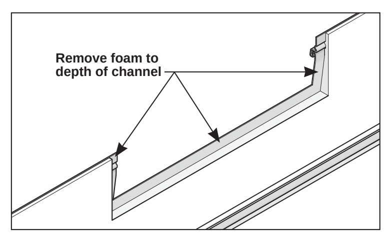



Fig.4

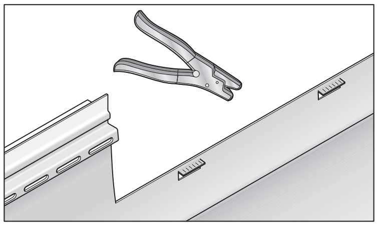


Fig.1

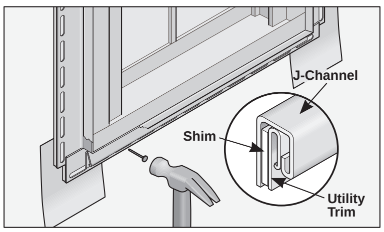


Fig.2

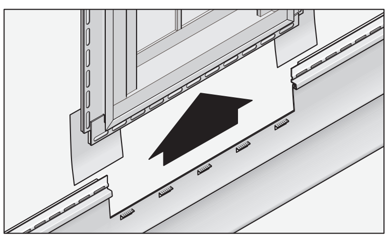


Fig.3

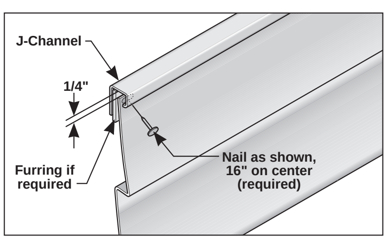


Fig. 4

*Installing Around Openings continued*

Use a snap-lock tool to create a tab every 16″ on the cut edge of the panel. These tabs should face out. (Fig.1)

Install a finish trim into the bottom J-Channel at the opening. A shim must be installed behind the finish trim. The foam that was cut from the panel can be used as the finish trim shim.
(Fig.2)

Snap the tabs of the cut edge of the panel into the finish trim under the windowsill. (Fig.3)

A shim must be installed. (Fig.4)

An optional method for this area is to nail slot the cut edge of panel every 16″ on center.

The face of the channel can be held to facilitate nailing. Nail in middle of every slot.

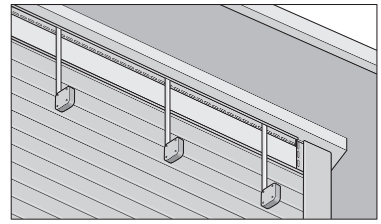
*Final Course*

Take the height measurement of the remaining open section in several locations.

Subtract 1/4″ from each location to allow for movement. (Fig.1)

Cut the panel to required measurement. (Fig.2)

Cut back foam 2″ for 1-1/4″ J-Channels or 3-1/2″ for 2-1/2″ J-Channels (Fig.3)



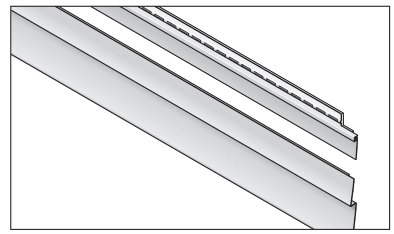


Fig.2

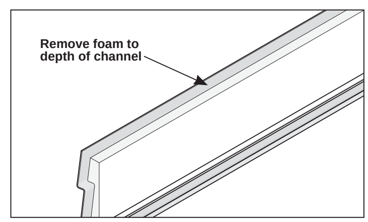



Fig.3

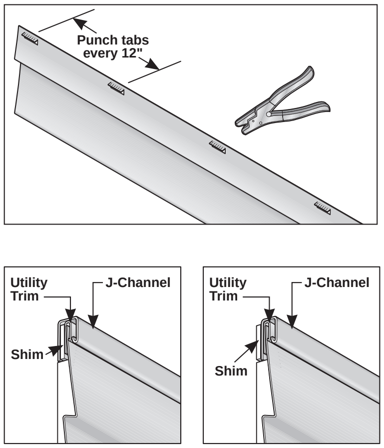
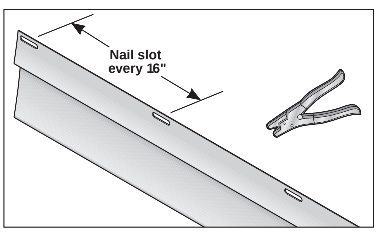
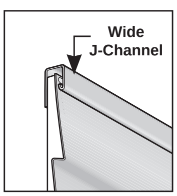
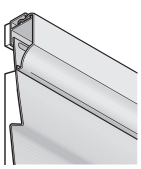



Fig.1

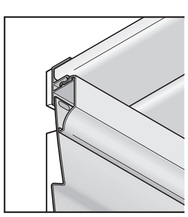



Wide Window Casing Trim



Snap-In Crown and Mount



Snap-In Crown and Mount with J-Channel

Fig.2

## *Snap Lock Options* (Fig.1)

Use a snap-lock tool to create a tab every 12″ on the cut edge of the panel. These tabs should face out. A utility trim must be used with this option.

## *Nail Slot Options* (Fig.2)

A second option is to nail slot the top of the panel. A utility trim is not used with this option. *See fig. 2 for the use of the snap in crown system.*

*NOTE: If Permatabs are used, nail slot the top of the panel every 16″.*

***Transition from Horizontal to Vertical (Fig. 1)***

Finish the last course of horizontal siding with the J-channel and finish trim. Install a drip cap and a J-channel. The top piece of J-channel must have minimum 3/16″ (4.8mm) diameter weep holes drilled no more than 24″ (610mm) apart to allow for water runoff.

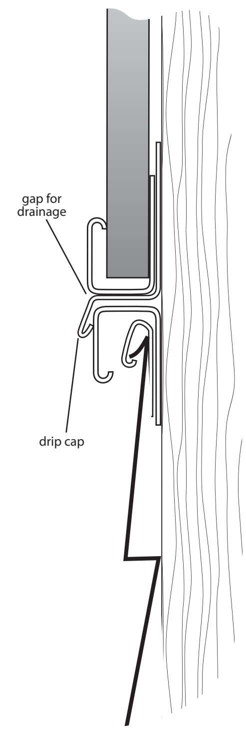



Fig.1

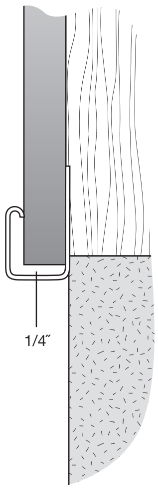



Fig.1

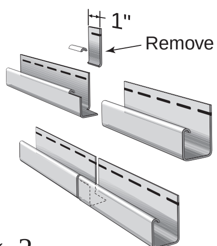



Fig. 2

When installing vertical siding, follow these steps:

**Preparation**

### *Step 1*

Install a solid, nailable sheathing prior to applying vertical siding, if needed, to level the surface or provide sufficient material for proper fastener penetration. Use minimum 7/16″ plywood, OSB or equivalent.

### *Step 2*

Snap a level chalkline around the base of the sidewalls. Typically, the chalkline is positioned so that the bottom of the J-Channel is 1/4″ below the lowest point on the wall that will be sided. (See the “Installing Accessories” section for tips on snapping a chalkline.) Install a J-Channel along the chalkline as a receiver for the vertical siding.

**Installation**

### *Step 1*

Install vinyl outside corner posts, inside corner posts, and door/window trim, and/or J-Channel as needed. See previous sections for corner post installation techniques.

### *Step 2*

Install top and bottom J-Channel: Apply J-Channel along the top and bottom of the walls to receive the siding panels (Fig. 1).

***A*** Install the bottom J-Channel. Overlap J-Channels 3/4″. To do this, cut out a 1″ section of the nailing flange and face return (see Fig. 2).

***B*** Install inverted J-Channel along the top of the wall, under the eave and the gable. Overlap J-Channels 3/4″ to allow for expansion.

*NOTE: If you’re going to install soffit, you may want to install the receiving channels for the soffit prior to this point.*

If a wall requires more than one course of vertical siding, use two lengths of J-Channel, back-to-back and flashing, at the joint between the two courses (Fig. 1).

If a wider wall is being covered, then you can start with a full width vertical panel. In this case you can install that first piece by utilizing a starter strip on the cut nailing hem of a vertical panel. (Fig. 1)

If a smaller wall is being covered, you should try to create a balanced appearance.

- To create a balanced appearance (Fig. 2) divide the length of the wall by the exposure of the vertical panel to be used. For example, if the wall requires 20 full panels plus an adeditional 8” (203mm), then the first and last pieces installed would be cut to a new width of 4” (102mm). Make sure to allow for proper depth in the receiving channels of the accessories at both ends when measuring.
- To install the siding, if partial panels are required, mark the line to cut by measuring from the edge of the lock of the panel and cut the panel to the proper width. This will leave a panel with an intact nail hem and proper exposure.

The top J-Channel must have a minimum of 3/16” (4-8mm) diameter weep holes drilled no more than 24” (610mm) apart to allow for water runoff.

### Step 1
Panel installation should begin at the end of a wall section at a corner post or J-Channel. An undersill trim piece should be installed and fastened inside the opening of the corner post or J-Channel to secure the edge of the first and last course of siding. Snaplock punch the cut edge every 6″ to 10″, and snap the edge into the secured undersill trim. Cut and install last course in similar fashion. (Fig. 3)

### Step 2
*TIP: A furring strip may be needed behind the undersill trim before fastening to shim it out and maintain the lines of the vertical panel.*

Maintain a 1/4″ gap at each end of panels where they butt to trim pieces such as J-Channel. Failure to maintain this gap may result in permanent panel warpage. Maintain a 3/8″ gap if installing at temperatures 40º F or below.

### Step 3
Fasten panels every 12″ through the middle of the nailing slots. Maintain 1/32″ minimum clearance between the fastener crown and nail hem of panel.

**Special note for vertical panel installation:** Vertical panels should be cut to allow clearance as specified. Panels should be positioned on wall allowing equal clearance top and bottom. One fastener should be placed at the top of a nail slot within the upper 12″ of the panel when installed. The panel will hang on this fastener and will expand in both directions rather than only upward. Balance of fastening should take place in the center of the nailing slots (Fig. 4).

### Step 4
Undersill trim should be installed inside J-Channel, or built-in window receiver on the sides of windows and/ or doors to secure cut edge of vertical panels. Vertical panels should be snap-locked before insertion into the undersill trim (Fig. 3). A furring strip may be needed behind the undersill trim to maintain the lines of the vertical panel.

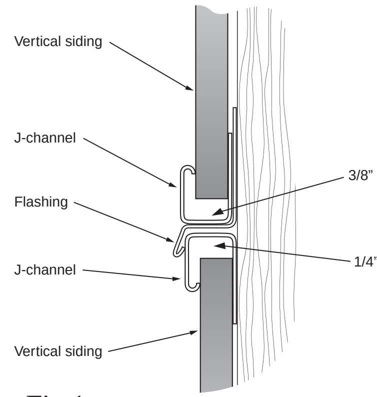


Fig.1

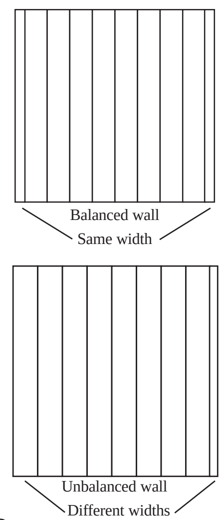


Fig. 2

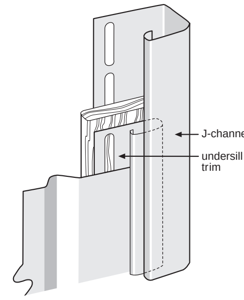


Fig. 3 Start and or finish

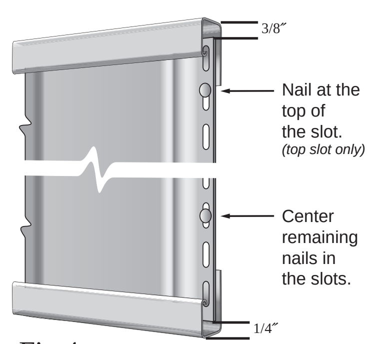


Fig.4

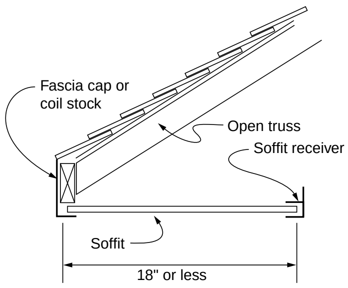



Fig.1 16˝ or less

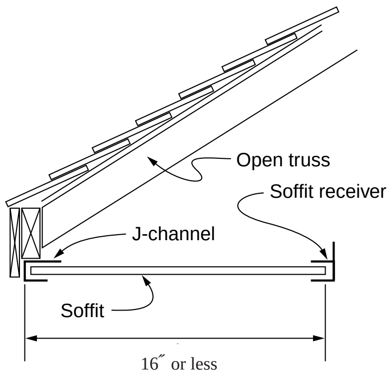



Fig. 2

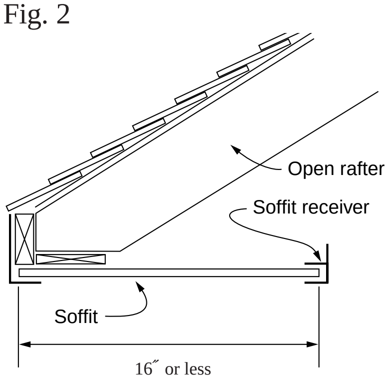



Fig. 3

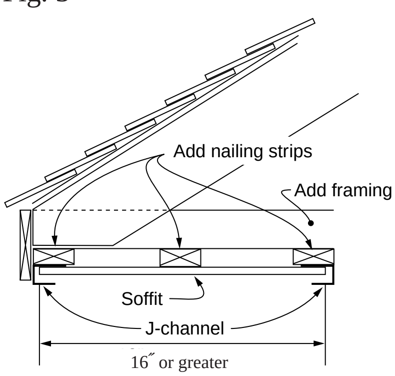



Fig. 4

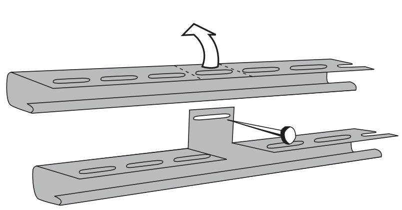


Fig. 5

Soffit is the name given to materials used to enclose the underside of eaves and porch ceilings. The installation of soffit will determine the positioning of the inside and outside corner posts.

Vinyl soffit is designed to be easily installed in residing or new construction. Soffit panels are similar to vertical siding. Soffits are available in aluminum or vinyl. Can be solid, fully perforated or lanced, or combination soffits. Also available in vinyl is a hidden vent system.

*NOTE: Proper attic ventilation is important for any home. Consult a local building official for the appropriate requirements for a specific geographical area, and use vented soffit or other vented products as necessary.*

### *Preparation*

Inspect and plan the job in advance. For residing applications, nail down any loose panels, boards or shingles. Check surfaces for straightness and fur when necessary. Surfaces should be uniform and straight from various viewing angles.

The procedure used to install soffit depends on the construction of the eaves. There are two different types of eaves:

## *TYPE ONE*

Open eaves with exposed rafters or trusses are typical of new construction. Open eave installation procedures are also used when removing damaged soffit during a residing project.

## *TYPE TWO*

Enclosed eaves (eaves with a wood or plywood soffit already in place) are typical of residing projects.

Installation Over Open Eaves:

### *Step 1*

Install receiving channels (F-Channel or J-Channel).

There are several ways to install receiving channels for soffit. You can use accessories such as J-Channel or F-Channel. The best approach is to select a method that works most effectively with the construction techniques used to create the eave.

Examine the illustrations at left and find one that most closely resembles the construction methods used for your particular project (Figs. 1-4). Another option is to cut tabs into J-Channel and to nail into those tabs.

Install the receiving channels following the details shown in the illustrations. Nail channels every 12˝, positioning the nail in the center of the slot. Fasten channels, just snug to take out excessive play. Do not overdrive fasteners.

*NOTE: If the eave span is over 16˝, nailing strips must be installed (Fig. 4).*

***5-step procedure continued:***

### *Step 2*

Measure soffit panels 1/2" shorter than opening. Mark this dimension on a soffit panel and cut using a power saw with a reversed finetooth blade or snips.

### *Step 3*

Insert one end of the panel into the channel on the wall, nail the other end to the wood fascia. (Fig. 1)

- Make certain the panel is perpendicular to the wall, and then nail. Depending on the installation method being used, nails will be hammered either into a nailing strip or fascia board.
- Do not nail soffit panels tightly.
- Continue the installation by locking and nailing the panels. Make certain the panels are fully locked along their entire length.

### *Step 4*

To turn a corner, measure from the channel at the wall corner to the channel at the corner of the fascia board (Fig. 1). Subtract 1/4″ for expansion. Cut and install H-Molding lineal or back-to-back J-Channel. If necessary, install nailing strips to provide backing for the lineal. Miter cut the corner soffit panels and install as described in Step 3.

### *Step 5*

Install aluminum fascia as needed to finish installation. (see section on fascia installation)

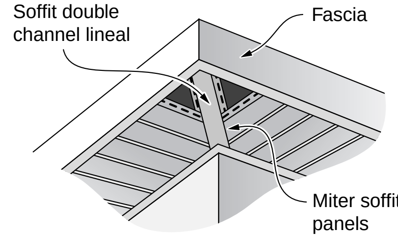



Fig. 1

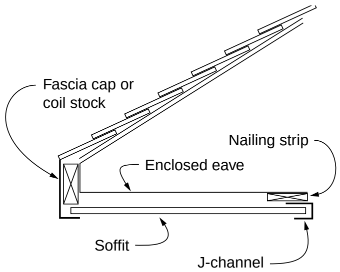



Fig.1

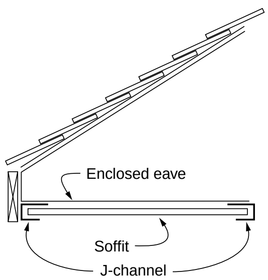



Fig. 2

## *Type 2*

### *Installation Over Enclosed Eaves*

The procedure used to install soffit over enclosed eaves is almost identical to that used for open eaves. A J-Channel or F-Channel can be used to recieve soffit panels. (Fig. 1& 2)

Determine the preferred method of installing soffit at the fascia board.

*NOTE: If the existing soffit is rotted or damaged, remove it completely before installing vinyl soffit, then use the instructions for open eaves.*

***Step 1***
Install soffit per instructions stated previously. Choose the soffit installation method that applies to your specific needs.

***Step 2***
Install metal drip edge, gutter trim, undersill trim, etc. along the top of the fascia board to receive and secure the top edge of the aluminum fascia.

***Step 3***
Measure from the lower side of the soffit panels to the top of the trim installed on the upper side of the fascia board. Deduct approximately 1/8″ from this dimension and cut fascia panel using snips, or score and break with a utility knife and straight edge.

***Step 4***
For the best appearance, we suggest that you do not face nail aluminum fascia. The recommended procedure is to slip the top edge of the fascia into the drip edge (or utility trim) and secure the fascia in place with trim nails installed through the bottom side (Fig.1). Nail no greater than 2´ on center.

***Step 5***
Outside corners: bend a 1″ flange at a 90-degree angle so it turns the corner. Then cut the overlapping fascia and position as shown (Fig. 2).

Inside corners: Use same technique as outside corners.

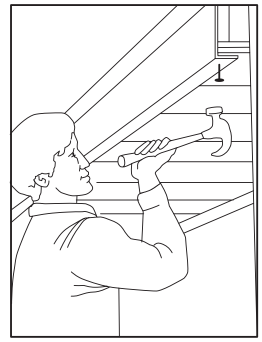


Fig. 1

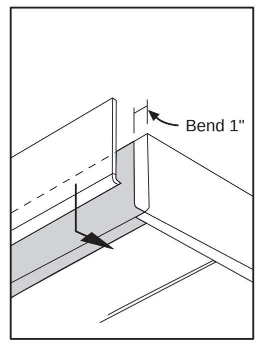



Fig. 2

*NOTE: Nails or fasteners installed through the bottom of the aluminum fascia panel may penetrate the ends of the soffit panels in some installations. The following procedures are recommended if this situation occurs.*

- *Line up the aluminum fascia fasteners with the V-grooves in the soffit panels to avoid cupping the soffit panel faces.*
- *If vinyl soffit panels are over 24″ in length, enlarge the fastener hole in the soffit panel 1/4´ larger than the fascia fastener diameter. This will allow the soffit panels to expand normally and avoid potential buckling.*
- *When fastening aluminum trim, you can only use aluminum or stainless steel painted trim nails. You should always pre-drill (1/8”) diameter hole in the aluminum and do not drive the nail tight.*

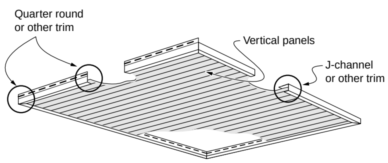



Fig.1

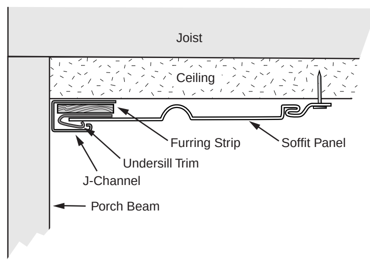



Fig. 2

### *Porch Ceilings*

The procedures to install a porch ceiling are in many ways similar to those used to install soffit. These procedures vary slightly, depending on whether the installation is a new construction or a residing project.

*INSTALLATION TIP: In hot climates or in attics with limited ventilation, it is advisable to install solid sheathing to the underside of the porch ceiling joists. This will protect vinyl soffit panels from excessive heat.*

### *New Construction*

#### *Step 1*
Begin by installing receiving F- or J-Channels on all four sides of the porch (Fig. 1). If F-Channels are being used, nail them to the existing walls or porch beams. If J-Channels are being used, a nailing base will have to be installed.

#### *Step 2*
When planning to use light blocks to attach external light fixtures, install them to adequate backing.

#### *Step 3*
Plan the layout of the ceiling panels to achieve an even balance or to align with adjacent work. If the ceiling joists run parallel to the direction of the soffit panels, additional 1″ x 3″ wood furring nailing strips will have to be installed. Install these nailing strips perpendicular to the ceiling joists, placing a strip every 12″.

#### *Step 4*
Install an undersill trim shimmed down by a furring strip into the J-Channel or F-Channel on the starting end (Fig. 2). Cut the hook side (opposite the nailing hem) off the panel and install snap locks every 6″ to 10″. Install the soffit panel locking the cut edge into the undersill trim and nailing the other side through the nailing slots. DO NOT NAIL TIGHTLY. Install remaining panels.

#### *Step 5*
For large areas where more than one panel length is needed, use a H or T mold or back-to-back J-Channel to separate the sections.

#### *Step 6*
To install last soffit panel, use same technique as outlined in step 4 and Figure 2, except that the nailing hem sidewall be trimmed and snap lock punched every 6″ to 10″. Install the final panel by locking the hook side of the panel on the previous panel and inserting the cut edge into the undersill trim for a secure fit.

### *Residing*

#### *Step 1*
Check to be sure the existing ceiling can serve as a solid nailing base.

#### *Step 2*
If the existing ceiling is solid, remove all existing moldings and fixtures from the ceiling and begin by nailing inverted J-Channels along the perimeter of the ceiling area.
Then follow Steps 2 through 6 in the instructions under “New Construction”. With a solid ceiling, however, additional nailing strips are not necessary. Use the existing ceiling as the nailing base for the panels.

If the existing ceiling is not solid, install nailing strips to provide a secure nailing base, then install the J-Channels. Additional nailing strips should be installed if the ceiling panels are to run parallel to the ceiling joists. Follow the instructions in Steps 2 through 6 for “New Construction”.

*Vinyl Siding Panel*

To repair or replace a siding panel, insert the zip-lock tool under the butt of the course above the damaged panel.

Pull downward and slide the tool along the length of the panel.

Remove the nails of the damaged panel.

Install the replacement panel making sure the lock is re-engaged. (Use the ziplock tool to re-engage the panel by forcing the bottom lock over the newly replaced panel.) (Fig.1)

When re-nailing, be sure panel can move freely in a horizontal direction to allow for expansion and contraction. (Fig. 2)

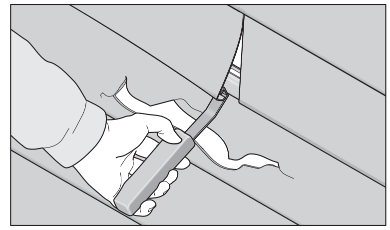


Fig. 1

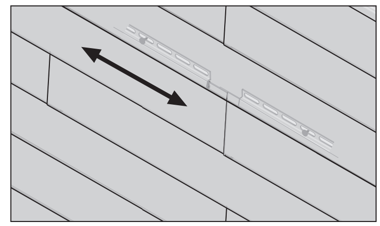


Fig. 2

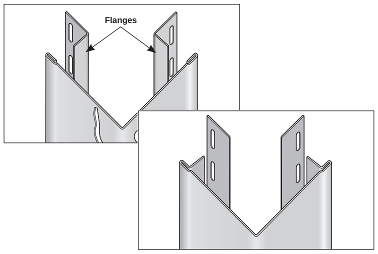
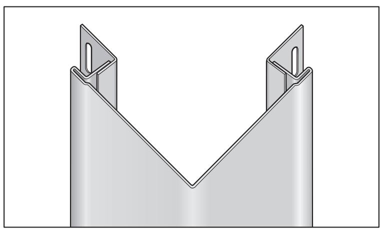



Fig. 1



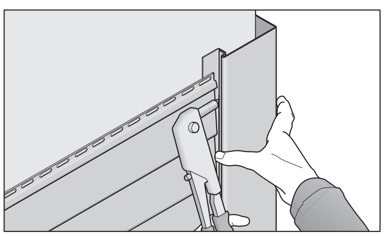


Fig. 3

*Corner Posts*

Using a utility knife cut away the nailing hem of the damaged corner. Be sure to leave the flange.

Trim the new corner post to fit (leaving the same flange). (Fig.1)

Position the new corner in place with flanges overlapping. (Fig. 2)

Attach the new corner posts to the existing flange with pop rivets. (Fig. 3)

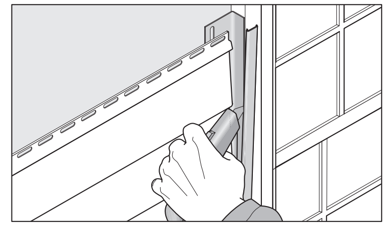
*J-Channel*

Cut away the face of the channel.

Cut the new J-Channel away from the nailing hem. (Fig.1)

Position the new J-Channel over the old. (Fig.2)

Pop rivet the new piece into place. (Fig.3)



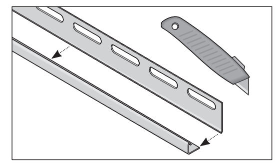


Fig. 1

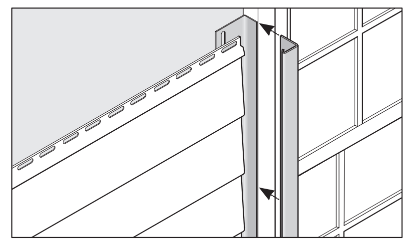


Fig. 2

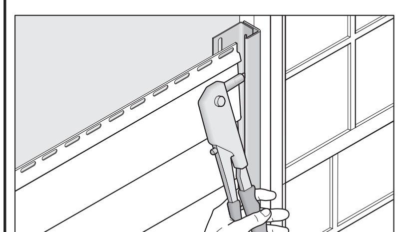


Fig. 3

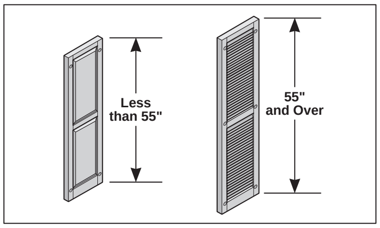



Fig. 1

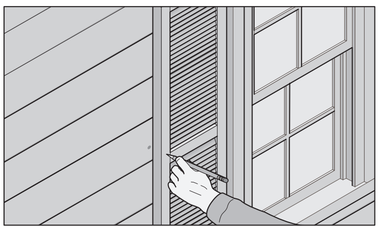


Fig. 2

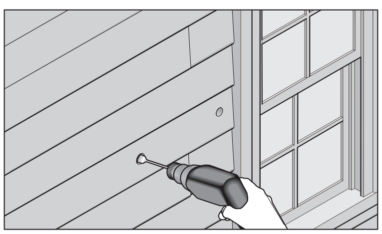


Fig. 3

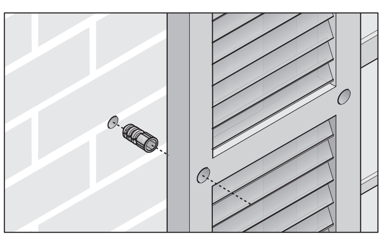


Fig. 4

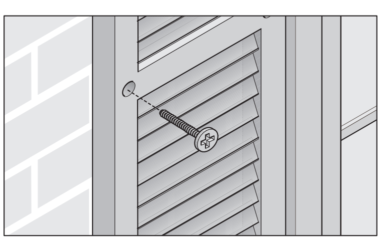


Fig. 5

## *Shutters*

Two types of fasteners are included within the packaging of the shutter product; **metal screws** and **polymer shutterplugs.**

Use four fasteners for shutters less than 55″ in length. Position top screw/plug approximately 6″ down from the top of the shutter, and bottom screw/plug approximately 6″ up from the bottom of the shutter. (Fig.1)

Use six fasteners for shutters 55″ and longer in length. Attach the two additional screws at the midpoint along the length of the shutter. (Fig.2)

***Following are the instructions when using the two types of fasteners:***

## *Polymer Shutterplugs*

Suggested for permanent, non-removable installations; works well on brick or block; solid-base construction material required; not for vinyl over foam insulation without sheathing.

Locate shutter beside window.

Drill a 1/4″ diameter hole in shutter and into solid base material a minimum of 2″ deep (into mortar joint locations for masonry).

Insert plug by tapping lightly with a hammer.
*DO NOT FORCE SHUTTERPLUG SO TIGHTLY AS TO CAUSE DEPRESSION OF SHUTTER SURFACE.*

## *Metal Screws*

Can be used for all solid wall surfaces.

*Wood Substrates*

Locate shutter beside window

Drill 7/32″ diameter hole in shutter and in wood surface.

For vinyl siding applications, redrill a 3/4″ hole in the vinyl siding only to allow for expansion and contraction.

Screw shutter in place with 3″ long metal screws (included). DO NOT FORCE SCREW TIGHT ONTO SHUTTER SURFACE. (Fig.5)

*Masonry Construction*

Locate shutter beside window.

Drill 7/32″ hole into shutter making sure to position at mortar locations.

Drill hole in mortar joint of masonry as instructed by insert manufacturer. (Fig.4)

It is necessary to incorporate inserts (not supplied in shutter packaging) to provide holding power for the screw.

Place insert in hole with hammer.

Position shutter and screw in place with 3″ long screws. *DO NOT FORCE SCREW TIGHT ONTO SHUTTER SURFACE.* (Fig.5)

*NOTE: Allow 1/4″ gap between shutter and window and all other stops to allow for expansion and contraction.*

*Optional hidden fasteners for standard shutters are available from your distributor.*

*The tough, long-lasting polypropylene construction of Cedar Discovery® Siding will bring years of beauty to a home without the maintenance required with natural cedar.*

*To avoid waste and make installation faster, please take a few minutes to read and understand these instructions.*

*Tools Required*
- Hammer
- Pencil
- Snips
- Nail Slot Punch
- Circular Saw with 18-24 Tooth Carbide Tipped Blade (not reversed)
- Chalk Line
- Utility Knife
- Tape Measure
- Level
- Corrosion-Resistant Siding Nails or Screws

### *Important*

*A SOLID NAILABLE SHEATHING, SUCH AS PLYWOOD OR OSB IS NECESSARY FOR A PROPER AND SECURE INSTALLATION.*

*PANELS MUST BE INSTALLED FROM RIGHT TO LEFT.*

When nailing through slots, always nail in CENTER of slot. DO NOT NAIL TIGHT. Panels must be able to move to allow for expansion and contraction caused by temperature change.

All panels (full and partial) must have the following nailing sequence:

1. First, nail through center of Nail Slot at the right end of panel.

2. Nail through center of Nail Slot toward the left end of panel. Note, Do NOT nail through the far left nail slot.

3. Nail through center of the Nail Slot in the Left Side Flange.

4. Nail through Nail Hole (NOT Nail Slot) at the center of panel.

5. For maximum wind load nail through center of Nail Slots every 8˝.

Panels should be acclimated to air temperature by placing them in the general work area at least one hour prior to installation. Air temperature should be checked when installing the first course of each new wall to determine the amount of panel overlap. As air temperature changes, it is NOT necessary to go back and adjust the spacing of previously installed panels.

Installation Tip for Cedar Discovery Triple 5: *For the best appearance, it is very important to be aware of panel temperature instead of air temperature. To accomplish this, the panels should be placed in a shaded area before being installed to acclimate to the ambient temperature. Another option is to measure the panel temperature with an Infrared Temperature device, In either case, install the panel to the appropriate temperature gauge mark.*

Special thought should be taken to eliminate short pieces.

Allow 1/4˝ clearance for all stops, such as corner posts and J-Channels. When installing products in very cold temperatures (<40°F), allow 3/8˝ clearance for expansion and contraction.

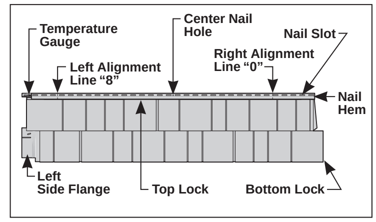
In order to finish the wall without a short course at the top, measure down from the soffit and adjust as needed.

This product is for exterior use only, and should be installed on flat, vertical walls to maintain an even appearance. It can be installed on mansard roofs with a slope of 45/12 or greater (15-degree angle or less). See Mansard Roof Installation instructions.

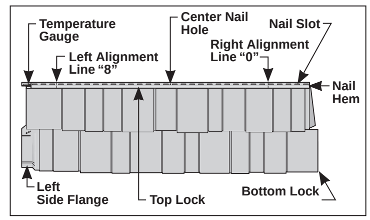
*Maintenance*

To clean, use mild soap with warm water to remove dirt, dust or surface stains that may collect from time to time.

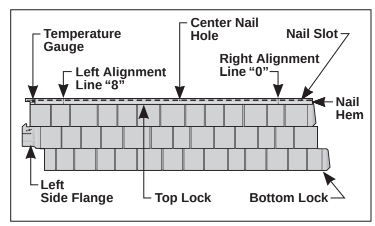
- Product should not be painted.



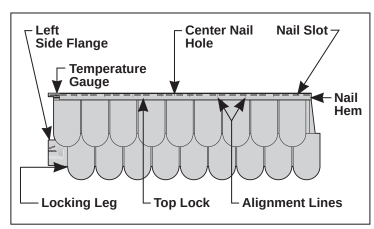

Cedar Discovery® Perfection Shingle Double 7"




Cedar Discovery® Hand-Split Shake




Cedar Discovery® Perfection Shingle Triple 5"




Cedar Discovery® Half-Round

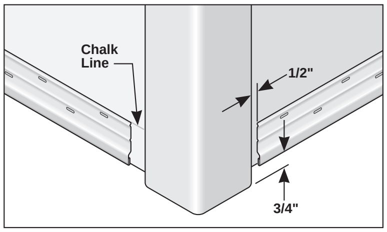



Fig. 1 (Cedar Discovery® Perfection Shingle Double 7")

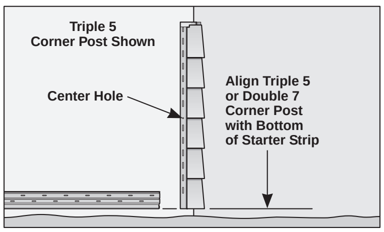



Fig. 2 (Cedar Discovery® Perfection Shingle Triple 5")

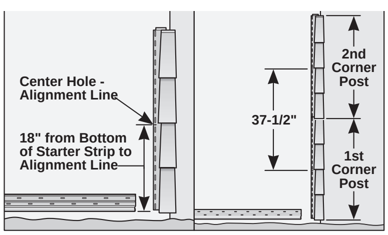



Fig. 3 (Cedar Discovery® Hand-Split Shake)

### *Starter Strip Installation*

Snap a chalk line on all walls to align the top edge of the starter strip (or J-Channel). Make sure to use the special starter strip for Cedar Discovery®.

Installation of starter strip (or J-Channel) and panels should begin on the lowest wall.

Install starter strip (or J-Channel) along the chalk line, nailing in nail slots to allow for penetration into solid wood. Wood stripping may be required to accomplish this. Nail every 6-8″. DO NOT NAIL TIGHT.

To allow for movement, install starter strip (or J-Channel) 1/2″ from corner post. Let corner post hang 3/4" below the bottom of the starter strip (see Figure 1).

Install all accessories including J-Channel, corners, etc.

*NOTE: Accessories must have 3/4″ receiver for all Cedar Discovery panels with the exeption of the hand-split shakes, which require 7/8″ pocket accessories.*

### *Corner Post Installation*

For all four Cedar Discovery panels, the Universal Corner Post can be used. In this case, hang the corner post 3/4″ below the starter strip or J-Channel. (see Figure 1).

For Cedar Discovery Perfection Shingle Triple 5″ and Double 7″, align bottom of corner post with bottom of starter strip or J-Channel (see Figure 2).

1. Nail through center hole.
2. Continue nailing corner post every 8″ through center of nail slot.

*NOTE: Do Not Nail Tight.*

### *Installing Cedar Discovery Hand-Split Shake Corner Post*

1. Measure up 18″ from bottom of Starter Strip and mark wall (see Figure 3).
2. Position Alignment Line with mark, and nail through Center Hole.
3. Continue nailing Corner Post every 8″ through center of Nail Slots.

*NOTE: Do Not Nail Tight.*

4. To install additional Corner Post sections, measure and mark 37-1/2″ from previous post Alignment Line.
5. Position Alignment Line with mark, and nail.
6. Repeat Steps 4 and 5 as needed.

### *Installing Less Than Full Length Corner Post*

Remainder of cut corner post can be used as starter corner post. Cut and remove section below last full cap.

1. For Triple 5″ and Double 7″, install modified corner aligning it with the bottom of starter.
2. Full length corner post can be installed as previously described.
3. For Hand-Split Shake Corners, the first alignment line should be adjusted to allow for the modified corner post by adding increments of 9-3/8” as needed.

### *Nailing Procedures*

*NOTE: Be sure panel is pulled up. Do not nail tight.*

All panels (full and partial) must have the following nailing sequence: (see Figures 1-2).

1. First, nail through center of Nail Slot at the right end of panel. (See “N1”).
2. Nail through center of Nail Slot toward the left end of panel. (See “N2”).
   *NOTE: Do NOT nail through the far left nail slot.*
3. Nail through center of the Nail Slot in the Left Side Flange. (See “N3”).
4. Nail through Nail Hole (NOT Nail Slot) at the center of panel. (See “N4”).
5. For maximum wind load nail through center of Nail Slots every 8″.

*NOTE: For full panels, center hole is marked on nail hem (Fig. 2). For cut panels, measure to locate center point on nail hem.*

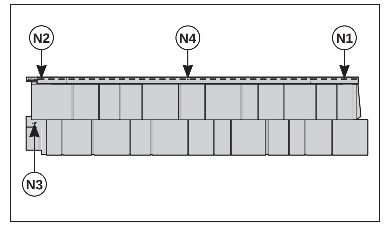



Fig. 1

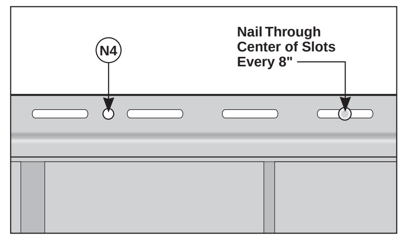



Fig. 2

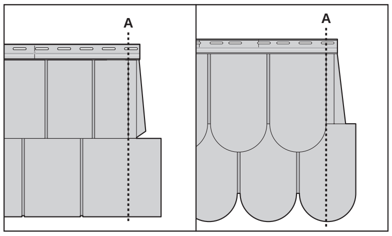



Fig. 1

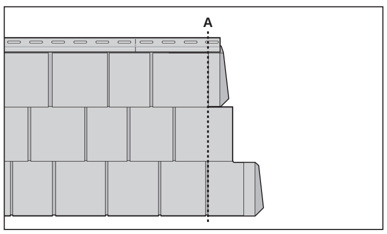



Fig. 2 (Cedar Discovery® Perfection Shingle Triple 5″)

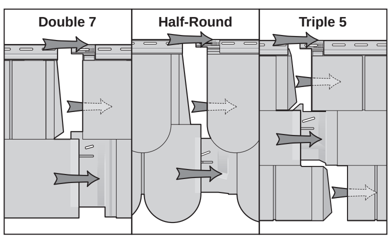



Fig. 3 Perfection Shingle 7″ & Hand Split Shake.

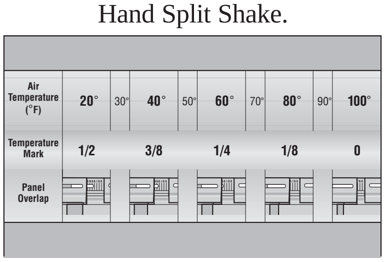



Fig. 4 Perfection Shingle 5″

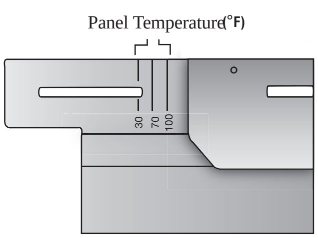



Fig. 5 Half Rounds

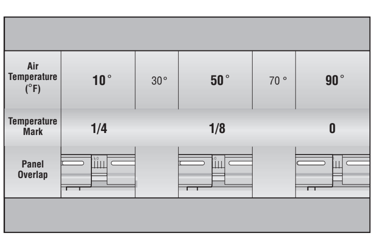



Fig. 6

## *First Course*

*NOTE: PANELS MUST BE INSTALLED FROM RIGHT TO LEFT.*

a. Cut the first panel at "A" (see Figures 1-2).

*NOTE: To provide for panel movement, allow 1/4″ gap at all corner posts, J-channels, or other stops.*

b. Engage bottom lock firmly into Starter Strip. Nail according to "NAILING PROCEDURES."

c. Slide the next panel into position. For Perfection Shingle Double 7″, Hand-Split Shake and Half-Rounds, the top half of the panel, except the Nail Hem, slides under, and the bottom half slides over the previous panel. For Perfection Shingle Triple 5″, the top section of the panel (except the Nail Hem) and the bottom section of the panel slide under, and the middle section slides over the previous panel. On all products, the Nail Hem will be on top of the previous panel (see Figure 3).

For Perfection Shingle Double 7″ and Hand-Split Shake overlap amount, see (Figure 4). For Perfection Shingle Triple 5″ overlap, see (Figure 5). For Half-Rounds overlap, see (Figure 6).

*NOTE: The amount of panel overlap is important and varies depending on air temperature. Check and monitor air temperature when starting to install the first course on each wall. See chart for amount of overlap (see Figures 4-6).*

Installation Tip for Cedar Discovery® Triple 5: *For the best appearance, it is very important to be aware of panel temperature instead of air temperature. To accomplish this, the panels should be placed in a shaded area before being installed to acclimate to the ambient temperature. Another option is to measure the panel temperature with an Infrared Temperature device, In either case, install the panel to the appropriate temperature gauge mark.*

d. Nail according to "NAILING PROCEDURES."

e. Install additional full panels, repeating Steps b-d.

## *Last Panel on Each Course*

*For Perfection Shingle Double 7˝, Hand-Split Shake and Half-Rounds*, measure the distance from the correct line on the temperature gauge into the corner post, less 1/4˝ (see “A” on Figure 1).

For *Triple 5˝*, measure the distance from the correct line on the temperature gauge to the edge of the corner post and ADD 1/4˝.

Cut off left end of panel (see “B” on Figure 1).

Engage lock into starter strip or continuous lock of previous course, pull up tight and nail according to *“NAILING PROCEDURES.”*

Installation Tip: Panels will flex to allow installation. To minimize waste, cut pieces can be used as starter pieces on adjacent wall.

## *Using Alignment Lines*

*NOTE: Temperature gauge is used only for installation of the first course on each wall. Do NOT adjust temperature gauge on panels after 1st course is complete “except when adjusting panels for windows or last panel of each course”.*

*Perfection Shingle Double 7˝, Triple 5˝ and Hand-Split Shake Panels* – For 2nd and subsequent courses, align Left Side Flange with Left “8” or Right “0” Alignment Line of previous course, according to instructions.

*Half-Rounds* – For 2nd and subsequent courses, align Left Side Flange with nearest Alignment Line that allows proper fit and overlap of shingles. Be sure to cut panel to stagger vertical laps.

## *Second Course (and all even courses)*

a. *Perfection Shingle Double 7˝ and Hand-Split Shake* – Measure the distance from the Left Alignment Line “8” of the panel below into the corner post or J-Channel, less 1/4˝ (see “A” on Figure 2).

b. *Perfection Shingle Triple 5˝* – Measure the distance from the Left Alignment Line “8” of the panel below into the corner post or J-Channel, PLUS 1/4” (see “A” on Figure 3). and subtract 1/4˝.

b. *Perfection Shingle Double 7˝*, and Hand-Split Shake – Measure from the Left Side Flange of panel and cut to this length (see “B” on Figure 2).

*Perfection Shingle Triple 5˝* – Measure from the Left End of the Lowest Panel and cut to this length (see Figure 3).

*Half-Rounds* - Measure appropriate distance from the Left Side Flange of panel (allowing for staggered vertical laps) and cut (see Figure 4).

c. *Perfection Shingle Double 7˝* and Hand-Split Shake – Align Left Side Flange with Left Alignment Line “8” of the course below (see Figure 5).

*Perfection Shingle Triple 5˝* – Align Lowest Panel Left Edge with Left Alignment Line “8” of the course below (see Figure 6).

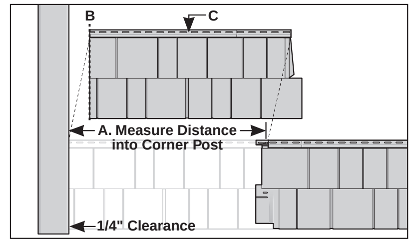



Fig. 1

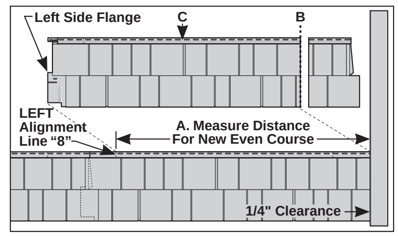



Fig. 2

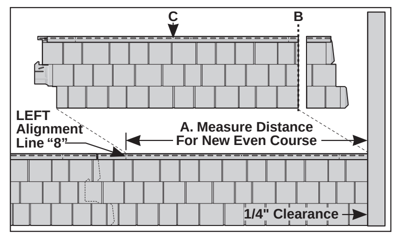



Fig. 3

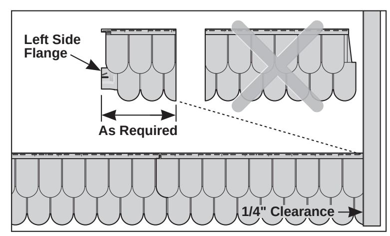



Fig. 4

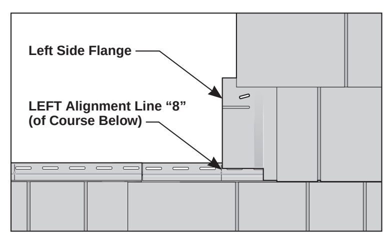



Fig. 5

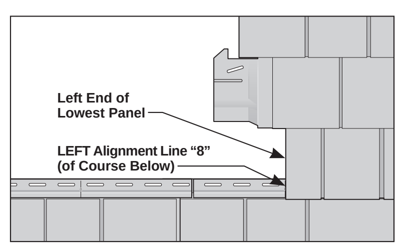



Fig. 6

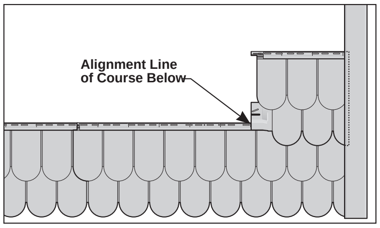



Fig.1

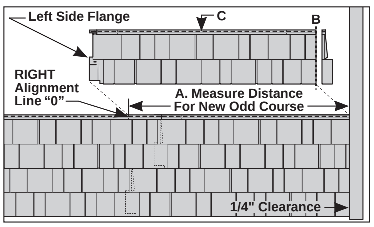



Fig.2

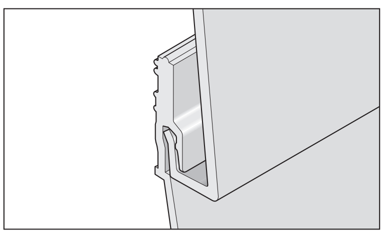


Fig.3

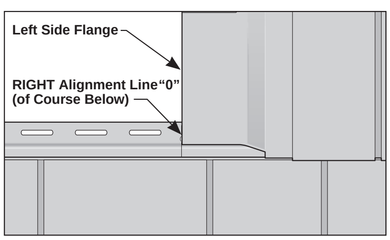



Fig.4

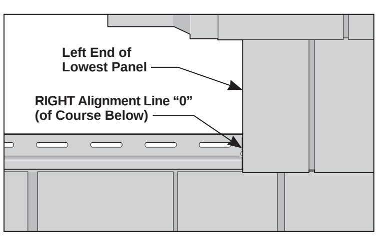



Fig.5

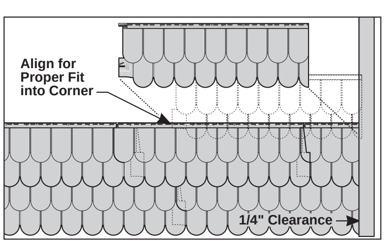



Fig.6

## *Half-Rounds*

Align Left Side Flange with nearest Alignment Line of course below that allows for proper fit into corner post or J-Channel (see Figure 1).

d. Engage lock securely into continuous top lock of course below (Figure 3).

e. Pull up tight and nail according to *"NAILING PROCEDURES."*

f. Continue installing full panels in the course, following Steps c-e.

g. To finish course, refer to previous section titled *"Last Panel on Each Course"*.

## *Third Course (and all odd courses)*

a. *Perfection Shingle Double 7˝, Triple 5˝ and Hand-Split Shake* – Measure the distance from the first RIGHT Alignment Line "0" of the course below into the corner post or J channel and subtract 1/4˝ (see "A" on Figure 2).

b. *Perfection Shingle Double 7 " and Hand-Split Shake* – Measure from the Left Side Flange of panel and cut to this length (see "B" on Figure 2).

*Perfection Shingle Triple 5˝* – Measure from the Left End of the Lowest Panel and cut to this length.

c. Engage lock securely into continuous top lock of course below.

d. *Perfection Shingle Double 7˝ and Hand-Split Shake* – Align Left Side Flange with RIGHT Alignment Line "0" of the course below (see Figure 4).

*Perfection Shingle Triple 5˝* – Align Lowest Panel Left Edge with Right Alignment Line "0" of the course below (see Figure 5).

*Half-Rounds* – Align Left Side Flange with nearest Alignment Line of course below that allows for proper fit into corner post or J-Channel (see Figure 6).

e. Pull up tight and nail according to *"NAILING PROCEDURES."*

f. Continue installing full panels in the course, following Steps c-e above.

g. To finish course, refer to section titled *"Last Panel on Each Course"* on page 58.

## *Securing Panels Around Windows*

Measure and cut panels around windows, allowing 1/4″ into all window channels for movement. (see Figure 1).

Make sure to install water diverters at the bottom corners of the window (refer to Basic Accessory Installation Section Installing J-Channel, Flex-J and Flashing).

Use a nail slot punch to create nail slots every 8″ on the cut edge of the panel.

Furr as needed.

Slide panel into window channel.

Pull up tight and nail according to

Installation Tip: A nail set can be used to ease installation.

## *Installing Final Course*

*NOTE: A crown molding, J-Channel or wide window casing can be used in eaves and gables to receive the final course (see Figure 2).*

Measure the required width for last course less 1/4″ to allow for panel movement.

Cut panel height as required.

Punch nail slots every 8″.

Nail through center of slots.

*NOTE: Furring may also be required.*

*Alternative Method:*

Cut 2″ wide piece of utility trim.
Nail into the eave J-Channel, making sure to locate them at the flat areas of the shakes. Using the snaplock punch, install a lug at each utility trim location.

*Cedar Finish Trim*
The Cedar Finish Trim can also be used to help provide a finished appearance and to help secure cedar products around windows and at the last course of siding. The Cedar Finish Trim has a wider opening that allows for the exta material thickness. Secure the panel with a finish trim nail.

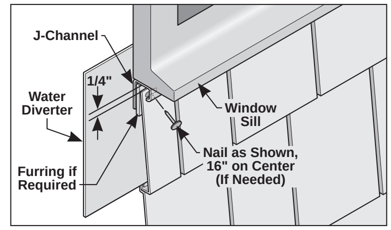



Fig. 1

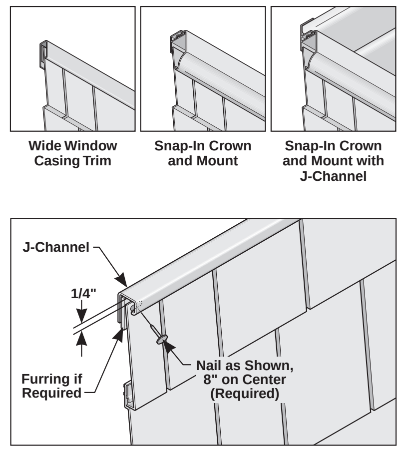



Fig. 2

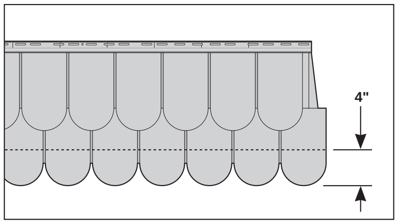



Fig. 1

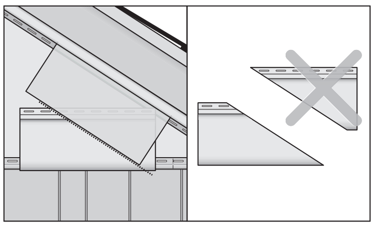


Fig. 2

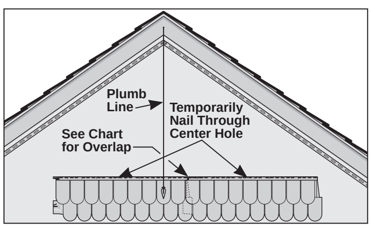



Fig. 3

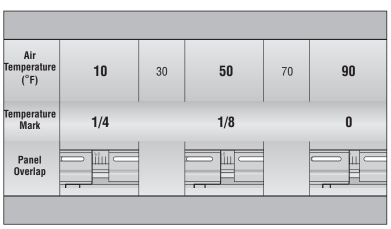



Fig. 4

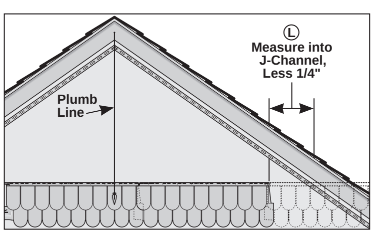



Fig. 5

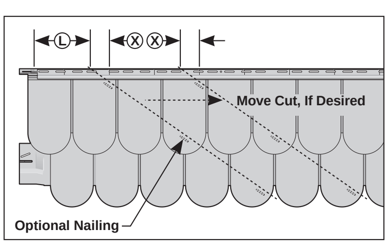



Fig. 6

## *Installing Cedar Discovery® Half-Rounds on Gable Ends*

Cedar Discovery Half-Rounds can be locked directly onto other Cedar Discovery panels . If desired for transitions, panels can be installed using Starter Strip (CDSS) over Drip Cap, or into T-Channel or Lineals. When installing into any channel or lineal, cut 4˝ from the bottom of the Half-Round (see Figure 1). Allow 1/4˝ gap for panel movement.

*NOTE: PANELS MUST BE INSTALLED FROM RIGHT TO LEFT. Do not nail tight. Allow 1/4˝ into all channels, posts and stops. Make a template for gable angle by locking a short piece of siding into the gable starter course. Hold a second piece against the gable finish trim. Mark angle on first piece and cut (see Figure 2). Make templates as needed.*

## *Centering Cedar Discovery Half-Rounds on Gable Ends*

When installing Half-Rounds in gables, the last piece should be centered at the peak of the gable for proper appearance.

a. For symmetrical appearance at peak, position and lock full panel in the first course with Half-Rounds at center of the gable (see Figure 3). Temporarily fasten through center hole. Continue temporarily installing full panels toward right side of the gable (see chart, Figure 4, for overlap).

b. When less than full panel is needed, measure top of Nail Hem into gable end trim, less 1/4˝ (see Figure 5). Use this dimension (L) to cut first piece for installation.

c. To locate the cut mark on 1st panel, measure from the appropriate temperature mark to the right and mark top of Nail Hem (see “L” on Figure 6).

d. Use template and cut at mark. If needed for secure installation, move the mark an equal distance (X on Figure 6) from any Alignment Line.

e. Remove temporarily nailed panels.

### *Installing First Course on Gable End*

a. Use panel cut in step “d” in the previous section. If installing into Siding or Starter Strip, lock firmly, pull up tight and nail according to *“NAILING PROCEDURES.”*

b. Slide the next panel into position. The top half of the panel, except the Nail Hem, slides under, and the bottom half slides over the previous panel. The Nail Hem will be on top of the previous panel (Figure 1). Nail slots can be placed at angle cut for additional nailing.

c. If this is your first course of Half-Rounds, refer to chart for over lap amount (Figure 2).

d. If this is not your first course of Half-Rounds, align Left Side Flange with nearest Alignment Line of course below that allows for proper fit into right end finish trim.

e. Engage bottom lock firmly into Siding or Starter Strip, pull up tight and nail according to *“NAILING PROCEDURES”*.

f. Install additional full panels, repeating Steps c-e.

### *Last Panel on Each Course*

a. Make template for angle if needed.

b. Measure distance from correct line on temperature gauge into the gable end trim, less 1/4″ (see “L” on Figure 3).

c. Measure panel from right end of Nail Hem and cut at correct angle (see “L” on Figure 4).

d. Engage lock into starter strip or continuous lock of previous course, pull up tight and nail according to *“NAILING PROCEDURES.”*

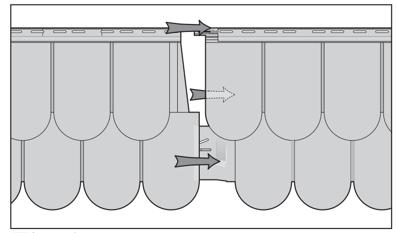


Fig. 1

| Air Temperature (°F) | 10 | 30 | 50 | 70 | 90 |
|---|---|---|---|---|---|
| Temperature Mark | 1/4 | | 1/8 | | 0 |
| Panel Overlap | | | | | |

Fig. 2

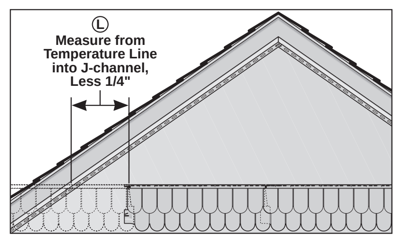



Fig. 3

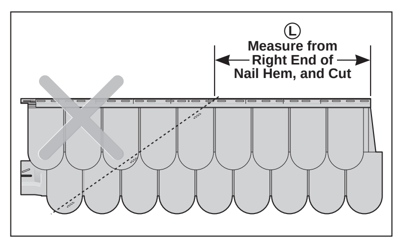



Fig. 4

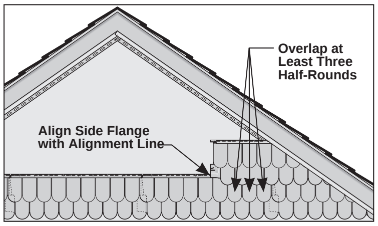



Fig. 1

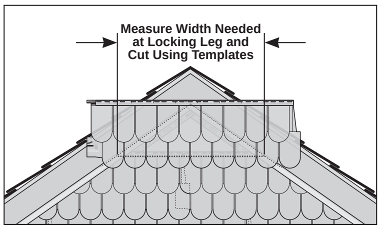



Fig. 2

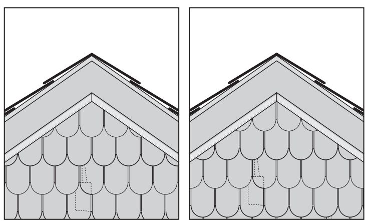


Fig. 3

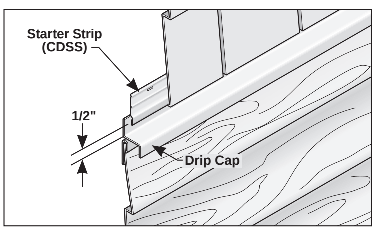



Fig. 4

## *Second and Subsequent Courses on Gable End*

a. Make new template for angle if needed.

b. Measure from the Left Side Flange making sure to stagger the laps by at least 3 half-rounds (Figure 1).

c. Align Left Side Flange with nearest Alignment Line of course below (Figure 1).

d. Insert Bottom Lock into Top Lock of course below. Pull up tight and nail according to *"NAILING PROCEDURES."*

e. For second and subsequent panels, align Left Side Flange with nearest Alignment Line of course below that allows for proper fit. Insert Bottom Lock into Top Lock of course below. Pull up tight and nail according to *"NAILING PROCEDURES."*

## *Final Course on Gable end*

Measure width needed at bottom lock (see Figure 2).

Carefully check alignment of Half Rounds to center full or partial rounds as needed and cut (see Figure 3).

Insert Bottom Lock of final course into Top Lock of course below, pull panel up tight, and nail at peak using a color matching trim nail.

## *Installing Above Horizontal Siding*

Starter Strip "CDSS" with Drip Cap (see Figure 4).

*Mansard Roof Installation Instructions*

Cedar Discovery® can only be installed on mansard roofs with a slope of 45/12 or greater (15-degree angle or less). It must be attached with standard siding nails into a solid wood substrate.

The sheathing must be covered with either:

1 layer 30 lb. roofing felt with a 6˝ minimum horizontal and vertical laps.

2 layer 15 lb. roofing felt (see Figure 1).

A field formed flashing must be installed at the bottom of the mansard. This can also be the cap for the soffit. The flashing should go up the roof a minimum of at least 4˝. (see Figure 2).

The Cedar Discovery starter strip should be installed onto the flashing. Follow the standard installation guidelines. (see Figure 3).

Install any 3/4˝ corner post system at all transitions. The bottom of these corner posts should be closed off by bending flaps as shown (see Figure 4).

Install all Cedar Discovery courses cutting the last course as required. Slot nail holes and nail into top of mansard following standard installation guidelines for last panel installation (see Figure 5).

Form a cap from trim sheet that will cover the top of the mansard and come down to cover the nails that are holding the last course of Cedar Discovery. It is recommended that this flashing be installed under the top roofing or behind the sidewall system (see Figure 6).

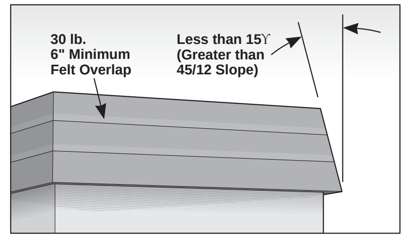



Fig. 1

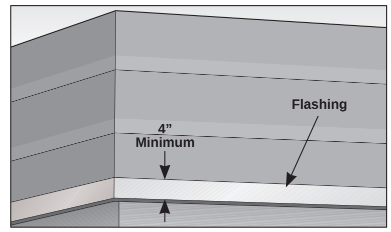



Fig. 2

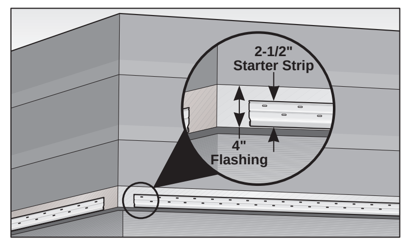



Fig. 3

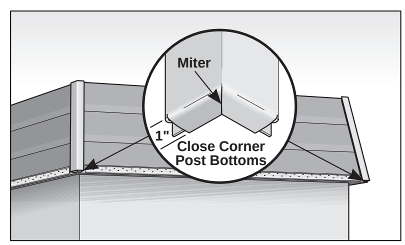



Fig. 4

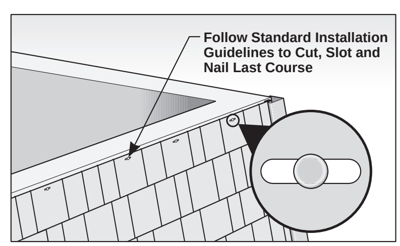



Fig. 5

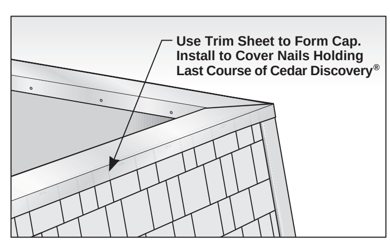



Fig. 6

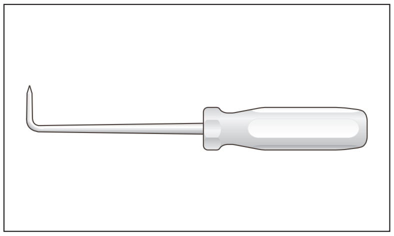


Fig. 1

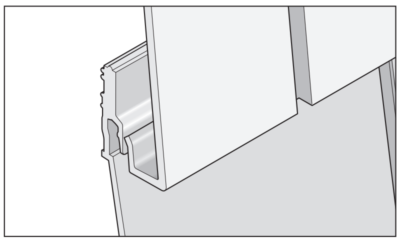


Fig. 2

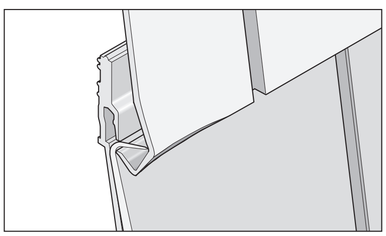


Fig. 3

*Replacing A Damaged Panel*

To repair or replace a damaged panel, unlock panel above the damaged panel in order to expose nail hem of damaged panel.

*NOTE: This can be done by either pulling out at bottom lock with your hand, or using a Hook & Cotter Pin Puller Tool (NAPA Auto Parts No. 3470 or equivalent) (see Figure 2).*

Remove nails from damaged panel, and unlock from previous course. (see Figure 3).

Install replacement panel by locking into course below, then nailing according to “NAILING PROCEDURES”.

Using a Hook & Cotter Pin Puller Tool (NAPA Auto Parts No. 3470 or equivalent), start at the left end of the panel, and begin locking the panel above to the new installed panel (see Figure 1).

*NOTE: For best results, engage 3″-4″ of lock at a time, continuing from left to right along the length of the panel.*

When historic restoration projects arise, the manufacturer recommends the following:

***Step 1***
If a building is in a historic area, local Historic District or has been designated as a historic building, make sure that approval for the use of vinyl siding has been obtained from the local historic society or local Historic District Commission. This applies to building additions as well.

***Step 2***
Before a historic building is resided, it should be examined for moisture, insect infestation, structural defects, and other problems that may be present. These problems should be addressed and the building pronounced "sound" before residing with any material.

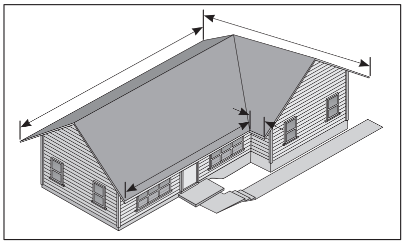
***Step 3***
Do not damage or remove the original siding. If at all possible, do not alter the original structure, so that the application of vinyl siding is reversible (i.e., the original siding would remain intact in the future, so that if desired, the vinyl siding could be removed). Exception: "In cases where a non-historic artificial siding has been applied to the building, the removal of such a siding before application of vinyl siding would, in most cases, be acceptable".

1Preservation Briefs, Number 8, U.S. Department of Interior, 1984.1

***Step 4***
Exercise every care to retain architectural details wherever possible. Do not remove, cover, or add details until the building owner's written approval has been obtained. Determine that the owner has consulted the local historic society for approval.

***Step 5***
Use siding that closely approximates the appearance of the original siding in color, size and style. In historic districts, the goal is to match the product as closely as possible and retain the original trim.

*For further information, contact:*
*Historic Preservation at www2.cr.nps.gov*



## *Planning, Measuring and Available Systems*

Determine the lengths of gutters necessary. Minimize seams by selecting from various gutter lengths available.

Determine the number of accessories necessary.

Calculate the number of downspouts necessary. The number and placement of downspouts used determine the water carrying capabilities of a gutter. Use the following guide to calculate the proper amount of downspouts:

- a 2x3 downspout will carry an average rainfall amount of 600 sq. ft. of roof area
- a 3x4 downspout will carry an average rainfall amount of 1,200 sq. ft. of roof area

## *Sectional Gutters and Accessories Hangers*

*Determine which of these hanger systems will work best. All hangers should be attached with two 1-1/4″ stainless steel screws or screw shank aluminum nails.*

### *Snug Fit Hanger*

This hanger is ideal for remodeling use where it is necessary for the back leg of the gutter to fit tightly under roof shingles. A chalk line should be struck along the fascia to act as a guide when installing these hangers. These hangers will allow the gutter to be installed level or with a slight slope. After all hangers are installed, the gutter is attached by engaging the front lip of the gutter into the front lip of the hanger and rotating the back leg of the gutter up against the fascia. The clip at the back of the hanger should be loosened so that it is free to slide under the lip on the back leg of the gutter. Once the clip is engaged in the back leg of the gutter, the nut and bolt should be tightened.

### *Combination Hanger*

This hanger is ideal for both remodeling and new construction use. A chalk line should be struck along the fascia to act as a guide when installing these hangers. These hangers can
be installed level or with a slight slope. Once the hangers are installed, the gutter is attached
by engaging the front lip of the gutter into the front lip of the hanger and rotating the back leg of the gutter up against the fascia so that the two hooks on the back of the hanger lock into the lip on the back of the gutter.

### *Strap Hanger*

Use in combination with roof or fascia apron* – This combination is ideal for new construction and re-roofing applications. In lieu of a drip edge, the roof apron should be installed continuously along the edge of the roof above the fascia and nailed every 16″ with 1-1/4″ aluminum nails through the top flange of the roof apron. The gutter is then attached by sliding the back leg of the gutter up under the roof apron so that the lip on the gutter locks into the hook portion of the roof apron. Once the gutter is locked up along the entire length of the roof apron, strap hangers can be installed by engaging the front of the strap hanger into the front lip of the gutter and rotating the other end of the hanger down into the roof surface. This type of installation is designed for level applications of gutter or an application which is parallel to the roof edge of fascia.

**NOTE: Roof apron is not applicable for slopes greater than 6:12. Hanger is to be installed on roof sheathing under shingles.*

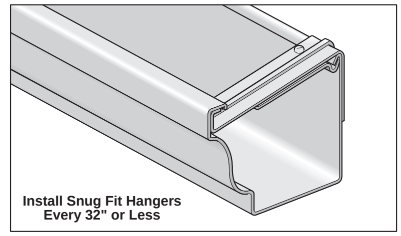



Fig. 1

| | 5" | 6" |
|---|---|---|
| Hanger | OG91 | N/A |
| Leaf Relief® | TP53ZIP | |

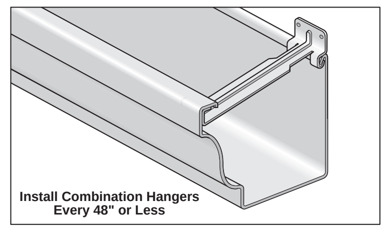



Fig. 2

| | 5" | 6" |
|---|---|---|
| Hanger | OG101 | OG1061 |
| Leaf Relief® | TP53ZIP | N/A |

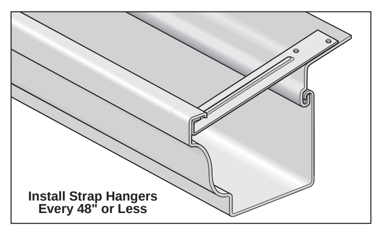



Fig. 3

| | 5" | 6" |
|---|---|---|
| Hanger | OG111 | OG1161 |
| Leaf Relief® | See page 97 | See page 97 |

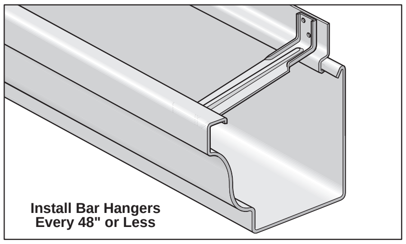



Fig. 1

| | 5" | 6" |
|---|---|---|
| Hanger | OG12R1 | OG12R61 |
| Leaf Relief® | TP53ZIP | N/A |

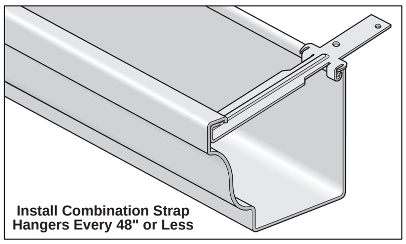



Fig. 2

| | 5" | 6" |
|---|---|---|
| Hanger | OG141 | N/A |
| Leaf Relief® | TP53ZIP | N/A |

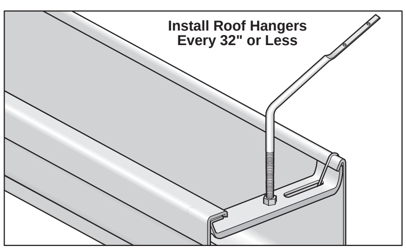



Fig. 3

| | 5" | 6" |
|---|---|---|
| Hanger | OG131 | OG1361 |
| Leaf Relief® | N/A | N/A |

## *Bar Hanger*

When used with a fascia apron, this combination is ideal for remodeling applications. The fascia apron should be installed continuously along the top of the fascia and nailed every 16″ into the fascia. The fascia apron can be installed level, parallel to the roof edge or to a desired slope. The gutter is then attached by sliding the back leg of the gutter up under the fascia apron. Once the gutter is locked into the fascia apron continuously, the bar hangers are installed by engaging the front of the bar hanger into the front lip of the gutter and rotating the back of the bar hanger down to rest on the fascia apron. Bar hangers should be fastened into a solid fascia board (minimum 3/4″ thickness) through the fascia apron with two 1-1/4″ stainless steel screws or screw shank aluminum nails. (Figure 1)

## *Combination Strap Hanger*

This hanger is ideal for re-roofing or new construction applications. The hanger should be fastened into solid roof sheathing (minimum 1/2 thickness). The gutter is attached by engaging the front lip of the gutter into the front lip on the hanger and rotating the back leg of the gutter up so that the top lip engages into two hooks on the back of the hanger. The back leg is then locked in place by bending down the two tabs on either side of the hanger. This hanger will provide for a level installation, assuming that the edge of the roof and fascia are level. (Figure 2)

*NOTE: Hanger is to be installed on roof heathing under shingles.*

## *Roof Hanger*

This hanger is ideal for new construction or remodeling work. It can be used in applications where there is no existing fascia board, a crown molding exists, or the fascia is attached to the rafter ends which are not parallel to the walls of the home. There is a flattened relief portion of the aluminum rod of the roof hanger that is designed to be bent to the pitch of the roof. After the rod has been bent to the pitch of the roof, the top flattened portion of the rod should be nailed into solid roof sheathing (minimum 1/2″ thickness). Once the hangers are nailed into place, they can be adjusted up or down by loosening or tightening the two nuts on either side of the hanger bracket for a level or sloped installation. (Figure 3)

The gutter is attached by engaging the front lip of the gutter into the front of the hanger and rotating the back leg of the gutter up so that the top lip of the gutter engages on the back leg of the hanger bracket. The metal tab on the hanger is then bent up over the back leg of the gutter to lock the back leg of the gutter into place. (Figure 3)

*NOTE: Hanger is to be installed on roof sheathing under shingles.*

## *Preparing Gutters for Leaf Relief® Application*

*Installing NEW Gutters using Snap-In (Free Float) Gutter Hangers (OG13LR5) with Roof Apron or Fascia Apron*

Prepare gutters with drop tubes, miters and endcaps as required.

Snap back of gutter into the hook portion of the apron.

Hook front of gutter hangers into front lip of gutter every 24″ along length of gutter.

Position block of wood inside gutter at hanger locations. Using claw hammer, apply pressure to bottom of each hanger until hanger engages into existing roof apron or fascia apron. Remove wooden block.

If desired, begin installing TP5300 Leaf Relief® product. Refer to Leaf Relief® instructions for proper installation.

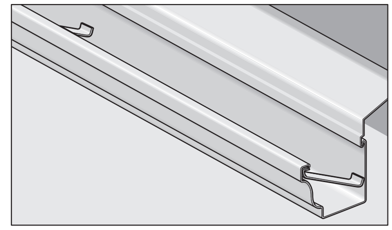


Fig. 1

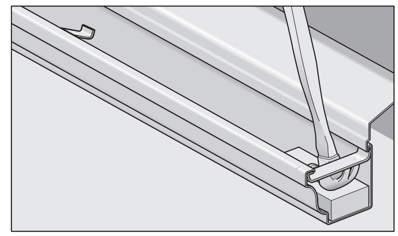


Fig. 2

| | 5" |
|---|---|
| Hanger | OG13LR5 |
| Leaf Relief® | TP5300 |

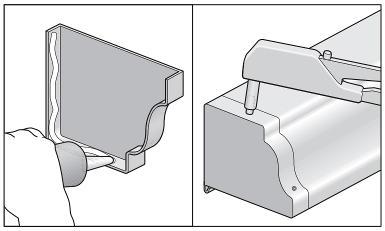


Fig. 1

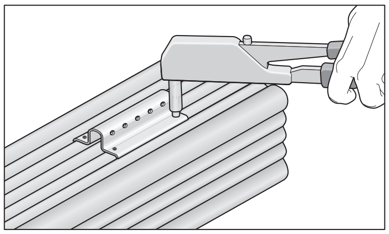


Fig. 2

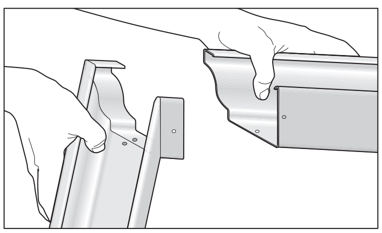


Fig. 3

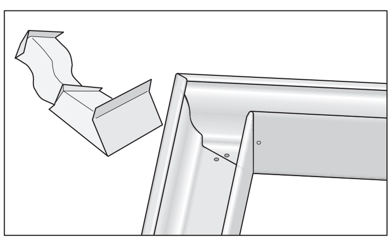


Fig. 4

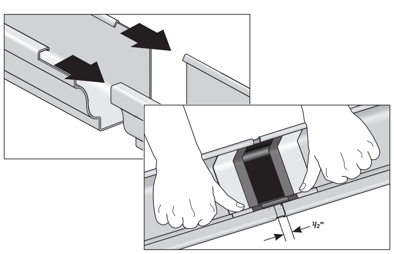


Fig. 5

### *Installing the Gutter*

Using a hacksaw or a power saw, cut the gutter to the proper length.

Install end caps by first applying a bead of sealant to the ends of the gutter and then rivet the end caps into place with aluminum rivets. (Figure 1)

Using aluminum blind rivets, attach downspout clips to the back of the gutter downspouts approximately every eight feet. (Figure 2)

Cut a hole in the gutter to accommodate the eave tube (where the gutter attaches to the downspout). Be sure to allow sufficient clearance on all sides for the flange of the eave tube. (Figure 3)

Apply a bead of gutterseal and rivet the eave tube in place.

### *Assembling Miters*

Occasionally, it will be necessary to miter gutter around an inside or outside corner. Determine the proper point on the gutter to be mitered and cut both left and right-hand gutter lengths at an approximate 45° angle for both inside and outside miters. Seal and rivet miter to one section of gutter and then position gutters onto hangers. Seal and attach miter to second gutter. (Figure 4)

*NOTE: Most outside or inside corners are 90° angles.*

The second option is to install both gutter sections onto the hangers. The strip miter can then be placed over the top of the mitered joint between the two pieces of gutter Using Gutterseal, seal and pop rivet the strip miter to the two pieces of gutter and then seal all rivet heads and joints on the interior of the gutter.

### *Installation of Expansion Joints*

To join gutter sections together, modify one end by notching the top front bead and rear hook edge 2. Overlap sections 1-1/2″ as shown. Apply sealant to all laps and rivet.

On long runs over 37′, or where there is no room for expansion, apply expansion joint. Notch gutter as shown and apply a sealant under both sides of the joint. Center the expansion joint over the 1-1/2″ metal lap and rivet. (Figure 5)

*Installing the Downspouts*

### *Step 1*

Attach an elbow to the eave tube, drill holes and rivet the elbow to the eave tube with aluminum rivets. (Figure 1)

Measure and square off the downspout cutting it with either a hack saw or power saw.

It may be necessary to use a second piece of downspout to connect the downspout with the eave tube. If so, rivet all three together, otherwise rivet the downspout directly to the eave tube.

Measure for the downspout clamp.

### *Step 2*

Make a 3/4″ hole through the siding only using a boring bit. (Figure 2)

### *Step 3*

Nail or screw the clamp through the center of the oversized hole. (Figure 3)

### *Step 4*

Attach the downspout to the clamp and rivet. (Figure 4)

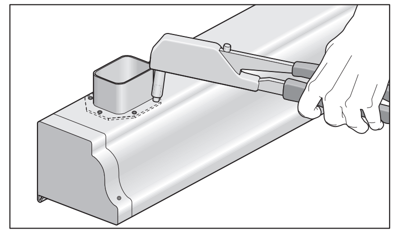


Fig. 1

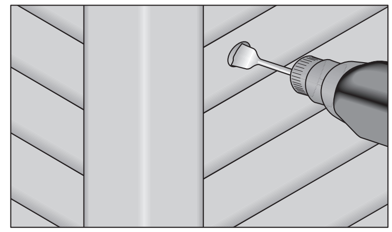


Fig. 2

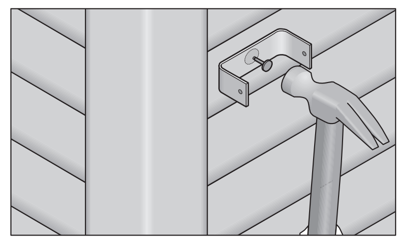


Fig. 3

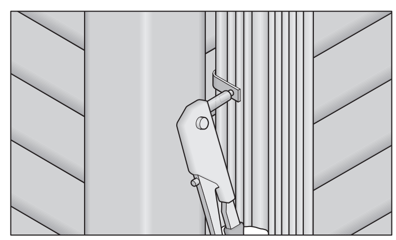
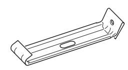
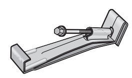


Fig. 4

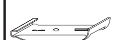
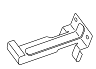
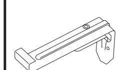
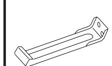
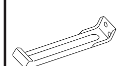
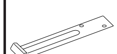
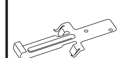
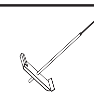
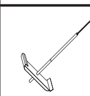
GUTTERS, DOWNSPOUTS AND LEAF RELIEF

## *Leaf Relief® Chart*

### *Seamless Gutters*

| | Spike/ Ferrule | Hidden Hanger Systems | Zip Hanger Systems | No Hanger/ New Gutter |
|---|---|---|---|---|
| |  |  |  | |
| **TP5300/ TP6300** | ✔ | ✔ | | |
| **TP5100/ TP6100** | ✔ | ✔ | | |
| **SN5200S SN6200S** | | | | ✔ |
| **TP53ZIP TP63ZIP** | | | ✔ | |

### *Foldover Style Gutter*

| | Snap In (Free Float) (OG13LR5) | Combin -ation (OG101) | No Hanger | Snug Fit (OG91) | Bar 5" (OG12R1) | Bar 6" (OG12R61) | Strap 5" (OG111) | Combin -ation Strap 5" (OG141) | Roof Hanger 5" (OG131) | Roof Hanger 6" (OG1361) |
|---|---|---|---|---|---|---|---|---|---|---|
| |  |  | |  |  |  |  |  |  |  |
| TP5300/ TP6300 | ✔ | | | | | | | | ■ ✔ | ■ ✔ |
| TP5100/ TP6100 | ✔ | | | | | | | | ■ ✔ | ■ ✔ |
| SN5200S SN62005 | | | ✔ | | | | | | | |
| TP53ZIP | | ✔ | | ✔ | ✔ | | | ✔ | | |
| TP63ZIP | | | | | | ✔ | | | | |
| OG13LR5 | | | | | | | ★ ✔ | | | |

■ Field notch Leaf Relief® at rod.
★ Cut or remove existing hanger.

*NOTE: See product guide for ordering code.*

### *5″/6″ Leaf Relief® New Gutter Installation*

*Prepare the Gutter*

Prepare the gutter for downspouts and end caps (including sealant) according to job requirements.

*NOTE: Shingles shall extend past drip edge no more than 1/2″.*

*Install Leaf Relief® System*

Option One (Preferred)

Use snap-lock punch (Malco SL5) or end-cap crimping tool (Malco SL2 – adjustment required) to create lugs every three feet on the back of the gutter (open lug toward fascia). (Figure 1)

Clip the Leaf Relief® into the front of the gutter and snap it over the lugs on the back. (Figure 2)

Clip subsequent Leaf Relief® sections with 1/2″ overlap. (Figure 3)

Lift the gutter and system into place against the fascia and align for proper drainage to outlet.

Fasten into the fascia every 24″ using #9x1-1/2″ gasketed screws. (Figure 4)

*NOTE: Required to use a 6″ extension on drill for inserting screws.*

Option Two
(when no drip edge is present)

Clip the Leaf Relief® system on the gutter (overlap sections 1/2″) and secure every two feet by screwing #9x1-1/2″ gasketed screws.

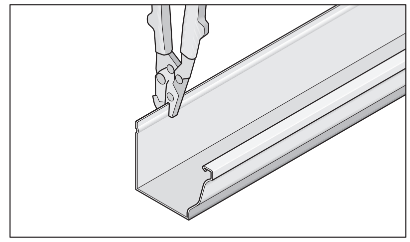


Fig. 1

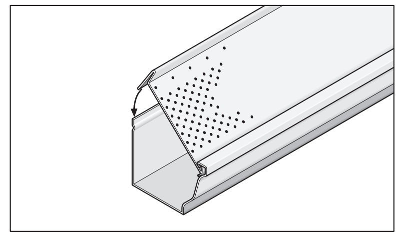


Fig. 2

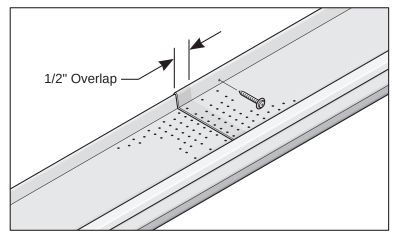



Fig. 3

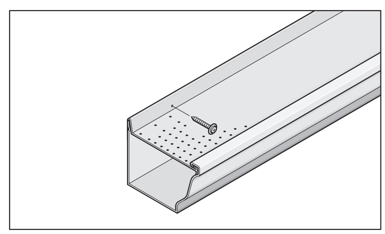


Fig. 4

GUTTERS, DOWNSPOUTS AND LEAF RELIEF

GUTTERS, DOWNSPOUTS AND LEAF RELIEF

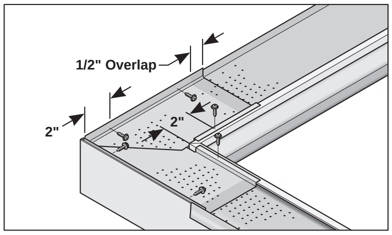


Fig. 1

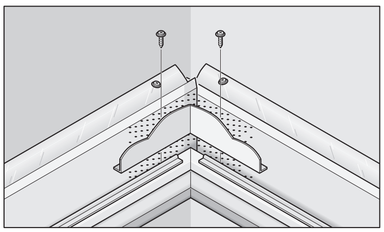


Fig. 2

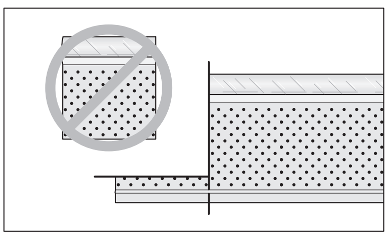


Fig. 3

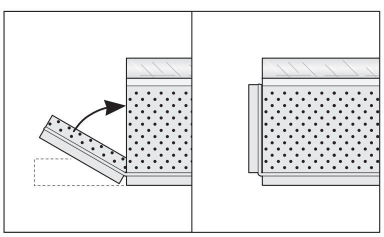


Fig. 4

## *Install Leaf Relief® Corners*

At inside/outside corners, install Leaf Relief® sections towards the corner with a minimum 1/2″ overlap with adjacent Leaf Relief® sections.

Attach Leaf Relief® 5″ corners (IC5220/ OC5220) or 6″ corners (IC6220/OC6220) using 6 screws as shown in the drawing. (Figure 1)

*NOTE: Prefabricated corners must be at the same level as the Leaf Relief® sections.*

*Important*

Downspouts 3″ x 4″ or larger are recommended for proper function in a coniferous tree zone.

To prevent overflow, all inside corners and valleys must have a water diverter/deflector. Diverter/ deflector must be installed on the top surface of the Leaf Relief® (behind front lip). (Figure 2)

The flow from high-level gutters must be transferred within downspouts directly into lower-level gutters and sealed. An alternative to this would be to install water diverters.

In applications where the Leaf Relief® is level with the endcap.

At the end of the run, make a 4″ cut on the back of the Leaf Relief® up to the lip on the front. (Figure 3)

Cut parallel to the front about 1/2″ from the lip.

Make another cut in the opposite direction to the lip.

Turn and fold under the excess material. (Figure 4)

*NOTE: If Leaf Relief® is lower than the endcap, stop the Leaf Relief® 1/16” short of the endcap.*

*Preparing Existing Foldover Gutters for Leaf Relief® Application*

*Replacing Strap Hangers or Bar Hangers on Existing Gutters*

Hook front of snap-in (free float gutter hangers (OG13LR5) into front lip of gutter every 24″ along length of gutter. (Figure 1)

*NOTE: See product guide for ordering code.*

Position block of wood inside gutter at hanger locations. Using claw hammer, apply pressure to bottom of each hanger until hanger engages into existing roof apron or fascia apron. Remove wooden block. (Figure 2)

For strap hangers use a metal cutting tool, such as a reciprocating saw, to cut old strap hangers at drip edge and remove from gutter system. (Figure 3)

For bar hangers remove nail or screw and remove bar hanger from gutter system.

Begin installing TP5300 Leaf Relief® product. Refer to Leaf Relief® instructions for proper installation.

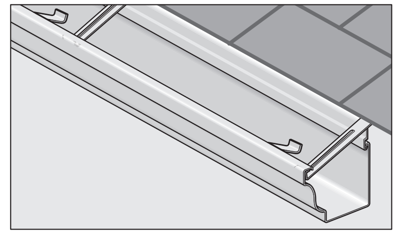


Fig. 1

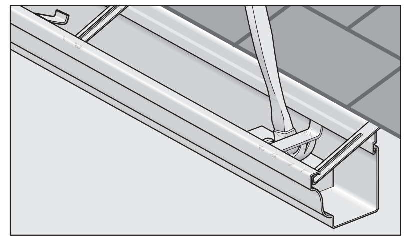


Fig. 2

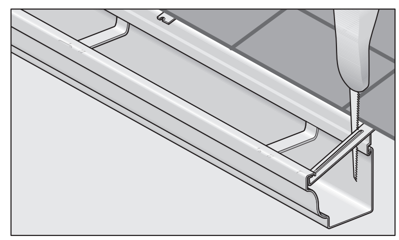


Fig. 3

GUTTERS, DOWNSPOUTS AND LEAF RELIEF

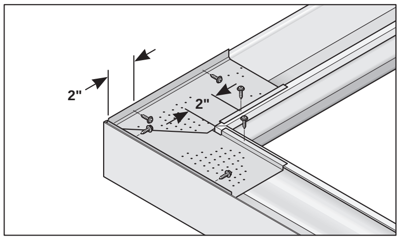



Fig. 1

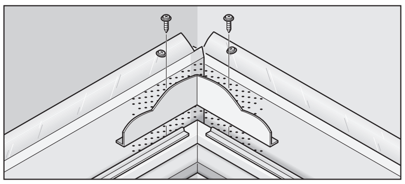


Fig. 2

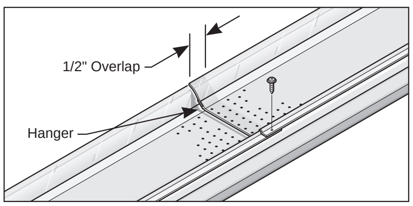



Fig. 3

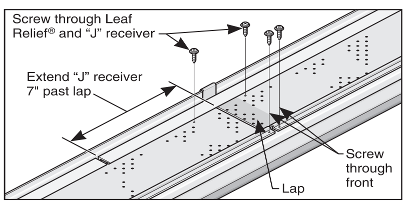
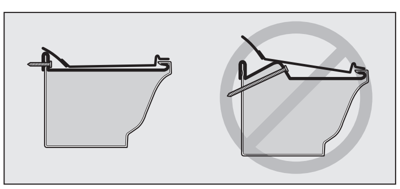



Fig. 4



*For application using zip hangers, see* Leaf Relief® Installation (Zip Hangers) *section.*

## *5″/6″ Leaf Relief® Retro-Fit Installation on Flat Hangers or Spike/Ferrule*

*Prepare the Gutter*

Clean and flush existing gutters and downspouts thoroughly with water.

*Install Leaf Relief® Corners*

Attach Leaf Relief® 5″ corners (IC5220/ OC5220) or 6″ corners (IC6220/OC6220) using 6 screws as shown in the drawing. (Figure 1)

*NOTE: Pre-fabricated corners must be at the same level as the Leaf Relief® sections.*

*Important*

Downspouts 3″ x 4″ or larger are recommended for proper function in a coniferous tree zone.

To prevent overflow, all inside corners and valleys must have a water diverter/deflector (ASDIV). Diverter/deflector must be installed on the top surface of the Leaf Relief® (behind front lip). (Figure 2)

The flow from high-level gutters must be transferred within downspouts directly into lower-level gutters and sealed. An alternative to this would be to install water diverters.

## *Install Leaf Relief® System*

*NOTE: For TP5100P and TP6100P; slide "J" receiver onto the Leaf Relief® sections.*

Place the Leaf Relief® sections on top of the gutter with the vinyl strip against the fascia or drip edge. For proper function, the Leaf Relief® surface (front-to-back) must be level or have a slight slope toward the fascia. Do not install Leaf Relief® over hangers that will result in a forward slope.

For best support, place Leaf Relief® so that the piece nearest the hanger is beneath the adjoining Leaf Relief® section (overlap 1/2″ with adjacent Leaf Relief® section – do not butt). Add or replace hangers as needed for proper support (maximum support spacing is 30″). (Figure 3)

Starting at one end, fasten front of Leaf Relief® to gutter every 24″ using #6-3/8″ screws. (Figure 4)

*NOTE: For TP5100P and TP6100P; adjust the "J" receiver to fit the width of the gutter. Using same screws as noted above, attach every 2´ as shown.*

*Installing Leaf Relief®*
*on Half-Round Gutters*

*Wrap-Around Fascia Hangers*

Lay Leaf Relief® on gutter in front of hanger and mark location of bracket (see Figure 1).

Notch back of Leaf Relief® as shown in Figure 2.

Firmly press back of Leaf Relief® behind gutter, and pivot down to rest on front lip of gutter (see Figure 3).

Attach with screws through Leaf Relief® and front lip of gutter every 24″ (Figure 4).

Continue installing Leaf Relief® panels, overlapping 1/2″. As required, a screw can be inserted through overlapping panels to reduce sagging.

*Spring Clip Bar Hangers*

Lay Leaf Relief® on gutter in front of hanger and mark location of bracket (see Figure 5).

Cut and notch Leaf Relief® as shown in Figure 6.

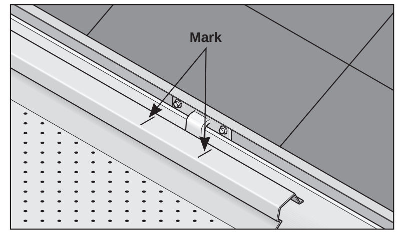


Fig. 1

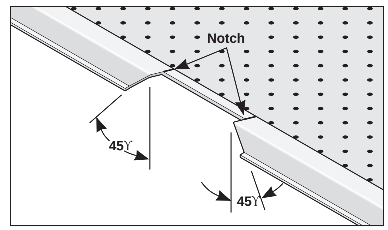


Fig. 2

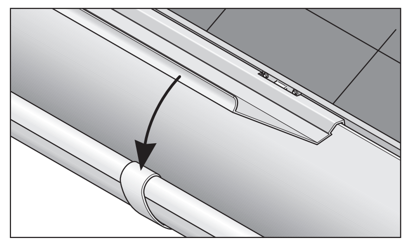


Fig. 3

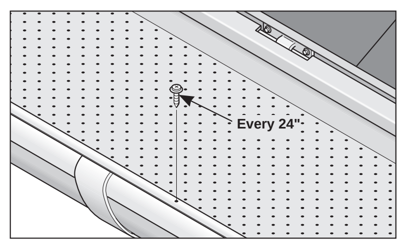


Fig. 4

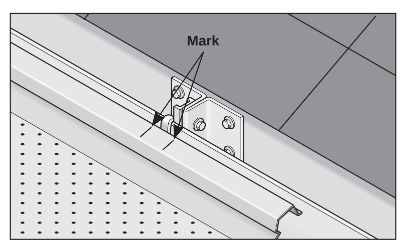


Fig. 5

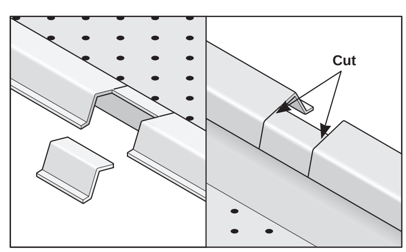


Fig. 6

GUTTERS, DOWNSPOUTS AND LEAF RELIEF

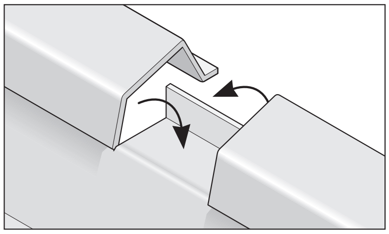


Fig. 1

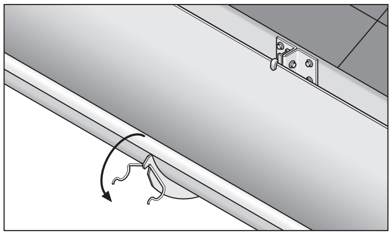


Fig. 2

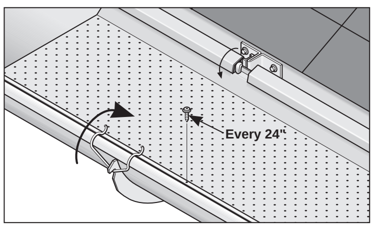



Fig. 3

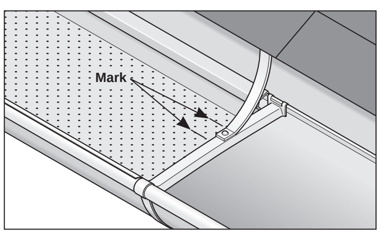
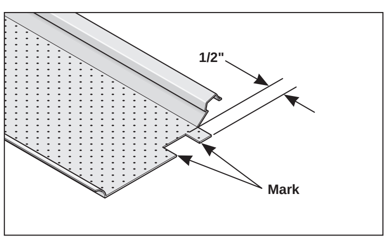



Fig. 4

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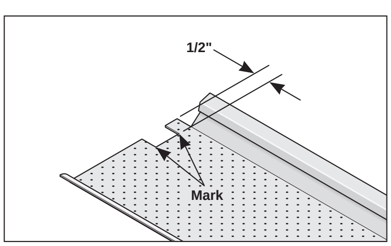


Fig. 6

## *Installing Leaf Relief® on Half-Round Gutters continued*

*Spring Clip Bar Hangers continued*

Bend tab on Leaf Relief® as shown in Figure 1.

Release spring clip on front of gutter and bend up back tab holding gutter. (Figure 2).

Place Leaf Relief® on gutter, bend hanger back tab over the back of the Leaf Relief®. Fasten hanger spring clip over Leaf Relief® (Figure 3).

Continue installing Leaf Relief® panels, overlapping 1/2″, attaching with screws through Leaf Relief® and front lip of gutter every 24″. As required, a screw can be inserted through overlapping panels to reduce sagging.

*Wrap-Around Strap Hangers (Existing Gutters)*

Place first Leaf Relief® panel on gutter in front of hanger and mark location of strap (see Figure 4).

Cut and notch Leaf Relief® as shown in Figure 5 and lay in position on gutter.

Place next section of Leaf Relief® on gutter, mark location of strap, then cut and notch as shown in Figure 6.

## *Installing Leaf Relief® on Half-Round Gutters continued*

*Wrap-Around Strap Hangers (Existing Gutters) continued*

Install on gutter in position so that it overlaps previous section by 1/2″.

Attach with screws through Leaf Relief® at every hanger overlap. Also, attach the Leaf Relief® every 24″ through the front lip of the gutter (Figure 1). As required, a screw can be inserted through overlapping panels to reduce sagging.

*Wrap-Around Strap Hangers (New Gutter Installation)*

Plan location of strap hangers and Leaf Relief® panels. Remember that Leaf Relief® must overlap 1/2″. Notch Leaf Relief® at each hanger as shown in Figure 2.

Install Leaf Relief®, overlapping panels by 1/2″. Screw through front edge of Leaf Relief® into front lip of gutter every 24″ (see Figure 3). As required, a screw can be inserted through overlapping panels to reduce sagging.

Attach hangers, over Leaf Relief®, to gutters (Figure 4).

Install gutters to structure per manufacturer's instructions.

*Mitering Corners*

*For Outside Corners:*

Use perforation pattern as a guide to create corners. Using tin snips, cut diagonally along the perforation to create a 45° angle, starting at the outside edge and cutting as shown. Notch and remove one inch of the front edge from the newly formed angle (Figure 5).

When mounted, the pieces will overlap one inch and form a 90° outside corner. Place one screw through the overlapping pieces (Figure 6).

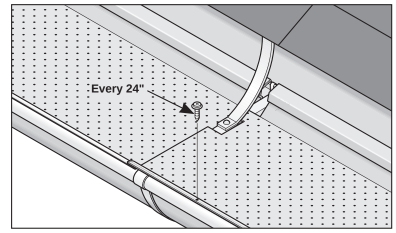

Fig. 1

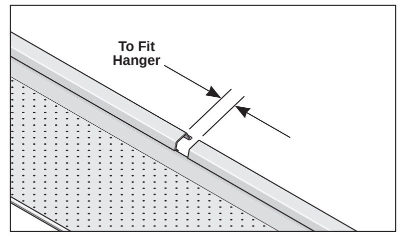

Fig. 2

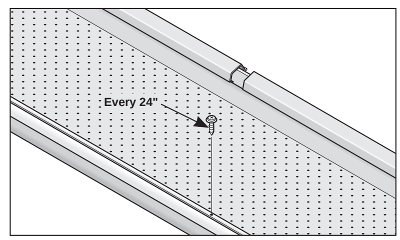

Fig. 3

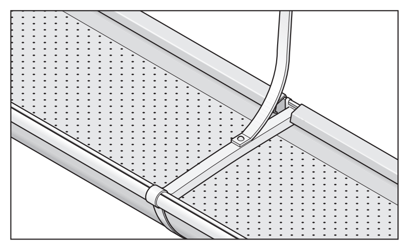
Fig. 4

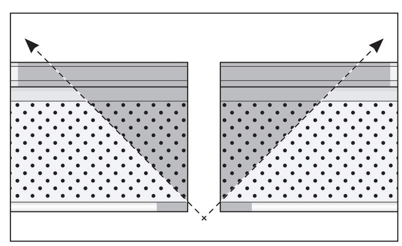
Fig. 5

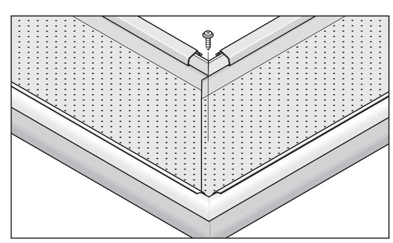
Fig. 6

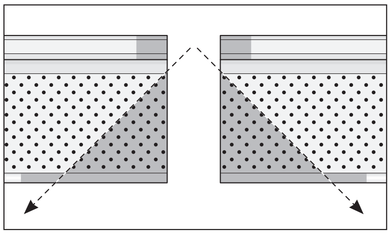

Fig. 1

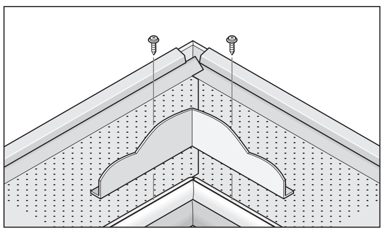

Fig. 2

*Installing Leaf Relief® on Half-Round Gutters continued*

*Mitering Corners continued*

*For Inside Corners:*
Use perforation pattern as a guide to create corners. Using tin snips, cut diagonally along the perforation to create a 45° angle, starting at the rear edge and cutting as shown. Notch and remove one inch of the front edge from the newly formed angle (Figure 1).

When mounted, the pieces will overlap one inch and form a 90° inside corner. Place one screw through the overlapping pieces (Figure 2).

*NOTE: To prevent overflow, all inside corners and valleys must have a water diverter/deflector. Diverter/ deflector must be installed on the top surface of Leaf Relief®.*

## *Leaf Relief® Installation (Zip Hangers)*

*Prepare the Gutter*

Clean and flush existing gutters and downspouts thoroughly with water.

*Important*

Downspouts 3″ x 4″ or larger are recommended for proper function in a coniferous tree zone.

To prevent overflow, all inside corners and valleys must have a water diverter/deflector. Diverter/ deflector must be installed on the top surface of the Leaf Relief® (behind front lip).

The flow from high-level gutters must be transferred within downspouts directly into lower-level gutters and sealed. An alternative to this would be to install water diverters.

*Install Leaf Relief® System*

Place the Leaf Relief® sections on top of the gutter with the vinyl strip against the fascia or drip edge. For proper function, the Leaf Relief® surfaces (front-to-back) must be level or have a slight slope toward the fascia. (Figure 1)

For best support, place Leaf Relief® so that the piece nearest the hanger is beneath the adjoining Leaf Relief® section (overlap 1/2″ with adjacent Leaf Relief® section – do not butt). Add or replace hangers as needed for proper support (maximum support spacing is 30″). (Figure 2)

Starting at one end, fasten front of Leaf Relief® to gutter every 24″ using #6-3/8″ screws (SQ6X038).

*NOTE: To prevent overflow, all inside corners and valleys must have a water diverter/deflector. Diverter/ deflector must be installed on the top surface of Leaf Relief®.*

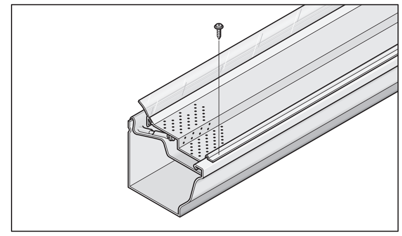

Fig. 1

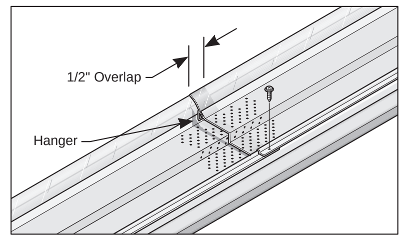


Fig. 2

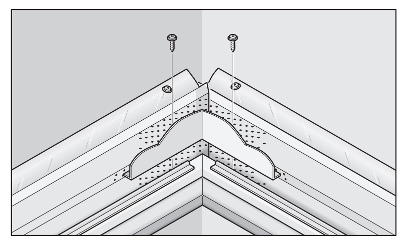

Fig. 3

GUTTERS, DOWNSPOUTS AND LEAF RELIEF

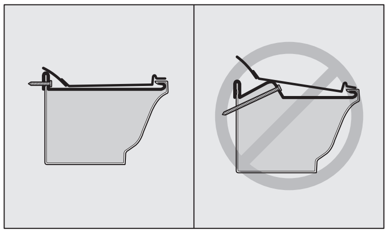

Fig. 1

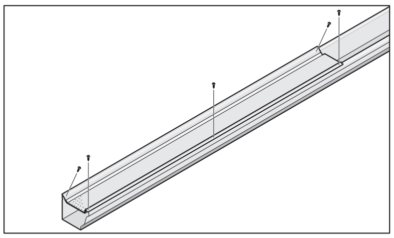

Fig. 2

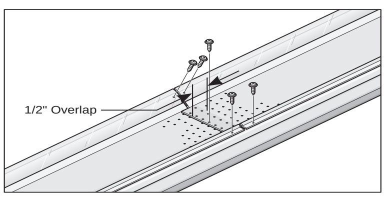


Fig. 3

## *Leaf Relief® EZ5340-DIY Installation*

*Prepare the Gutter*

Clean and flush existing gutters and downspouts thoroughly with water.

*Install Leaf Relief® System*

For proper function, the Leaf Relief® surface (front to back) must be level or have a slight slope toward the fascia. (Figure 1)

*NOTE: Call 1-800-962-6973 for assistance with hangers that cause a forward slope.*

*Mounting to Gutter*

Using the existing spikes or hidden hangers for support, place Leaf Relief® section flat on the gutter (see sticker denoting “This Side Down”).

Using screws provided, attach Leaf Relief® with three (3) screws on front and two (2) screws through the plastic strip on back as shown. (Figure 2)

Attach remaining pieces, making sure to overlap 1/2″ with adjacent Leaf Relief®sections. Place one screw through metal overlap. (Figure 3)

## *Leaf Relief® Installation (Mitered Corners)*

*Outside Corners*

Use perforation pattern as a guide to create corners. Using tin snips, cut diagonally along the perforation to create a 45° angle, starting at the outside edge and cutting as shown, through the plastic strip. Notch and remove one inch of the front edge and plastic strip from the newly formed angle. When mounted, the pieces will overlap one inch and form a 90° outside corner. Place one screw through the overlapping pieces. Attach to back through plastic strip, with screws, two inches from the point of the corner.

## *TP53ZIP/TP63ZIP – Inside Corner*

*NOTE: Because TP product has profile, pre-fabricated corners can not be used.*

Use the perforated pattern to cut a 45° angle at the ends of the Leaf Relief sections. Then cut away 1″ from the front and back of one section as shown.

The sections will overlap by 1″ and be attached with a #6x3/8″ stainless steel screw.

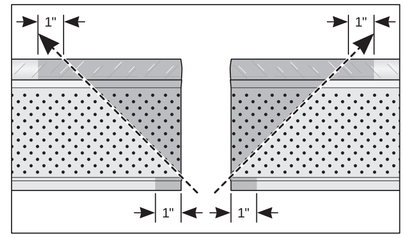


Fig. 1

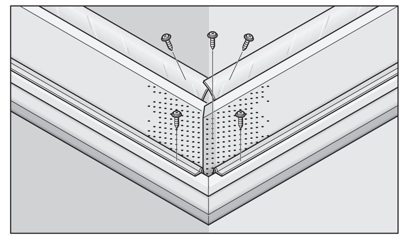

Fig. 2

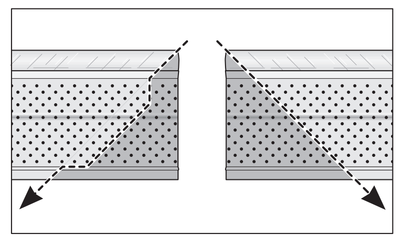

Fig. 3

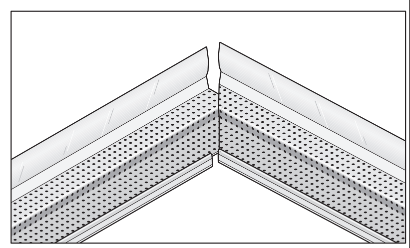

Fig. 4

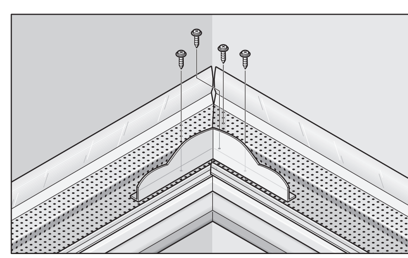

Fig. 5

GUTTERS, DOWNSPOUTS AND LEAF RELIEF

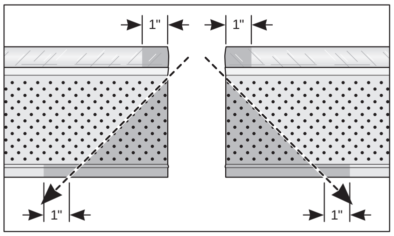


Fig. 1

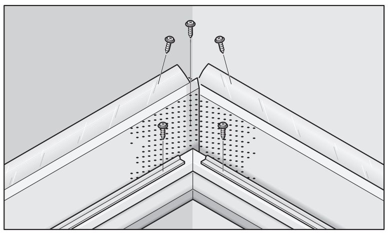

Fig. 2

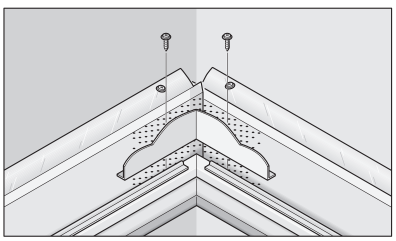

Fig. 3

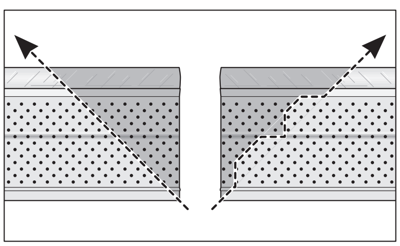

Fig. 4

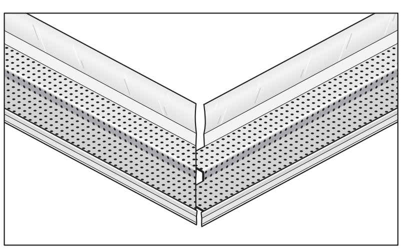

Fig. 5

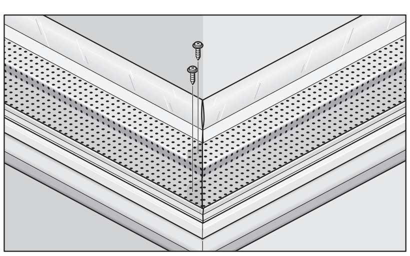

Fig. 6

## *Leaf Relief® Installation (Mitered Corners) continued*

*Inside Corners*

Use perforation pattern as a guide to create corners. Using tin snips, cut diagonally along the perforation to create a 45° angle, starting at the rear edge (plastic strip) and cutting as shown, until complete. Notch and remove one inch of the front edge and plastic strip from the newly formed angle. When mounted, the pieces will overlap one inch and form a 90° inside corner. Place one screw through the overlapping pieces. Attach to back through plastic strip, with screws, two inches from the point of the corner.

*Important*

To prevent overflow, all inside corners and valleys must have a water diverter/deflector, sold separately. Diverter/deflector must be installed on the top surface of the Leaf Relief® (behind front lip).

## *TP53ZIP/TP63ZIP – Outside Corner*

Use the perforated pattern to cut a 45° angle at the ends of the Leaf Relief sections. Then cut away 1” from the front, first step and back of one section as shown.

Overlap sections by 1˝ and attach with a #6x3/8˝ stainless steel screw.

# NOTES

# SIDING WITH CODES

INTERNATIONAL CODE COUNCIL®

**If the siding you inspect or specify is one of thousands of products certified through the VSI Certification Program, your job just got easier.**

Building codes established by the International Code Council (ICC) require vinyl siding, polypropylene siding, and insulated vinyl siding to be certified and labeled by an approved quality control agency to show it conforms to ASTM D3679, ASTM D7254, or ASTM D7793, respectively. Plus, federal, state, and local building code entities throughout the United States adopt I-Code models including International Residential Code (IRC), International Energy Conservation Code (IECC), and International Building Code (IBC).

*Choose Quality:*

## CERTIFIED PRODUCTS AND INSTALLERS MAKE A DIFFERENCE

**For more than 20 years, vinyl and other polymeric siding products certified through the VSI Product Certification Program have been verified by an accredited quality control agency, Intertek.** The organization conducts two unannounced inspections at each plant every year, reviews quality test data, pulls siding right off the production line and conducts performance tests in its accredited laboratory to ensure that vinyl siding, polypropylene siding and insulated siding meet or exceed their respective ASTM and I-Code standards.

**400**
**VINYL SIDING CERTIFIED COLORS**

*Did you know?*

**Today's vinyl siding is available in more than 400 certified colors.** The VSI Certification Program is the only cladding certification program referencing ASTM standards to validate claims regarding color retention and helps ensure beautiful looks that are engineered for life.

**Vinyl siding certified through the VSI Certification Program is evaluated to ensure it complies with the ASTM D3679 standard for:**

- Weatherability, windload, and impact resistance
- Expansion and shrinkage
- Surface distortion
- Length, width, and thickness
- Color retention (Where applicable)

The credibility of these ASTM standards, combined with this third-party verification, gives added confidence to vinyl and other polymeric siding purchasers setting them apart from other exterior cladding products. In addition, vinyl siding is the only exterior cladding with both third-party product certification and a certified installer program.

VINYL SIDING INSTITUTE™

# MEETING RIGOROUS STANDARDS FOR PERFORMANCE

ASTM D3679, ASTM D7254, and ASTM D7793 were developed by consensus through ASTM International, Vinyl and other polymeric siding that meet ASTM standards:

- Withstand the impacts of recommended installation procedures
- Lay straight on a flat wall and not buckle under normal conditions
- Withstand wind speeds of 110 mph or more
- Weather the effects of sunshine and rain
- Meet manufacturers' advertised specifications, including length, width, gloss, and thickness
- Demonstrate a minimum thermal resistance (R-value) of at least R-2.0 (applies to insulated siding only)

**Building products specifiers want assurance that the homes they're designing stay durable and beautiful for life. With independent certification programs for products, colors and the professionals who install them, vinyl siding is specified more than any other exterior cladding.**

## LOOK FOR THE LABELS

Keep quality top-of-mind by looking for these product labels on cartons or VSI's certified product logo on promotional materials. **Visit VSI's website at www.vinylsiding.org for a current list of certified products and colors.**

## GET THE MOST OUT OF VINYL SIDING

**Certified products perform best when installed by a qualified installer.**

The VSI Certified Installer Program tests experienced vinyl siding installers on their knowledge of proper vinyl siding installation techniques based on the industry standard, ASTM D4756.

Currently, more than 2,400 installers are certified by an independent, third-party administrator. To find a certified vinyl siding installer visit the *Certified Professionals* page at **www.vinylsiding.org**.

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