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HOME INSULATION

With rising energy costs, families are considering all possible ways to manage their home heating bills. A well-insulated home, new or old, will require less energy.

Why insulate?

If you would like to use less energy for heating and cooling, have a more comfortable home, reduce home and equipment maintenance, and possess a better investment, plan on ample insulation in your home. Insulation provides resistance to the flow of heat, either out of the home in the winter, or into the home in the summer.

Types of insulation

All building materials have some insulating value; effective insulation is generally associated with lightweight, porous, bulky materials incorporating dead air spaces. Insulation values for various building materials are shown in table 1 ("perm rating" is explained under "Water vapor barriers"). The comparative insulation values are indicated as "R" values, which describe the ability of material to *resist* heat flow. The "R" value is normally indicated on the package or label of the insulation material, either as "R" value per inch or total "R" value for a listed thickness of material.

For reflective materials such as aluminum foil, the "R" value is not based on thickness of the foil, but on its equivalent effectiveness as a surface to resist heat flow by reflecting the heat. To be an effective reflector of heat, the reflecting surface must be associated with an air space next to its reflecting surface.

Insulation is manufactured in several common forms from a variety of materi-

Table 1. Approximate insulation and vapor-barrier value of various building materials

	Insulation value (R)		Perm Rating[a]
Material	Per inch thickness	For thickness listed	Per inch or thickness listed
Batt and blanket insulation			
Fiberglass, rock wool, cellulose	3.1-3.7		100
Fill-type insulation			
Cellulose	2.9-3.7		100
Fiberglass or rock wool	2.2-3.5		100
Vermiculite (expanded)	2.13-2.27		
Rigid insulation			
Extruded polystyrene	4.0-5.9		0.3-1.2
Expanded polyurethane	5.8-6.25		0.4-1.6
Expanded polystyrene-bead	3.57		2.0-5.8
Polyisocyanurate 1"		7.20	
Building materials			
Brick, high density	0.11		
Concrete, poured	0.08		3.2
Concrete block, 3 hole, 8"		1.11	2.4
Lumber, fir or pine	1.25		
Plywood, ½" (exterior)		0.62	.4-.7
Particle board, med. density	1.06		20-90
Insulating sheathing, 25/32"		2.06	50-90
Gypsum or plaster board, ½"		0.45	20
Exterior doors			
Solid core wood, 1¾"		2.17	
+ wood storm		3.92	
+ metal storm		3.23	
Metal urethane core, 1¾"		5.26	
Metal polystyrene core, 1¾"		2.13	
Window glass, includes surface conditions			
Single-glazed		0.86	
Single-glazed with storm windows		1.82	
Double-pane insulating glass		1.5-1.75	
Triple-glazed		2.79	
Air space (¾"-4")		0.96	

[a]Approximate values—to provide general idea of resistance to vapor flow.

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OREGON STATE UNIVERSITY EXTENSION SERVICE

als. Those forms most frequently used in residential dwellings are batt, blanket, loose-fill, rigid boards, formed-in-place, and reflective.

Batt and blanket insulations are made from processed fiberglass or rock wool. One side of the batt or blanket normally has an attached vapor barrier. (See the section on vapor barriers.) Batt and blanket insulations are also available without the attached vapor barrier, for use where vapor barriers have already been installed for moisture protection. Batts and blankets vary in thickness from 1 to 12 inches and are made in widths to fit spaces of 16, 24, and 48 inches. Batts usually come in 4-foot lengths. Blankets are made in rolls of various lengths.

Loose-fill insulations are made from rock wool, cellulose fiber, fiberglass and vermiculite. They are usually packaged in bags or bales. Loose-fill insulation is well adapted for use in walls and in ceilings of existing and new buildings when proper vapor barriers are used.

Rigid board or slab insulations are made from cellulose fiber, fiberglass, polystyrene, polyurethane, polyisocyanurate, and other insulating materials. The rigid boards usually come in 16-, 24-, or 48-inch widths and normally in 8-foot lengths. Thicknesses vary from ½ to 3 inches.

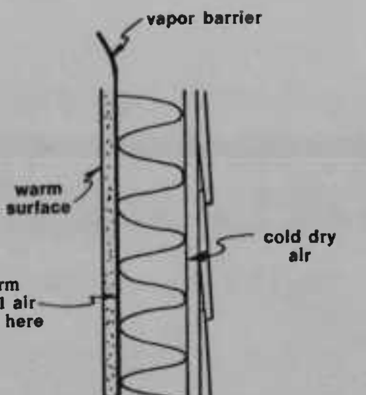
Formed-in-place insulations are available as liquid components or combinations of liquids and solids and include sprayed and plastic foam types. Because of the need for special equipment and techniques required for installation of most formed-in-place insulations, it is advisable to have the work done by licensed commercial applicators. The plastic foam types are generally compounds of urethanes. Others combine a treated cellulose material and a liquid glue that is sprayed on a building surface.

Reflective insulation consists of reflective foils such as aluminum that interrupt flow of radiant heat. To be effective, the foil surface must maintain a highly reflective surface that faces an air space of at least ¾ inch. Generally, reflective insulation in walls and ceilings is used as a combination vapor barrier and a reflective surface, with the foil attached to batts or blankets.

When you use reflective materials under floors, punch holes into the reflective foil every 12 inches along the low point of the foil to drain off any collected or condensed water. The foil layers must not, therefore, form an airtight chamber. Dust and oxidation on reflective surfaces will reduce the foil's effectiveness to reflect radiant heat.

Water vapor barriers

You must have water vapor barriers to maintain maximum insulating quality of insulation materials and to reduce chances of damage by condensation on the structural portions of your house. Water vapor barriers are materials that provide a resistance to the transmission of water vapor. The term used for the rate of water vapor transmission is called *permeance.*



In common terms, the *perm rating* is the capability of a membrane to resist passage of moisture vapor through itself—*the lower the perm rating number, the greater the resistance to moisture penetration.* Commonly used vapor barrier materials are plastic films such as polyethylene (4- to 6-mil thickness) or kraft-backed aluminum foil. Selected ratings for various building materials are shown in table 1.

Some perm ratings are per inch of thickness or given thickness. Generally, insulation materials that have a perm rating less than 1.0 per inch of thickness can be considered for use without a vapor barrier. A roof ceiling without an attic needs a vapor barrier of 0.5 perm or less.

As shown in table 1, some insulating materials are highly vapor-resistant and can be used without additional vapor barrier if the edges between segments are caulked with proper vapor-resistant compounds. Polystyrene insulation boards formed by an extrusion process and expanded polyurethane offer good resistance to water vapor transmission. Do not use expanded polystrene, called molded bead board, without additional vapor barrier—its perm rating is several times higher than that for extruded polystyrene or expanded polyurethane.

Always install the vapor barrier on the *warm* side (the side next to the living area) of the building. Install a vapor barrier on the sidewalls and ceiling and under floors that are over an unheated space. The vapor barrier under the floor must be immediately next to the flooring or its underlayment. Make vapor barriers continuous and be sure to patch any holes you punch during installation.

To keep water vapor from being drawn up out of the earth, cover the crawl space surface under a home with a 6-mil or heavier plastic sheet. Be sure to patch any holes and edges on the covering and tape them with water-resistant tape. Lap all joints 12 inches and tape them. A high water table could force the plastic apart and greatly increase moisture problems under the home.

When you are insulating an existing home, you can obtain fairly satisfactory moisture protection by any of these methods:

1. Apply a 4- to 6-mil plastic sheet over inside of existing walls and cover it with additional wood panelling or sheet rock.
2. Apply two or three coats of leafing aluminum in varnish, phenolic formulation, or alkyd paints.
3. Apply two or more coats of a good alkyd-based, semigloss paint over a primer coat of leafing aluminum paint.
4. Cover the walls and ceiling with a washable plastic or aluminum foil wallpaper.
5. Apply three coats of good quality, semigloss enamel on smooth sheet rock, plaster, or wood.
6. Apply three coats of urethane varnish to wood panelling.

When buying paint for use as an interior vapor barrier, check the label on the container. Some manufacturers list the perm ratings for paints, primers, and sealers. Most latex paints, stains, and water-repellent preservatives do not effectively exclude moisture vapor. Their ability to restrict moisture vapor is considered to be less than 20 percent effective. You can use a vapor-barrier latex primer-sealer as a base over which you would apply the standard latex paints. Some of these latex primer sealers are rated under 1 perm when you apply them as directed by manufacturers.

Safety precautions

1. When working with fiberglass insulation, use protective gloves. If you are installing it under floors, use gloves plus a protective face shield and breathing mask to prevent fiberglass dust and particles from entering your eyes, throat, and lungs.

2. Be cautious in using foams and other plastic insulation materials: Some are highly flammable and must be protected with a ½-inch gypsum board or an equivalent thermal barrier or fire-resistant material having a fire-finish rating of not less than 15 minutes, based on standard fire tests.

Table 2. Determining heating index

Fuel/heating system[a]	Cost of fuel in dollars[b]							
Oil/gallon (70%)	.72	.86	1.00	1.18	1.44	1.72	2.00	2.36
Oil/gallon (50%)	.51	.63	.72	.82	1.03	1.26	1.44	1.64
Gas/therm (70%)	.51	.63	.72	.82	1.03	1.26	1.44	1.64
Gas/therm (50%)	.36	.44	.51	.59	.73	.88	1.02	1.18
LP gas/gallon (70%)	.47	.57	.66	.76	.94	1.13	1.32	1.52
LP gas/pound (70%)	.11	.13	.16	.18	.22	.27	.32	.36
LP gas/gallon (50%)	.34	.40	.47	.54	.67	.81	.94	1.08
LP gas/pound (50%)	.08	.095	.11	.13	.16	.19	.22	.26
Resistance electric/kWh	.025	.03	.035	.04	.05	.06	.07	.08
Heat pump (1.7 cop)/kWh	.043	.051	.06	.068	.085	.102	.12	.136
Heat pump (2.0 cop)/kWh	.05	.06	.07	.08	.10	.12	.14	.16
Degree-days	**Heating index**							
2,000	15	18	21	23	29	35	42	46
3,000	22	26	31	35	44	53	62	70
4,000	29	35	41	47	59	70	82	94
4,500	33	40	46	53	66	79	92	106
5,000	37	44	51	59	73	88	102	118
6,000	44	53	62	70	88	105	124	140
7,000	51	61	72	82	103	123	144	164
8,000	59	70	82	94	117	141	164	188

[a]Percentages and cop figures (coefficient of performance) indicate the efficiency you as homeowner realize from fuel purchased for your particular heating system. "Cop" is the ratio of the energy delivered by the heating pump to the energy needed to run it.
[b]Include all taxes, surcharges, fuel adjustments, and delivery charges.

3. Insulation can trap heat, which may cause fires. Therefore, keep all types of insulation at least 3 inches from sides and 24 inches from the top of recessed light fixtures. Similarly, keep the insulation at least 3 inches from sides of furnace exhaust flues, stove chimneys, space heaters, or other heating devices.

4. *Cellulose fiber is flammable,* so retardant chemicals are used to reduce the flammability to acceptable levels. These chemicals can also reduce the insulation's thermal resistance, and sulfate additives can cause corrosion of pipes, ducts, and other metal items. Be sure the cellulose insulation you choose meets Federal and state specifications. If you're not sure, check with building inspectors. A reputable, licensed contractor will use only approved materials.

Table 3. Suggested insulation and storm door window needs

Heating index	Attic	Wall[a]	Floor (unheated space)	Duct[b]	Storm doors and windows[c]
15-30	R-30	R-11	R-19	R-11	no
31-44	R-30	R-11	R-19	R-11	yes
45-73	R-30	R-19	R-19	R-11	yes
74-83	R-38	R-19	R-19	R-19	triple glazed
84-117	R-38	R-19	R-30	R-19	triple glazed

[a]May require 6-inch walls.
[b]Do not install ducts in roof cavities in areas with heating index above 100.
[c]Double glazing plus storm windows and doors is approximately equal to triple glazing.

How much insulation do you need?

How much insulation should you use in walls and ceiling and under floors? These are questions that should be answered.

In the State of Oregon, you can generally meet the Uniform Building Code requirements for residences not more than three stories high if you insulate in this manner (for more detailed information, check with your local building inspector):

1. Insulate the ceilings for R-30.
2. Insulate the walls for R-11.
3. Insulate under floors over unheated space to R-19.
4. Slab on grade floors should have perimeter insulation as prescribed for the local area by building codes. Extend insulation down along the foundation and under slab for a total enveloped length of 24 inches. Use rigid plastic insulation with a perm rating under 1.7 per inch and an R value of 4.0 or higher.

To help determine the best combination of energy-conserving measures for your climate, fuel, and home, proceed as follows:

1. Determine degree-days for your location (see section on degree-days). Use local weather data of city nearest you that is listed. (Heating needs are in degree-days—the higher the number, the more energy needed to heat your home.)

2. Determine "heating index" from table 2. Follow your "fuel/heating system" line across to your present "cost of fuel," then straight down in that same column to the heating index figure on the same line as your degree-day figure (left).

3. Use table 3 to select suggested insulation and storm door/window needs for your heating index as you have determined it. Tables 3 and 4 are partially based on information published by the Department of Commerce (National Bureau of Standards) and the Department of Housing and Urban Development.

Example:

You live in Portland, and heating gas costs 63 cents per therm; so the heating index should be between 40 and 44 (Portland has 4,792 degree-days of heating). The minimum suggested combination of insulation "R" values for the various structural elements of the home, based on 70 percent efficiency in fuel combustion in furnace, would be:

Attic or ceiling R-30
Walls R-11
Underfloor (unheated space) R-19
Heating ducts R-11
Use storm doors and windows.

The Farmers Home Administration suggests for new homes in areas of more than

4,500 degree-days: R-19 for walls, R-30 for the ceiling, R-19 for floors over unheated crawl spaces, and at least double-glazed windows. In areas with more than 6,000 degree-days, they suggest increasing the ceiling insulation to R-38 and triple-glazed windows.

The Oregon Department of Energy has developed energy conservation standards for existing homes. Write for details to Department of Energy, Labor and Industries Bldg., Salem, Oregon 97310.

Relative effectiveness of insulation

For older homes, consider adding insulation to the ceiling first. The ceiling is the biggest source of heat loss in most homes. Ceilings with 4 inches (R-14 to 16) or less insulation need added insulation to bring the R value up to 30 to meet code requirements. When adding batts to the top of existing ceiling insulation, use only batts without a vapor-barrier covering. A vapor barrier on top of the existing insulation would trap water vapor *in* the insulation.

The next place to look for energy reduction is a floor that is over unheated spaces. Batt type insulation is recommended under floors. Use the amount of insulation suggested for your locality as determined by the heating index. Be sure your water pipes under the floor in unheated spaces are protected from freezing and that heating ducts in any unheated space are wrapped with insulation. Wrap at least 3½" of insulation (R-11) around heating ducts in unheated spaces to reduce heating energy losses. It has been estimated that the average home's uninsulated heating ducts in unheated crawl space lose as much as 40 percent of the heat in the ducts.

If you have single-pane windows, storm windows would provide another reduction in heating loss and condensation problems. In some homes, storm windows would be one of the first areas to consider in reducing heat losses.

The walls are one of the last areas to insulate. Unless you are planning to do extensive remodeling, you will find it difficult to add insulation that would not cause a moisture problem in the wall. A major concern with blowing or foaming insulation in the walls of existing homes is the accumulation of moisture in the insulation due to a lack of adequate vapor barrier in the walls. All insulated walls should have a vapor barrier on the warm interior side.

To assist in determining appropriate home weatherization measures, free audits are available in Oregon. See your fuel dealer or electric power supplier.

Calculation chart for your home

There is a simplified formula below that you as home owner can use to determine which investment in insulation will have the best economic return. You can complete the chart at the right by using the formula and obtaining current prices from firms selling home improvement products.

Table 4. R values for household structural elements

Structural elements	Total R value
Single window	.89
Single window with storm window	1.79
Double glazed or insulating window	1.79
Double window with storm window	2.78
2 x 4 stud wall, uninsulated	4.35
2 x 4 stud wall, R-7 insulation	11.36
2 x 6 stud wall, R-19 insulation	23.26
2 x 4 stud wall, R-11 insulation	14.29
Ceiling, no insulation	2.66
Ceiling, R-11 insulation	13.50
Ceiling, R-19 insulation	21.74
Ceiling, R-30 insulation	32.26
Ceiling, R-38 insulation	41.67
Floor, vinyl covering, no insulation	3.60
Floor, vinyl covering, R-11 insulation	14.70
Floor, vinyl covering, R-19 insulation	22.70
Floor, carpet/rubber pad, no insulation	4.85
Floor, carpet/rubber pad, R-19 insulation	23.80
Floor, carpet/rubber pad, R-30 insulation	35.70

How to calculate heat bill savings

You can calculate your approximate heat bill savings data resulting from any of the retrofitting practices listed above by using the following master formula and appropriate figures from the tables indicated. Such data will be useful for determining which investment will pay off most quickly.

Example:
You want to estimate the annual cost of heat loss through a ceiling insulated with R-7 as compared to R-30 in the Corvallis area. The house has no insulation in walls or under floor, and windows are single-glass. The cost of electrical energy is 4 cents per kWh.
The area of the ceiling is 1,000 sq. ft.
The number of degree-days for Corvallis area is 4,854 (table 5).
The C value from table 6 is 15 when using R-7 insulation in ceiling.
The C value from table 6 is 14 when using R-30 insulation in ceiling.

Therefore, use the formula:

$$\frac{\text{Area x DD x C x cents/kWh}}{\text{Total R value x 341,300}} = \text{cost/yr}$$

using R-7 ceiling:

$$\frac{1{,}000 \times 4{,}854 \times 15 \times 4}{7 \times 341{,}300} = \$121.90/\text{yr}$$

using R-30 ceiling:

$$\frac{1{,}000 \times 4{,}854 \times 14 \times 4}{30 \times 341{,}300} = \$26.55/\text{yr}$$

The annual estimated saving using R-30 insulation = $95.35

Explanation of the formula

Area (in square feet) of window, wall, ceiling, or floor.

DD (from table 5) is degree-days per year for your locality.

Ceiling
Yearly heat loss cost for ceiling is now .... ________
Yearly heat loss cost when ________ is added .... ________
Yearly savings (subtract second line from first line) .... ________
Cost of insulation and added vapor barrier* .... ________
Years to recapture investment (divide by yearly savings) .... ________

Floor
Yearly heat loss cost for floor is now .... ________
Yearly heat loss cost when ________ is added .... ________
Yearly savings (subtract second line from first line) .... ________
Cost of insulation* .... ________
Years to recapture investment (divide by yearly savings) .... ________

*If you figure interest on investment each year, the years to recapture the investment will be increased. Money invested in insulation cannot be put in a savings account at interest, so this "interest foregone" should be subtracted from the yearly savings.

Table 5. List of degree-days in Oregon

Arlington	4,821	Hillsboro	4,949
Ashland	5,089	Hood River	5,535
Astoria	5,295	Klamath Falls	6,516
Baker	6,906	LaGrande	6,069
Bandon	4,509	Lakeview	7,069
Bend	7,117	Madras	6,441
Brookings	4,281	Malheur	
Burns	7,212	Exp. Sta.	5,811
Clatskanie	5,233	McMinnville	4,970
Condon	6,643	Medford	4,930
Corvallis	4,854	Newport	5,235
Cottage Grove		North Bend	4,688
	4,890	Pendleton	5,240
Dallas	5,064	Portland	4,792
Dufur	5,832	Prineville	6,753
Elgin	6,685	Redmond	6,411
Enterprise	7,949	Reedsport	4,579
Eugene	4,739	Roseburg	4,885
Forest Grove	4,851	Salem	4,852
Grants Pass	4,975	Seaside	4,864
Heppner	5,744	Tillamook	5,338
Hermiston	5,123		

C is a generally accepted constant that converts degree-days to degree-hours plus allowing for miscellaneous factors (infiltration losses, living habits, room sizes, etc.). See table 6.

Cents/kWh is local cost of electrical energy for home heating. Note that the formula is set up for calculating *electric* energy (kWh). If you use gas or oil as a fuel, refer to table 2, select the column that lists your present or projected gas or oil cost, then use the kWh rate *in that column* and insert it as the "cents/kWh" in the formula.

Total R value describes the total resistance to heat flow of all the material in the structural element. See table 4.

341,300 is product of 3,413 (Btu's per kWh) and 100 (to convert cents to dollars).

$/yr is cost of energy to pay for the heat loss per year through the area of building component being calculated.

Use this formula (with the appropriate C-value and total R-value) first to figure the heat cost before adding insulation or storm windows. Then use the formula again with the new total R value and C value that result from the added insulation or storm windows. The difference in the costs of heating is the approximate savings that you will realize when you add storm windows or insulation.

Divide the cost of the windows or insulation by the savings (subtract interest on investment) to determine how many years it will take to pay off the money spent for the windows or insulation. Remember that the cost of heating fuels will go up in years to come, so the payback will probably be faster.

Table 6. Determining C values for various insulation/window combinations

Glass	Insulation: Ceiling	Wall	Floor[a]	Approximate C value
Single	*R-7*	*0*	*0*	*15*
Double	R-11	0	0	14
Single	*R-30*	*0*	*0*	*14*
Single	R-13	R-7	0	14
Double	R-13	R-11	0	13
Single	R-19	R-11	0	13
Double	R-30	0	0	13
Single	R-19	R-11	R-9	13
Single	R-30	R-11	R-11	12
Double....................	R-19	R-11	R-9	12
Double	R-30	0	R-19	12
Double	R-30	R-11	R-19	10
Double	R-38	R-19	R-30	10
Triple glazed	R-38	R-19	R-30	10

[a]In a two-story home, consider only floor over unheated space or on concrete slab (as in basement).

Degree-days

"Degree-days heating" (DD) is a convenient and graphic way to summarize a given location's adjusted daily mean outside temperatures for an entire year ("adjusted" because each day's mean is subtracted from 65° F). Mean temperature is computed by adding the maximum and minimum and dividing by two. Table 5 shows the great variation in degree days among Oregon cities.

C Value

Find the line in table 6 that describes the insulation and window situation of the house. The C value on the last column is the number to use in the master formula.

Ventilation

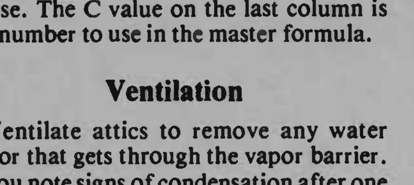
Ventilate attics to remove any water vapor that gets through the vapor barrier. If you note signs of condensation after one heating season, add more attic vents.

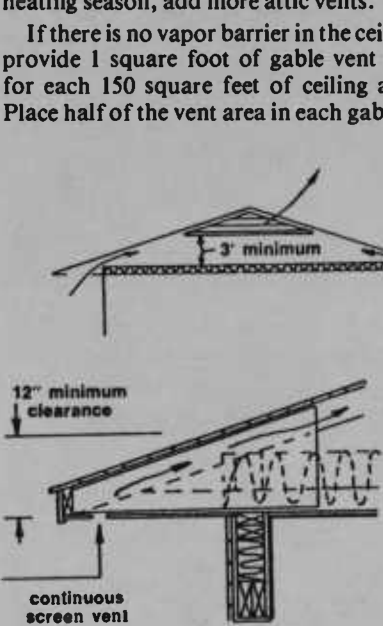
If there is no vapor barrier in the ceiling, provide 1 square foot of gable vent area for each 150 square feet of ceiling area. Place half of the vent area in each gable.

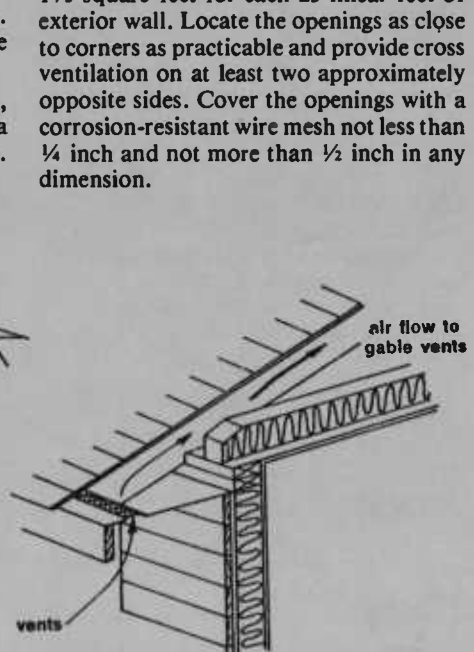
The vent area may be reduced to 1 square foot per 300 square feet of ceiling if at least 50 percent of the required ventilation area is provided by vents located in the upper portion of the space to be ventilated. Have upper vents at least 3 feet above each eave or cornice. The balance of the ventilation should be provided by eave or cornice vents.

To provide space for R-30 and greater insulation amounts in the ceiling and to maintain proper attic ventilation flow from eaves over ceiling insulation, new homes should use truss designs similar to that shown using a 12″ mimimum clearance between wall plate and roof. This would allow 10 inches of insulation and a 2 inch clearance for ventilation air.

Ventilate the crawl space area by openings in exterior foundation walls. The openings should have a net area of not less than 1½ square feet for each 25 linear feet of exterior wall. Locate the openings as close to corners as practicable and provide cross ventilation on at least two approximately opposite sides. Cover the openings with a corrosion-resistant wire mesh not less than ¼ inch and not more than ½ inch in any dimension.







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