



Washington State Energy Code

Builder's Field Guide

2006 / Seventh Edition

Applies to all building permits issued on or after July 1, 2007.





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Introduction

The 7th edition of the *Builder's Field Guide* outlines acceptable construction practices that meet the 2006 Washington State Energy Code Second Edition (WSEC) and the 2006 Washington State Ventilation and Indoor Air Quality (VIAQ) Code.

The current edition of the WSEC was adopted effective July 1, 2007; the current edition of the VIAQ Code was adopted effective July 1, 2006. The Codes apply to all building jurisdictions in the State for residential construction. For Non-residential construction, the code applies everywhere in the state, except Seattle, where municipal versions of the code have been adopted.

The *Builder's Field Guide* covers only residential practices and requirements. A similar guide for non-residential buildings is available from the Northwest Energy Efficiency Council. www.neec.net

In an effort to provide broad access to this Guide, and to reduce paper consumption, the Guide is available on-line. The on-line version of the Guide is provided to the public free of charge, and all users may print out copies as necessary. You may also want to consider downloading the electronic versions of the WSEC and VIAQ, also available on-line. The *Builder's Field Guide*, the WSEC and the VIAQ can be downloaded from: www.energy.wsu.edu/code/. See the copyright notice on the back side of the title page.

Code Review Process

These codes, and all Washington State Building Codes, are developed by the Washington State Building Code Council (SBCC). The SBCC oversees a public process that reviews all codes. The building community, utilities, local government, and state agencies participate in the public process through technical advisory groups organized around each code. The WSEC is updated every three years.

If you are interested in participating in the next code review process, please contact the SBCC at (360) 725-2966 or via e-mail at sbcc@cted.wa.gov.

While the practices included in this Guide are generally acceptable for Code compliance, your local building official has the final say as to what meets code in specific applications. Alternative practices not illustrated may be acceptable, but must be approved by the local jurisdiction.

The illustrations contained in this Guide reflect Code requirements. Occasionally, however, recommended practices that go beyond Code requirements are included.

The “good practices” are labeled as such and should not be construed as Code requirements.

Code References in the Guide

Code references throughout the Guide are bracketed and appear in the left-hand column.

- | | |
|-----------|-------------------------------------------------------------------------------------------------------------|
| [Number] | References to the 2006 Washington State Energy Code, Second Edition (WSEC) will look like this. |
| [VNumber] | References to the 2006 Washington State Ventilation and Indoor Air Quality Code (VIAQ) will look like this. |

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The 2006 version was updated by WSU Extension Energy Program staffers Gary Nordeen (project leader), Luke Howard, Cindy Wills, and Gerry Rasmussen (graphic designer), and supervised by Todd Carrier (team leader).

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List of Acronyms Used in the WSEC

ABS	Acrylonitrile Butadiene Styrene
ACCA	Air Conditioning Contractors of America Association, Inc.
ACH	Air Changes per Hour
AFUE	Annual Fuel Utilization Efficiency (DOE)
APA	American Plywood Association (<i>now called</i> APA–The Engineered Wood Association)
ASHRAE	American Society of Heating, Refrigerating and Air-Conditioning Engineers
ASTM	American Society for Testing and Materials
BTU (Btu)	British Thermal Units
CFM (cfm)	Cubic feet per minute
COP	Coefficient of Performance
DOE	U.S. Department of Energy
EPA	U.S. Environmental Protection Agency
EPS	Expanded Polystyrene
HSPF	Heating Season Performance Factor
HUD	U.S. Department of Housing and Urban Development
HVAC	Heating, Ventilation and Air Conditioning
HVI	Home Ventilating Institute
IC rated	Insulation Cover Rated
ICF	Insulated Concrete Form
IMC	International Mechanical Code
IRC	International Residential Code

NAECA	National Appliance Energy Conservation Act (1987)
NFRC	National Fenestration Rating Council
SBCC	Washington State Building Code Council
SHGC	Solar Heat Gain Coefficient
SMACNA	Sheet Metal & Air Conditioning Contractors National Association
UA	U-Factor x Area
UL 181	Underwriter's Laboratory Test #181
VIAQ Code	Washington State Ventilation and Indoor Air Quality Code
WSEC	Washington State Energy Code
WSUEEP	Washington State University Extension Energy Program
XPS	Extruded Polystyrene

Chapter 1: Compliance

[101]

Who Must Comply?

All new residential construction must comply with both the Washington State Energy Code and the Ventilation Code.

Exceptions. Exempt from envelope requirements but needing to comply with other Code provisions are:

[101.3.1.1]

- Buildings with peak design energy usage for space conditioning less than 1 watt (3.4 Btu/hour) per square foot of floor area. May apply to garage, shop, or similar part of building.

[101.3.1.2]

- Buildings neither heated nor cooled by a non-renewable energy source (for the purposes of the Code, wood heat is not considered renewable, and must comply).

[101.3.1.3]

- Greenhouses isolated from any conditioned space and not intended for occupancy.

[101.3.2.1 -
101.3.2.8]

Additions and remodeling to existing buildings must comply. See pages 1-15 through 1-18 for specific conditions.

Three Compliance Approaches

The Code allows three possible approaches to demonstrate compliance:

[101.2]

Prescriptive Approach. Follows prescribed building component efficiency levels. [WSEC Chapter 6]

Component Performance Approach. Compares building envelope heat loss rates of the proposed house design to a Code-defined reference house. [WSEC Chapter 5]

System Analysis Approach. Compares an estimate of annual building energy use of the proposed house design to that of a Code-defined reference house. [WSEC Chapter 4]

You must meet the requirements of only *one* approach to comply.

All three compliance options require that the project meet requirements concerning heating systems, water heating and ventilation systems. These requirements are detailed in other chapters of this Guide.

[502.2.1] Buildings constructed using log walls must use "other" fuels to apply the exception noted in Section 502.21 UA Calculations.

[502.2.2] **The WSEC defines two fuel types:**

Electric Resistance. Includes baseboard units, radiant units, boilers, and forced air units using more than 1kW per dwelling unit or 1 watt/ft.², whichever is greater. This applies whether units are primary or secondary sources of heat.

Other. Includes all gas, wood, oil, and propane heating systems, unless electric resistance is used as a secondary heating system (see above), and **all heat pump** heating systems.

The prescriptive approach does not distinguish between fuel types. All fuels have the same requirements for building envelope.

Climate Zones

[302.3]

The WSEC divides the state into two Climate Zones, shown in Figure 1-1.

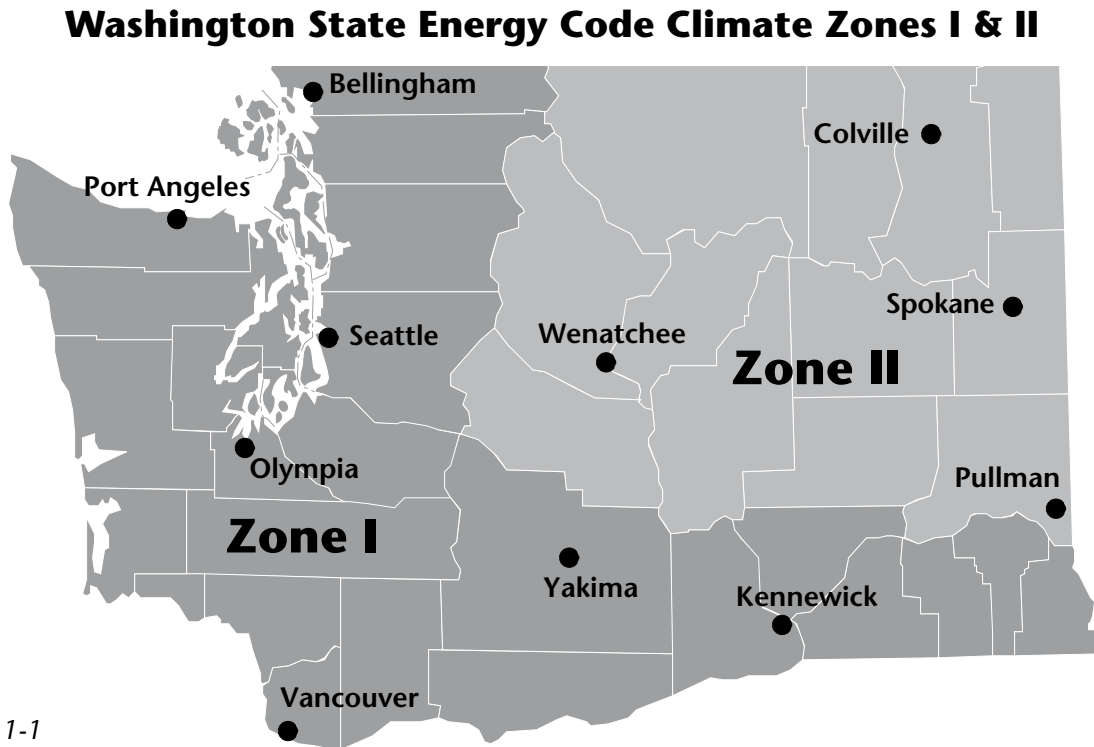


Figure 1-1

Prescriptive Approach

The Easiest Way

The prescriptive approach dictates the minimum insulation level required for each building component. Each component must meet or exceed the listed performance value to qualify.

[601.1]

The two prescriptive tables reproduced on pages 1-5 and 1-6 are taken from Chapter 6 of the WSEC. To select the correct table, simply determine your Climate Zone.

How To Use The Prescriptive Tables

Example House:

- Location: Olympia
- Occupancy: R-3, Single Family
- Conditioned floor area (measured to outside of exterior walls): 1000 ft.²
- Glazing area (measured window rough openings): 200 ft²
- Glazing to floor area ratio: 200/1000 = 20%

Process:

- Zone Map (Figure 1-1) identifies Olympia as Zone 1.
- Single Family (R-3) may use the prescriptive approach.
- 20 percent glazing area limits us to Option IV, unlimited glazing

[602.6]

Glazing in doors and skylights are treated like any other window. When a door contains over 50 percent glass, the entire rough opening is included in the glazing area.

If a portion of the glazing area is over the allowable U-factor, and a portion is under, you may use an area weighted average U-factor to show compliance with your prescriptive option. To determine the average U-factor, find the corresponding glazing area for each distinct U-factor. Multiply the U-factor by the corresponding glazing area. Add together the U x A for each distinct U-factor, and divide by the total glazing area.

Example of Area Weighted U-Factor Calculation

Window #1 area 10 ft ² U = .37	U x A = 3.70
Window #2 area 15 ft ² U = .32	U x A = 4.80
<hr/> Total area 25 ft ²	Total U x A = 8.50

Area weighted average $8.50/25 = 0.34$

WSEC Table 6-1
**Prescriptive Requirements^{0,1} for Group R Occupancy
 Climate Zone 1**

Option	Glazing Area ¹⁰ : % of floor	Glazing U-factor		Door ⁹ U-factor	Ceiling ²	Vaulted Ceiling ³	Wall ¹² Above Grade	Wall•int ⁴ Below Grade	Wall•ext ⁴ Below Grade	Floor ⁵	Slab ⁶ on Grade
		Vertical	Overhead ¹¹								
I.	10%	0.32	0.58	0.20	R-38	R-30	R-15	R-15	R-10	R-30	R-10
II. *	15%	0.35	0.58	0.20	R-38	R-30	R-21	R-21	R-10	R-30	R-10
III.	25% Group R-1 and R-2 Occupancies Only	0.40	0.58	0.20	R-38 / U=0.031	R-30 / U=0.034	R-21 / U=0.057	R-15	R-10	R-30 / U=0.029	R-10
IV.	Unlimited Group R-3 and R-4 Occupancies Only	0.35	0.58	0.20	R-38	R-30	R-21	R-21	R-10	R-30	R-10
V.	Unlimited Group R-1 and R-2 Occupancies Only	0.35	0.58	0.20	R-38 / U=0.031	R-30 / U=0.034	R-21 / U=0.057	R-15	R-10	R-30 / U=0.029	R-10

* Reference Case

0. Nominal R-values are for wood frame assemblies only or assemblies built in accordance with Section 601.1.
1. Minimum requirements for each option listed. For example, if a proposed design has a glazing ratio to the conditioned floor area of 13%, it shall comply with all of the requirements of the 15% glazing option (or higher). Proposed designs which cannot meet the specific requirements of a listed option above may calculate compliance by Chapters 4 or 5 of this Code.
2. Requirement applies to all ceilings except single rafter or joist vaulted ceilings complying with Note 3. "Adv" denotes Advanced Framed Ceiling.
3. Requirement applicable only to single rafter or joist vaulted ceilings where both (a) the distance between the top of the ceiling and the underside of the roof sheathing is less than 12 inches and (b) there is a minimum 1-

4. Below grade walls shall be insulated either on the exterior to a minimum level of R-10, or on the interior to the same level as walls above grade. Exterior insulation installed on below grade walls shall be a water resistant material, manufactured for its intended use, and installed according to the manufacturer's specifications. See Section 602.2.
5. Floors over crawl spaces or exposed to ambient air conditions.
6. Required slab perimeter insulation shall be a water resistant material, manufactured for its intended use, and installed according to manufacturer's specifications. See Section 602.4.
7. Int. denote standard framing 16

8. This wall insulation requirement denotes R-19 wall cavity insulation plus R-5 foam sheathing.
9. Doors, including all fire doors, shall be assigned default U-factors from Table 10.6C.
10. Where a maximum glazing area is listed, the total glazing area (combined vertical plus overhead) as a percent of gross conditioned floor area shall be less than or equal to that value. Overhead glazing with U-factor of U=0.40 or less is not included in glazing area limitations.
11. Overhead glazing shall have U-factors determined in accordance with NFRC 100 or as specified in Section 502.1.5.
12. Log and solid timber walls with a minimum average thickness of 3.5" are exempt from this insulation requirement [see page 1-10 for detail].

WSEC Table 6-2

**Prescriptive Requirements^{0,1} for Group R Occupancy
Climate Zone 2**

Option	Glazing Area ¹⁰ : % of floor	Glazing U-factor		Door ⁹ U-factor	Ceiling ²	Vaulted Ceiling ³	Wall ¹² Above Grade	Wall•int ⁴ Below Grade	Wall•ext ⁴ Below Grade	Floor ⁵	Slab ⁶ on Grade
		Vertical	Overhead ¹¹								
I.	12%	0.35	0.58	0.20	R-38	R-30	R-21 int ⁷	R-21	R-12	R-30	R-10
II. *	15%	0.35	0.58	0.20	R-38	R-30	R-19 + R-5 ⁸	R-21	R-12	R-30	R-10
III.	17%	0.32	0.58	0.20	R-38	R-30	R-19 + R-5 ⁸	R-21	R-12	R-30	R-10
IV.	25% Group R-1 and R-2 Occupancies Only	0.35	0.58	0.20	R-38 / U=0.031	R-30 / U=0.034	R-21 int ⁷ / U=0.054	R-15	R-12	R-30 / U=0.029	R-10 / F=0.54
V.	Unlimited Group R-3 and R-4 Occupancies Only	0.35	0.58	0.20	R-38	R-30	R-19+ R-5 ⁸	R-21	R-12	R-30	R-10
VI.	Unlimited Group R-1 and R-2 Occupancies Only	0.30	0.58	0.20	R-38 / U=0.031	R-30 / U=0.034	R-21 int ⁷	R-21	R-12	R-30	R-10
VII.	Unlimited Group R-1 and R-2 Occupancies Only	0.32	0.58	0.20	R-38 / U=0.031	R-30 / U=0.034	R-21 int ⁷ / U=0.054	R-15	R-12	R-30 / U=0.029	R-10 / F=0.54

* Reference Case

- 0. Nominal R-values are for wood frame assemblies only or assemblies built in accordance with Section 601.1.
- 1. Minimum requirements for each option listed. For example, if a proposed design has a glazing ratio to the conditioned floor area of 13%, it shall comply with all of the requirements of the 15% glazing option (or higher). Proposed designs which cannot meet the specific requirements of a listed option above may calculate compliance by Chapters 4 or 5 of this Code.
- 2. Requirement applies to all ceilings except single rafter or joist vaulted ceilings complying with Note 3. "Adv" denotes Advanced Framed Ceiling.
- 3. Requirement applicable only to single rafter or joist vaulted ceilings where both 9a) the distance between the top of the ceiling and the underside of the roof sheathing is less than 12 inches and (b)

- there is a minimum 1-inch vented airspace above the insulation. other single rafter or joist vaulted ceilings shall comply with the "ceiling" requirements. This option is limited to 500 square feet of ceiling area for any one dwelling unit.
- 4. Below grade walls shall be insulated either on the exterior to a minimum level of R-12, or on the interior to the same level as walls above grade. Exterior insulation installed on below grade walls shall be a water resistant material, manufactured for its intended use, and installed according to the manufacturer's specifications. See Section 602.2.
- 5. Floors over crawl spaces or exposed to ambient air conditions.
- 6. Required slab perimeter insulation shall be a water resistant material, manufactured for its intended use, and installed according to manufacturer's specifications. See Section 602.4.

- 7. Int. denote standard framing 16 inches on center with headers insulated with a minimum of R-10 insulation.
- 8. This wall insulation requirement denotes R-19 wall cavity insulation plus R-5 foam sheathing.
- 9. Doors, including all fire doors, shall be assigned default U-Factors from Table 10-6C.
- 10. Where a maximum glazing area is listed, the total glazing area (combined vertical plus overhead) as a percent of gross conditioned floor area shall be less than or equal to that value. Overhead glazing with U-Factor of U = 0.40 or less is not included in glazing area limitations.
- 11. Overhead glazing shall have U-Factors determined in accordance with NFRC 100 or as specified in Section 502.1.5.
- 12. Log and solid timber walls with a minimum average thickness of 3.5" are exempt from this insulation requirement.

Single Rafter Joist

[Table 6-1, 6-2, 5-1 footnote 3]

Footnote of Tables 6-1, 6-2, 5-1 limit the use of R-30 single rafter joist as follows:

Footnote 3. Requirement applicalbe only to single rafter or joist vaulted ceilings where both (a) the distance between the top of the ceiling and the underside of the roof sheathing is less than 12 inches and (b) there is a minimum 1-inch vented airspace above the insulation. Other single rafter or joist vaulted ceilings shall comply with the "ceiling" requirements. This option is limited to 500 square feet of ceiling area for any one dwelling unit.

If there is room in the joist for R-38 insulation, R-38 is required. This applies to all single rafter joist 13 inches or greater in depth.

R-30 single rafter joist now limited to 500 square feet of roof area. Additional rafter area must use R-38 insulation. A take off noting rafter area will be required for all R-30 rafter systems.

Figure 1-2 shows typical insulation requirements for single rafter joist. If the table notes R-38, then R-38 is required.

**Footnote 3, Table 6-1 or 6-2
Prescriptive Rafter Insulation Based on Fiberglass Batts**

Nominal	Actual	Max Depth with 1 inch Ventilation	First 500 SF R-Value	Over 500 SF R-Value
2 x 10	9 1/4"	8 1/4"	R-30 HD ²	Note ¹
2 x 12	11 1/4"	10 1/4"	R-30	R-38 HD ²
2 x 14	13 1/4"	13 1/4"	R-38	R-38
I-Joist	9 1/2"	8 1/2"	R-30 HD ²	Note ¹
I-Joist	11 7/8"	10 7/8"	R-30	R-38 HD ²
I-Joist	14"	13"	R-38	R-38
I-Joist	16"	15"	R-38	R-38

Note¹ – Upsize joist or provide an alternative method meeting U-.027.

HD² – Refers high density fiberglass batt or equivalent.

Figure 1-2

Component Performance Approach

[502.1]

Calculations Required

If none of the prescriptive options are suitable for your house design, you may be able to show compliance using the component performance approach. This process allows trading off the thermal efficiency of one component for another; for example, more attic insulation may allow less wall insulation.

To calculate energy performance, you must determine each building component's area and U-factor (default U-factors for common building practices are listed in Chapter 10 of the WSEC and summarized in Chapter 10 of this Guide). Multiply the U-factor for each component by the component area. That gives a component UA. Add component UAs to find overall UA for the proposed building.

The overall UA must be compared to a target value based on WSEC specifications, found in WSEC Table 5-1. The overall target UA is calculated by multiplying the component areas from the proposed design by prescribed U-factors from the Code. Glazing in the reference calculation is limited to 15 percent of the conditioned floor area. The proposed overall UA must be less than or equal to the target UA to show compliance.

To choose the correct target from WSEC Table 5-1, identify the Climate Zone for the home.

The WSU Extension Energy Program developed spread sheets that simplify the component performance calculations. They are discussed in more detail at the end of this chapter.

WSEC Table 5-1

Target Component Values for Group R Occupancy

Component	Climate Zone	
	1	2
Glazing % Floor Area	15%	15%
Vertical Glazing U-Factor		
Group R-1 and R-2	U = 0.400	U = 0.400
Group R-3 and R-4	U = 0.350	U = 0.350
Overhead Glazing U-Factor	U = 0.58	U = 0.58
Doors	U = 0.200 (R-5)	U = 0.200 (R-5)
Ceilings		
Attic	U = 0.031 (R-38)	U = 0.031 (R-38)
Single Rafter / Joist Vaulted ³	U = 0.034 (R-30)	U = 0.034 (R-30)
Walls ^{1,2}	U = 0.057 (R-21)	U = 0.044 (R-19A + R-5)
Floors	U = 0.029 (R-30)	U = 0.029 (R-30)
Slab on Grade	F = 0.54 (R-10)	F = 0.54 (R-10)
Below Grade Interior		
Wall R-Value	R-19	R-19
2' Depth: Walls	U = 0.043	U = 0.043
Slab	F = 0.69	F = 0.69
3.5' Depth: Walls	U = 0.041	U = 0.041
Slab	F = 0.64	F = 0.64
7' Depth: Walls	U = 0.037	U = 0.037
Slab	F = 0.57	F = 0.57
Below Grade Exterior		
Wall R-Value	R-10	R-12
2' Depth: Walls	U = 0.070	U = 0.061
Slab	F = 0.60	F = 0.60
3.5' Depth: Walls	U = 0.064	U = 0.057
Slab	F = 0.57	F = 0.57
7' Depth: Walls	U = 0.056	U = 0.050
Slab	F = 0.42	F = 0.42

1. Log and solid timber walls that have a minimum average thickness of 3.5" in spaces with space heating by "other fuels" are exempt from wall target UA and proposed UA calculations.

2. "A" means advanced framing. For more information, see Section 1005.2.

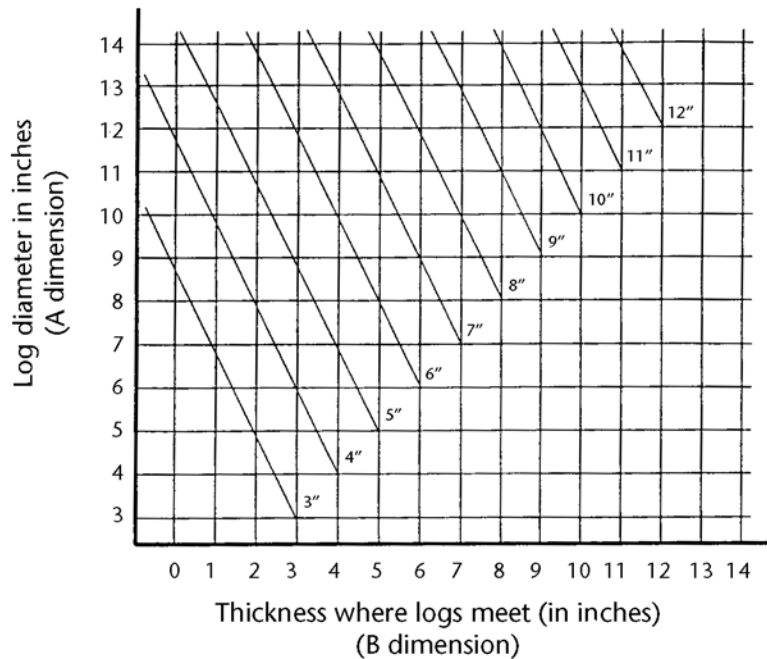
3. Requirement applicable only to single rafter or joist vaulted ceilings where both (a) the distance between the top of the ceiling and the underside of the roof sheathing is less than 12 inches and (b) there is a minimum 1-inch vented airspace above the insulation. Other single rafter or joist vaulted ceilings shall comply with the "ceiling" requirements. This option is limited to 500 square feet of ceiling area for any one dwelling unit.

Log Walls

Footnote 12 of Tables 6-1 and 6-2 and Footnote 1 of Table 5-1 provide an exemption for log walls with a minimum average thickness of 3.5". The home must be heated with "other fuels" to qualify for this exception.

Figure 1-3 provides a method for determining average thickness, based on the log diameter, and the thickness of where two logs meet.

Average Thickness For Round Log Walls



Example:
A = 11"
B = 5"



From chart:
Average thickness = 7"

Figure 1-3

Systems Analysis

Computer Simulation Recommended

[402.1.2]

The System Analysis Approach requires a calculation of the annual energy use of the proposed design. If the calculation demonstrates that the proposed design uses less heating energy than the Code defined target home, it meets the envelope requirements of the Code.

The calculation must be done as described in Chapter 4 of the Code. It must account for local weather data, air infiltration, heating system efficiencies, solar gains, and internal gains including occupancy loads, as well as the building shell insulation. The envelope requirements for the home are based on the component performance target UA. For other systems, refer to WSEC Chapter 4.

When your design includes high efficiency heating equipment, or solar gain and thermal mass, systems analysis may allow trades between other components. The calculation is complex, however, and should be done using a computer program that is capable of documenting all of the building system interactions. This may require the help of a design professional.

WSEC Chapter 8 suggests software that may be used for systems analysis. The WSU Extension Energy Program suggests that users interested in demonstrating compliance using the systems analysis approach use one of the many variations of DOE-2 software. Additional information on documenting code compliance is included at the end of this chapter.

Systems Analysis

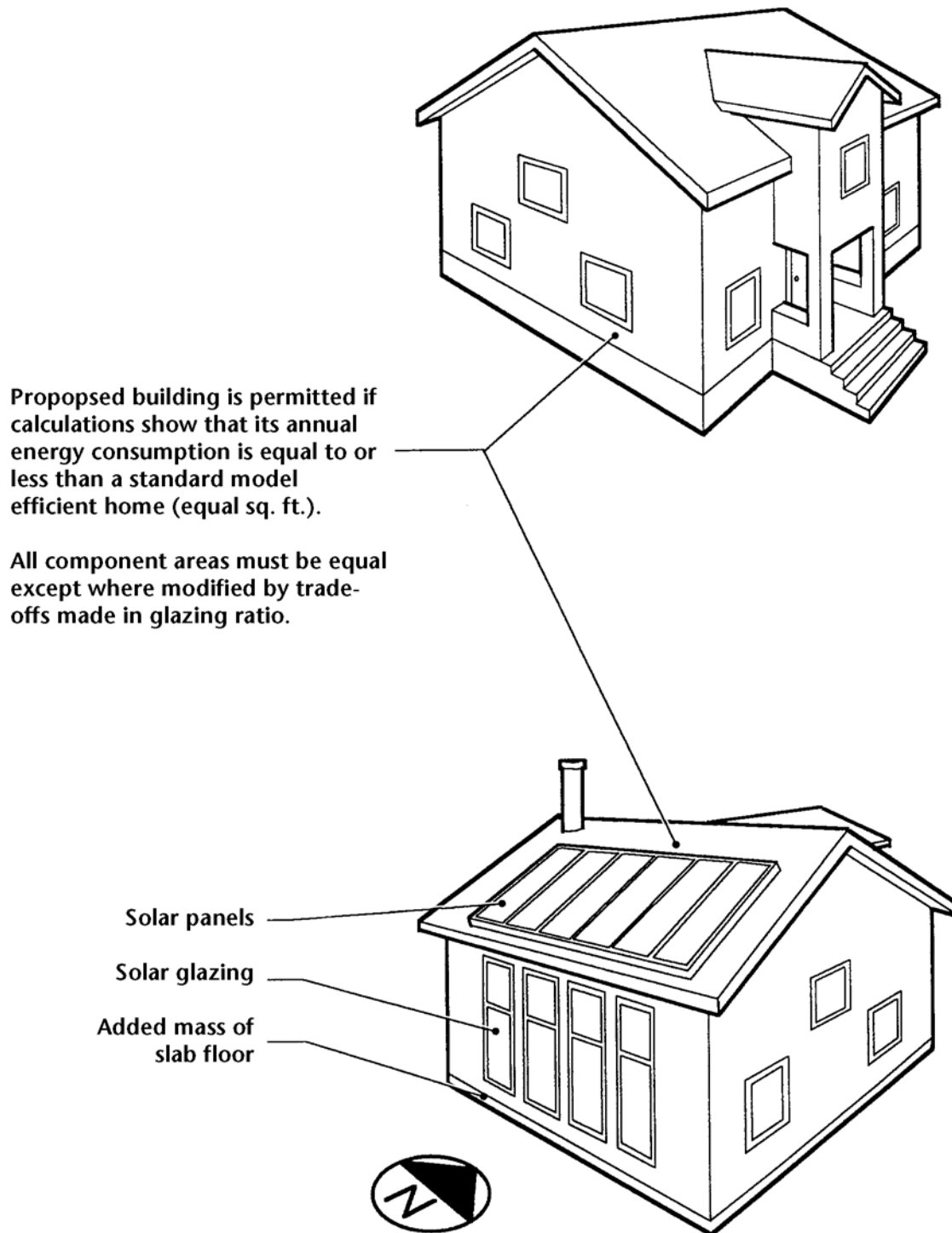


Figure 1-4

Ventilation and Indoor Air Quality

Regardless of the compliance approach used to meet the WSEC, *all homes* must also comply with the provisions of the VIAQ Code. This Code requires:

- [V302.3] Spot and whole-house ventilation in all residential construction.
- [V502] Radon mitigation measures for all crawl spaces and crawl-space plenum systems.
- [V401.1] Structural building materials with low levels of formaldehyde emissions.
- [V402.2] Combustion air supply for all solid fuel appliances.
- [V501.2.2] **Seven counties in the state** (Clark, Ferry, Okanogan, Pend Oreille, Skamania, Spokane, and Stevens) are considered at higher risk for radon and must meet additional prescriptive radon measures (see Figure 1-5). The additional measures include: sub-slab gravel, radon vent stack and sealing below-grade walls and floor.

Higher Risk Radon Counties

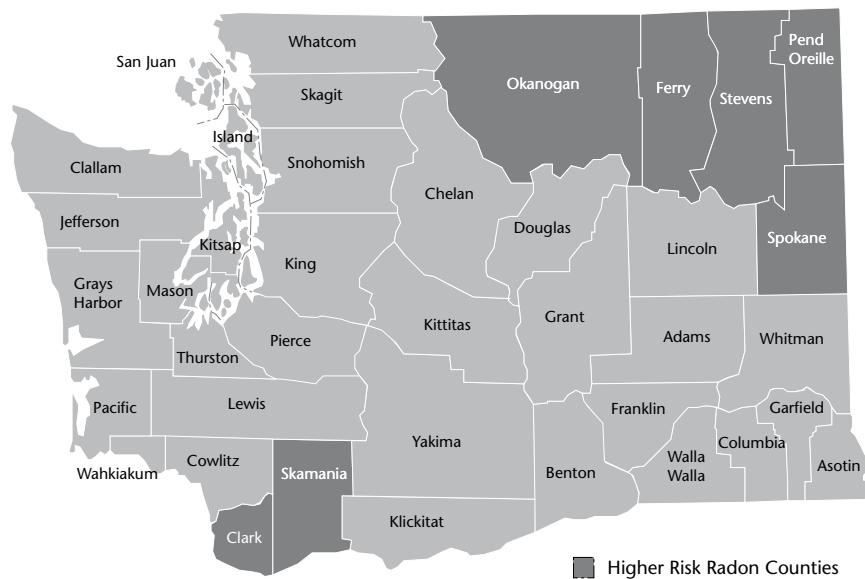


Figure 1-5

In 2006, Washington state adopted the International Residential Code *Appendix F, Radon Control Methods*. This appendix applies to one and two family dwellings only. All other Group R construction must meet the radon resistive construction requirements of the VIAQ.

The Washington state amendments to the International Residential Code, Section AF101.1, prohibits the use of the unvented crawl spaces in high risk Radon counties (Clark, Ferry, Okanogan, Pend Oreille, Skamania, Spokane, and Stevens). For all other counties, when unvented crawl spaces are constructed, Radon mitigation system in compliance with Appendix F is required.

Additions and Remodeling

[101.3.2.1-8,
V103.1.1-2]

Additions and remodeling to a home must meet requirements of the WSEC and the VIAQ Code.

Table 1-1

Remodeling Requirements

Replacement of:	Requirement
Combustion Furnace	Minimum AFUE 78%.
Heat Pump	Minimum HSPF 7.7
Water Heater	Meet 1987 National Appliance Energy Conservation Act (NAECA). Set to 120° F.
Electric Water Heaters	R-10 insulated pad in unconditioned space or on uninsulated slabs.
Solid Fuel Combustion Devices	Direct connection of outside combustion air. Tight fitting doors. See exceptions Chapter 9.
Window Replacement	Required U-factor – 0.35
Insulation Walls & Ceilings	Exposed cavities must be filled to the requirements of Table 6-1 or 6-2, or have an average UA that complies with the requirements of Table 5-1. Where structural elements limit the level of insulation that can be applied to less than the code requirements, the cavities must be filled. Roof decks must be insulated to the requirement of the code if a complete roof tear-off is part of the work.
[101.3.2.5]	

There are a few exceptions (historical buildings and other special cases) when the WSEC and VIAQ Code may not be fully enforced. Check with your local jurisdiction.

Table 1-2

Additions Requirements

Size	Code Compliance for Additions
Under 500 ft. ²	Must meet spot ventilation regulations. Whole house ventilation not required.
Over 500 ft. ²	Whole house and spot ventilation requirement.
Under 750 ft. ²	Addition can comply with the WSEC either by prescriptive approach, or by using tradeoffs with existing building for WSEC compliance.*
Over 750 ft. ²	Addition must show full WSEC compliance as a stand alone project.

**See component performance approach.*

The need to perform complicated tradeoffs for additions was reduced considerably with the introduction of unlimited glazing options in the prescriptive approach. Consider the prescriptive approach first.

Note:

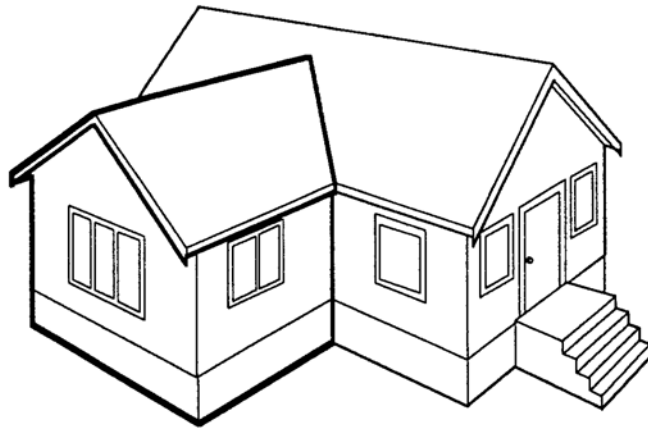
Radon protection is required in additions that call for construction of foundations, crawl-spaces, slabs or basements, and is not required where these features are not in the design.

All additions of any size must meet VIAQ specifications for formaldehyde and solid fuel combustion appliances.

[V501.1]

Energy Code Requirements for Additions

If an addition complies with the energy code... no change is required in the existing building.



A non-complying addition <750 sq. ft. is permitted if improvements made to existing building (increasing ceiling insulation) to compensate for a non-complying addition.

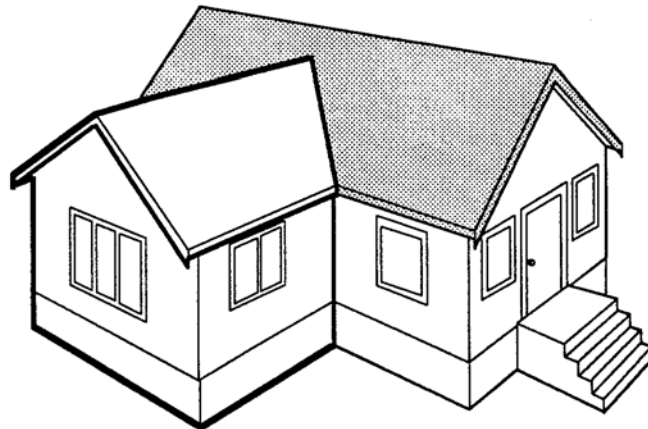
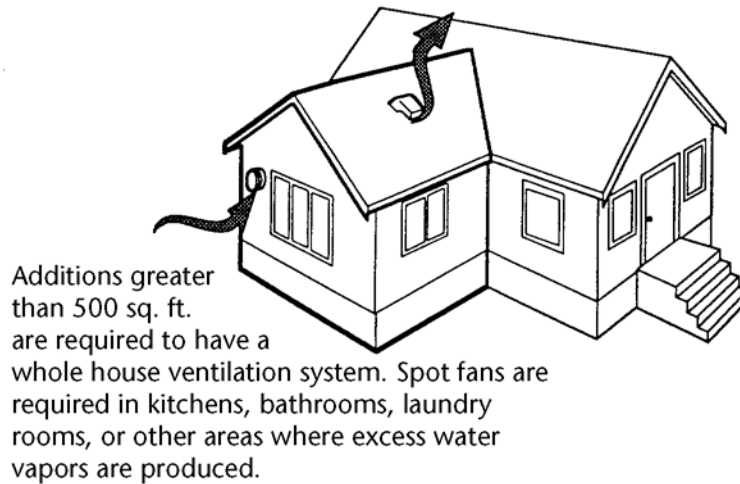


Figure 1-6

Ventilation and Indoor Air Quality Code Requirements for Additions



Radon Requirements for Additions

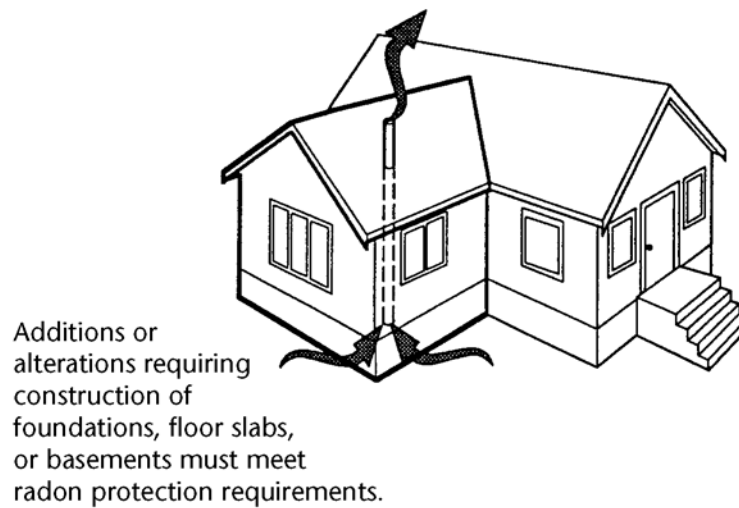


Figure 1-7

Documenting Code Compliance

To obtain a building permit you will be required to provide the local building department with a description of the Energy and Ventilation Code compliance approach that will be used. This will include details on the plans and documentation required to demonstrate compliance with the code requirements. This will typically include energy code compliance forms, and a description of the chosen ventilation systems.

Plans and Specifications

The codes requires that sufficient detail be included on the plan set to assure that the energy code requirements are implemented during construction. This *Builder's Field Guide* book includes many examples of insulation and air sealing details. A similar level of detail should be included as part of the plan set. A few examples of areas needing good details follow.

Framing:

- Show framing with sufficient depth to accommodate the required insulation.
- Detail header insulation when insulated headers are required.

Roof Ventilation:

- Show minimum 1" air space in single rafter joist systems. Provide details for ventilation openings top and bottom on all roof sections.

Slab Insulation:

- Detail insulation integration with the foundation and floor system. Show insulation protection when installed on the exterior. Show the thermal break on the vertical edge of below grade heated slabs.

Vapor Retarder:

- Indicate the type and location of vapor retarders.

Air Sealing:

- Detail difficult areas, including attic knee walls, cantilevered floor systems, mechanical and plumbing chases, etc.

Ducts:

- Provide framing details with specific space for major duct runs.

The Prescriptive Approach

For the Washington State Energy Code, the prescriptive approach is the simplest method of code compliance. The WSU Extension Energy Program has created an Excel[®] spreadsheet to help you provide documentation with the prescriptive building envelope sections of the code. This worksheet also helps you provide documentation required to meet the heating system sizing requirements of IRC section M1401.3. To select the correct worksheet, you will need know the building occupancy type and climate zone. The worksheet is available from the WSUEEP website at www.energy.wsu.edu/code/

Component Performance Approach

The WSU Extension Energy Program developed a package of Excel[®] worksheets designed to document the qualification of building designs by the component performance approach described in Chapter 5 of the WSEC.

There are two worksheets: The **CPLibrary** contains all of the component descriptions in Chapter 10 of the WSEC. The **CPworksheet** includes the compliance forms for all building types and climate zones. Both workbooks can be downloaded as a set from the WSU Extension Energy Program website: www.energy.wsu.edu/code/

Systems Analysis Approach

The WSU Extension Energy Program no longer provides software that supports a systems analysis approach. Select a DOE-2 based software package for this type of analysis. Use the WSUEEP component performance worksheet to develop a target and proposed building envelope as required by the code. Then load this information into a DOE-2 product and perform the systems analysis.

For a complete list of DOE-2 compliant software available from the Simulation Research Group at Lawrence Berkeley National Laboratory in Berkeley, California, visit their website at <http://gundog.lbl.gov>

The Simulation Research Group specializes in creating building energy simulation software.

Chapter 2: Foundation

Crawlspace

- [V502.1.2] **Vents.** Vents in the crawlspace help keep floor insulation and floor framing dry. Crawlspace vents also reduce the potential for radon buildup under the floor.
- Ventilation required is equivalent to IRC requirement (1 ft.² of net free vent area for each 150 ft.² of crawlspace area, or 1/150 ft.²).
- [V502.1.2] If venting area is less than 1/300 ft.² or the vents can be closed, a radon vent must be installed (see Radon, p. 2-18).
- Vents must be placed below floor insulation (see Figure 2-1) or they must be properly baffled (see Figure 2-2).
- [V502.1.3] **HVAC Plenum.** If the crawlspace is used as a supply plenum as part of the HVAC system, a functioning radon mitigation system must be installed (see Radon, p. 2-18). This includes:
- a radon vent.
 - 4-inch layer of aggregate.
 - Sealed soil gas retarder membrane.
 - 100 CFM in-line fan.
- [V502.1.3] Crawlspace may not be used as a return plenum.
- Insulation.** If you choose a prescriptive compliance path, the WSEC requires that the floor over the crawlspace be insulated to the required value determined by using WSEC Tables 6-1 or 6-2.

Foundation Vent

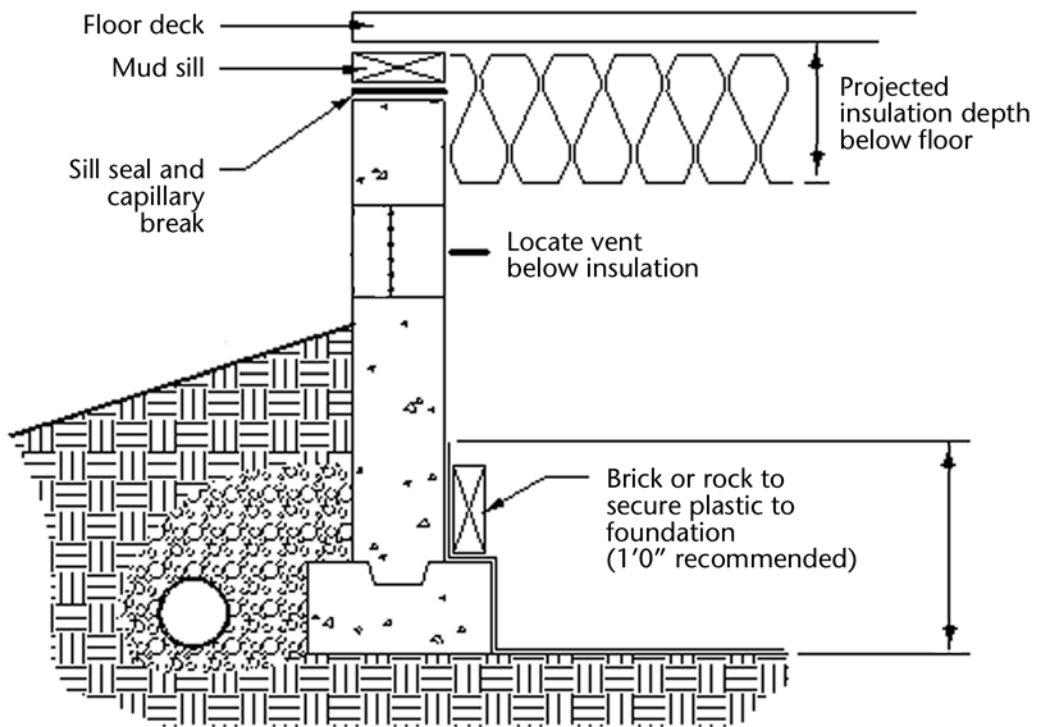


Figure 2-1

Baffled Foundation Vent

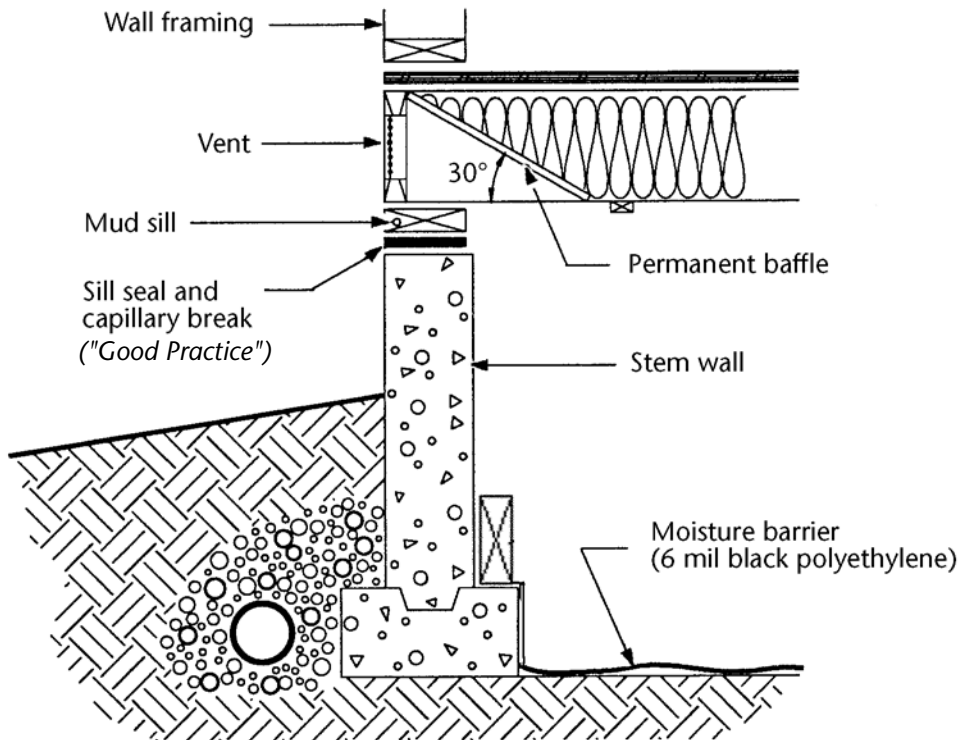


Figure 2-2

[502.1.4.8] **Thermal Break.** Where a crawlspace stem wall abuts a slab-on-grade within a conditioned space, insulation must be used to create a thermal break (see Figure 2-3 for possible detail.)

[502.1.6.7] **Ground Cover.** Six-mil black polyethylene (or approved equal) must be laid over the ground within all crawlspaces.

The ground cover:

- Must extend to the foundation wall.
- Seams must be lapped 12 inches (see Figures 2-1 and 4-6).
- May be omitted if a minimum 3¹/₂-inch concrete slab is poured in the crawlspace.

Thermal Breaks

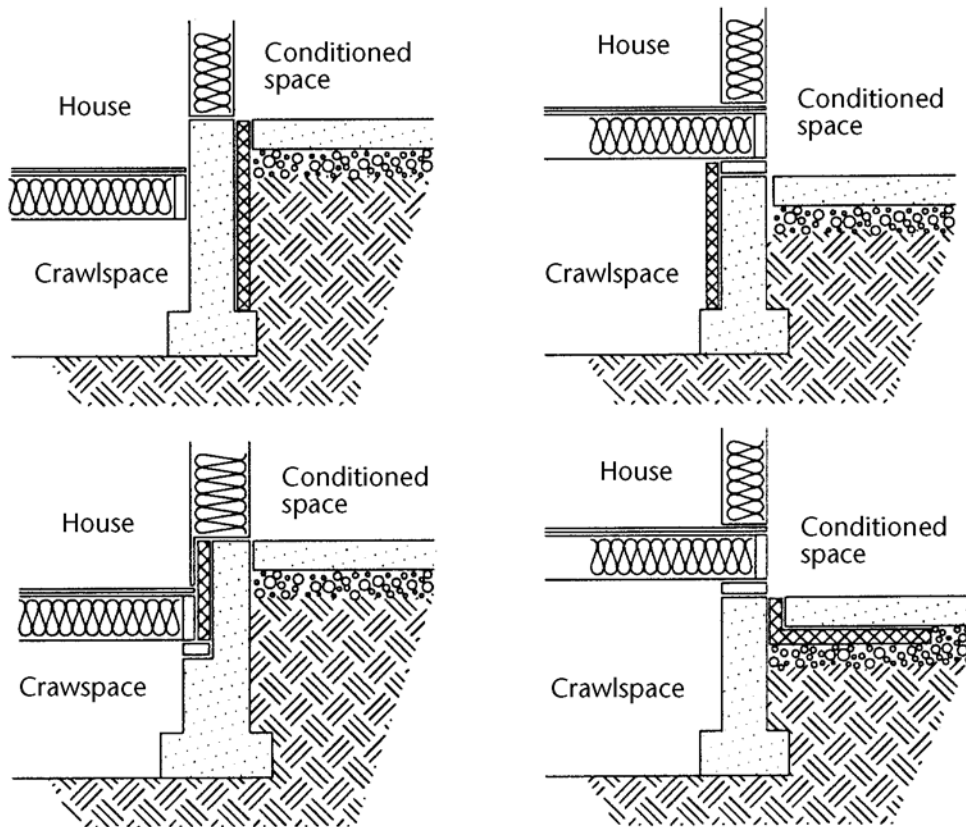
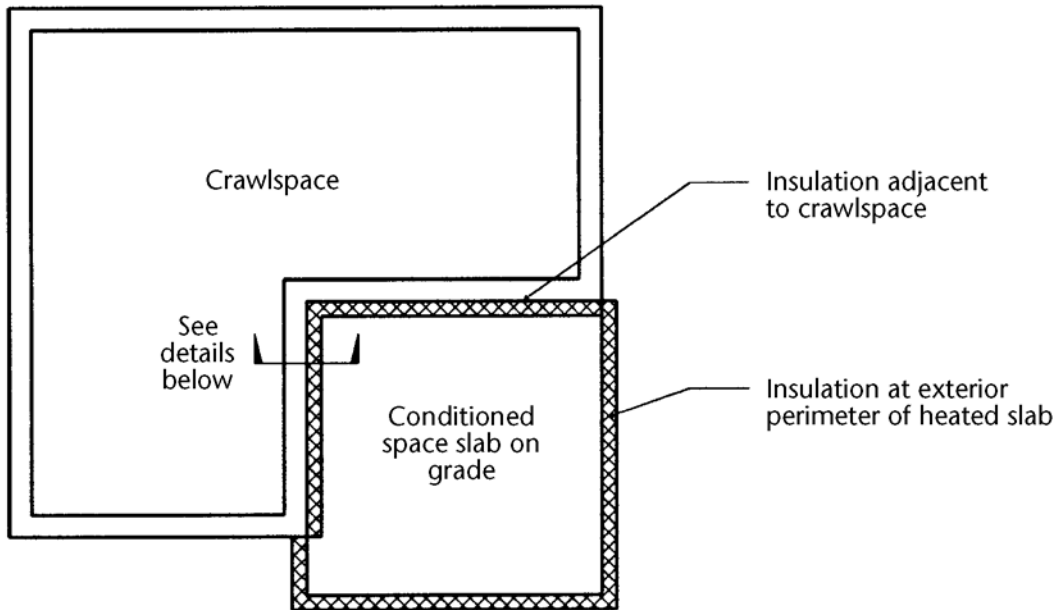


Figure 2-3

Slab-On-Grade

- [201.1] Defined by Code as any slab with its top surface less than 24 inches below the final exterior grade (see Figures 2-4, 2-5, and 2-7). In such cases, you must:
- Maintain a thermal break at the edge of a slab. Slabs must not run continuously from heated to unheated areas. (See Figures 2-8 and 2-9.)
- [502.1.4.8]
- Extend R-10 (Zone 1) or R-12 (Zone 2) insulation for a total of 24 inches either vertically or a combination of vertically and horizontally around the entire on-grade perimeter.
 - Install water-resistant insulation material manufactured for this purpose.
 - Install a cover flashing or parging to protect the insulation from moisture and physical damage above grade.
- [502.1.4.9] **Radiant Slabs.** If a radiant heating system is to be installed in a slab, a minimum of R-10 insulation (all zones) is required under the slab. The entire area of radiant slab in contact with the ground must be thermally isolated (see Figure 2-6).
- [V503]
[IRC
Appendix F] **Higher Risk Radon Areas.** Builders in the higher risk radon counties (see p. 1-3) must place 4 inches of aggregate and a soil gas retarder membrane under all slabs within conditioned space in residential construction. Penetrations of the slab must be sealed and a radon vent stack installed (see Radon, p. 2-18 and Figure 2-15).

Notes:

Ducts. Any heating system ductwork in or under a slab must be insulated to R-5 with insulation manufactured for this use.

Pipes. Any hot water pipes buried under a slab must be insulated to as noted in Table 5-12. (R-3.6 for $\leq 2''$ pipe, R-5.4 for $> 2''$)

Combustion Air. Installation of a wood stove or other solid fuel combustion appliance in a basement must provide combustion air to the appliance.

Slab Construction Perimeter Insulation

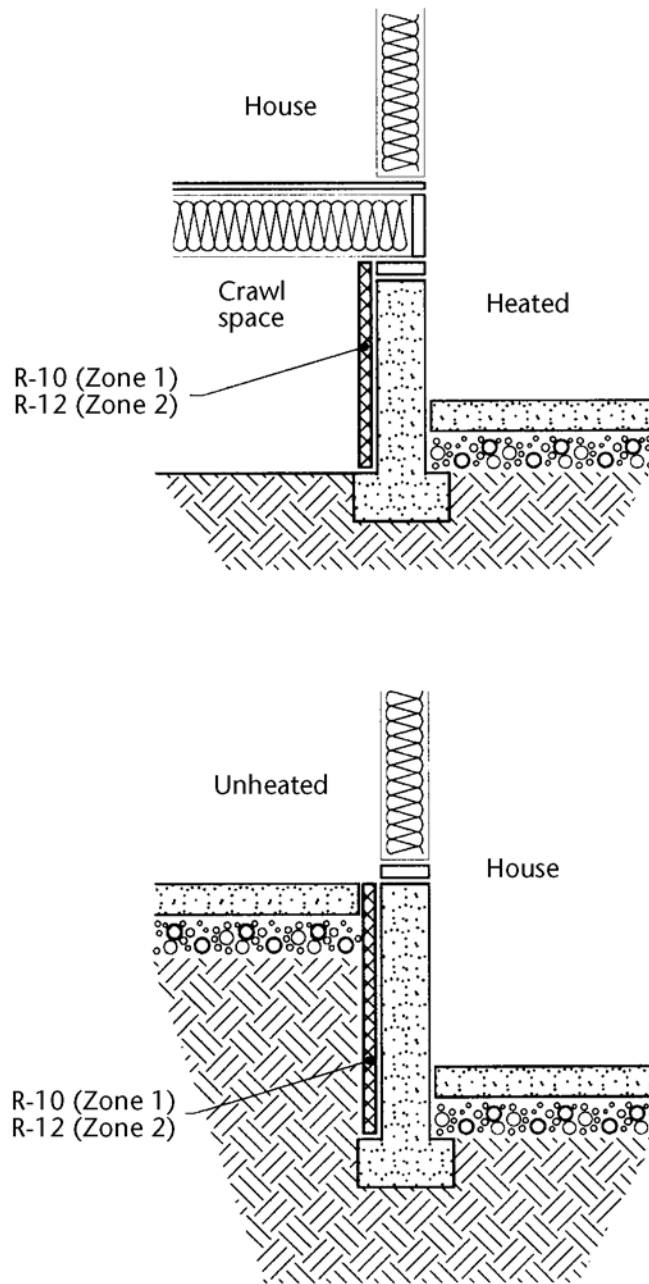


Figure 2-4

Slab-On-Grade

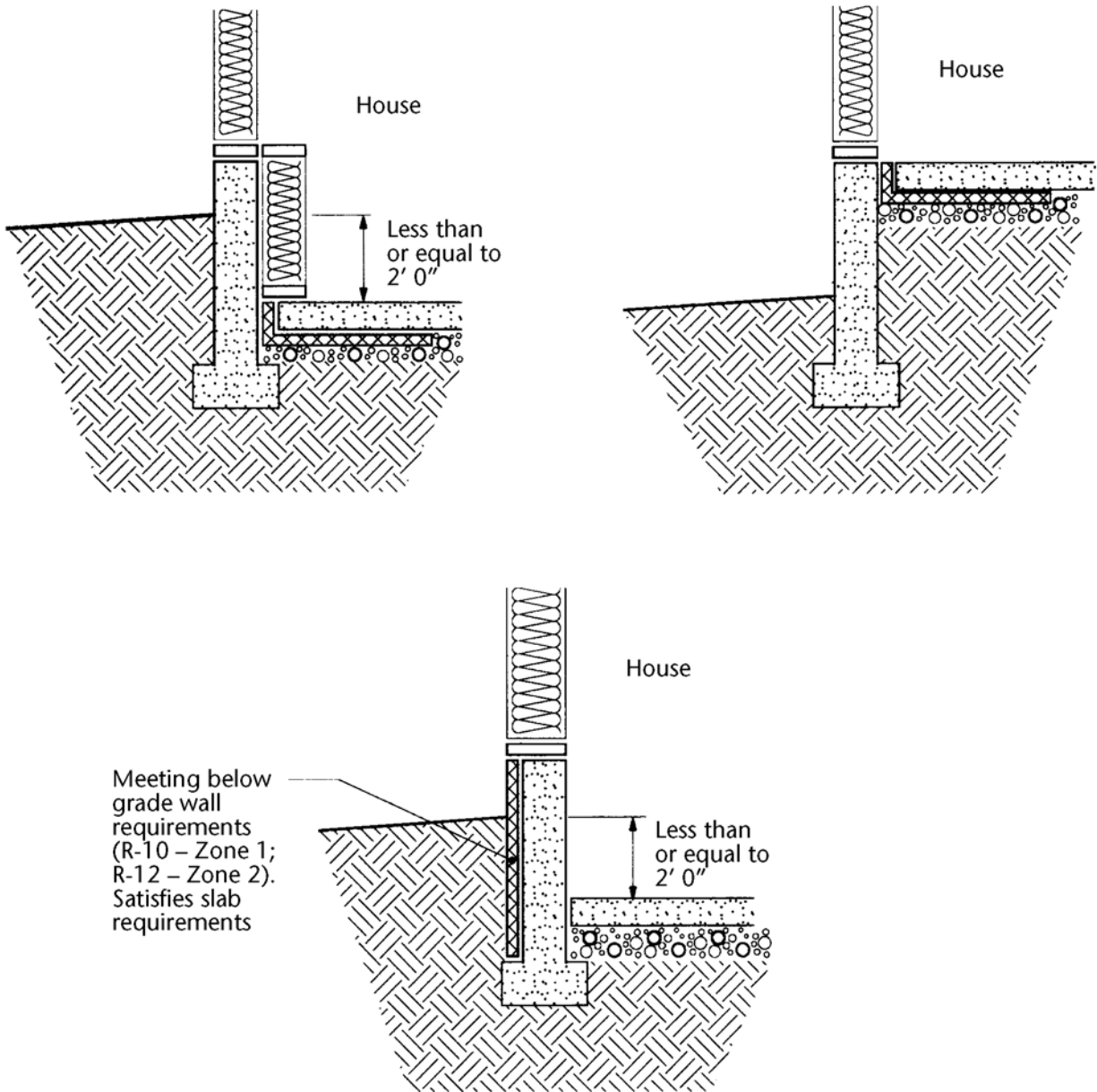
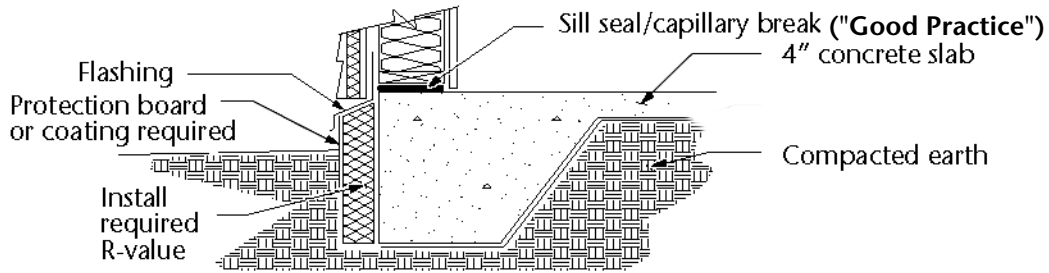


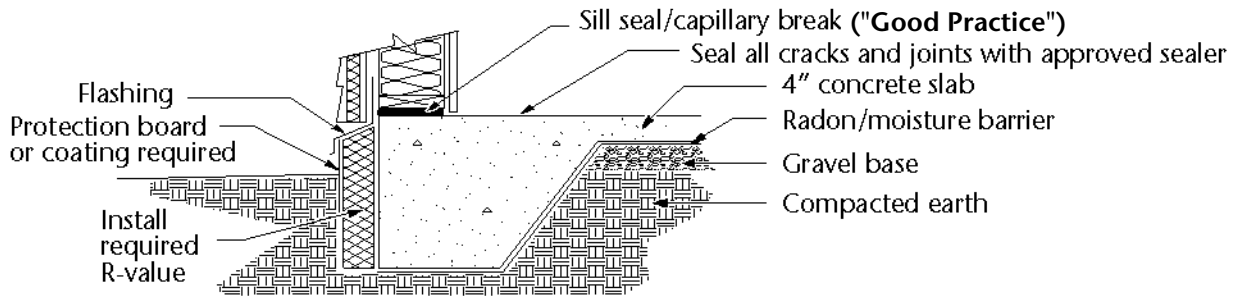
Figure 2-5

Meeting Below Grade Wall Requirements Monolithic Slab-On-Grade

Typical Slab with No Radon Source Control



Slab with Radon Source Control



Radiant Slab with Radon Source Control

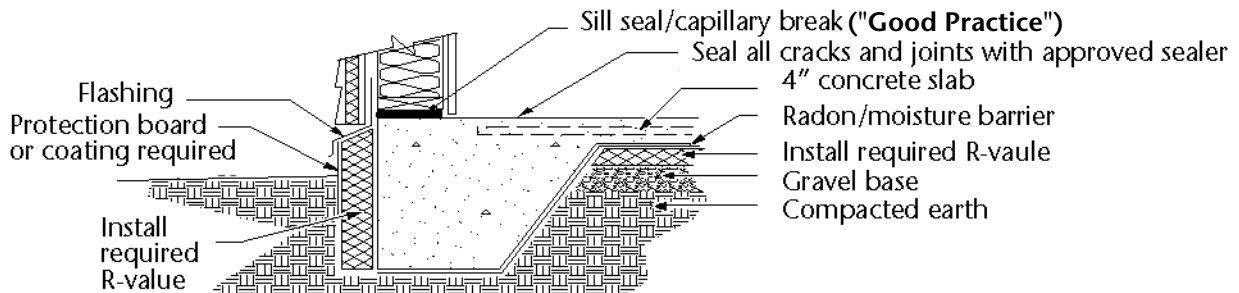
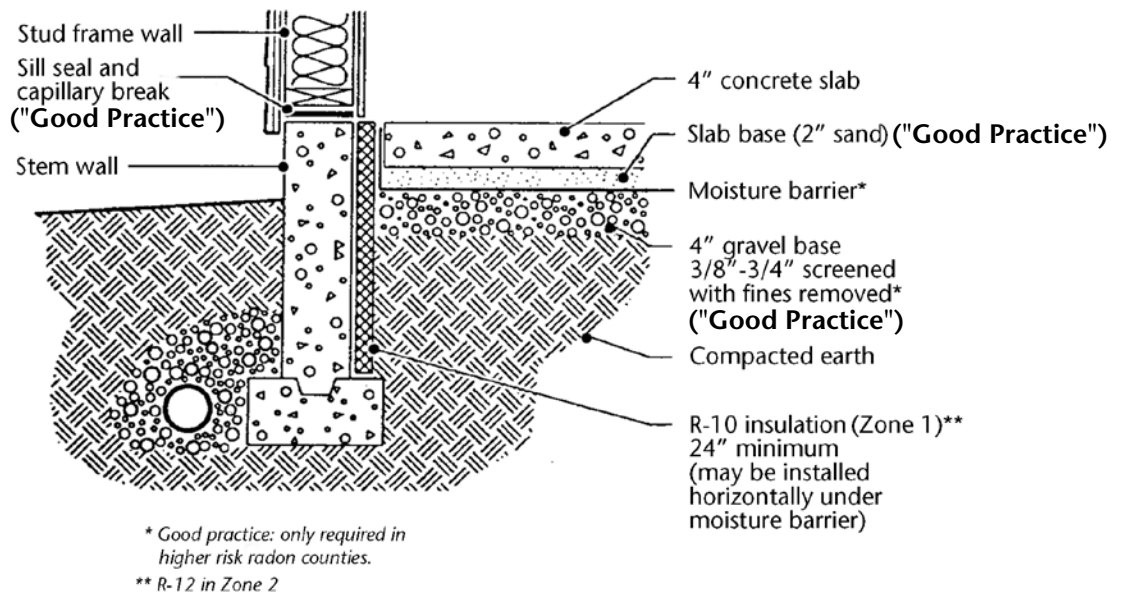


Figure 2-6

Note: See IRC Appendix F and VIAQ 503.2.4 for requirements in radon counties.

Interior Insulation



Exterior Insulation

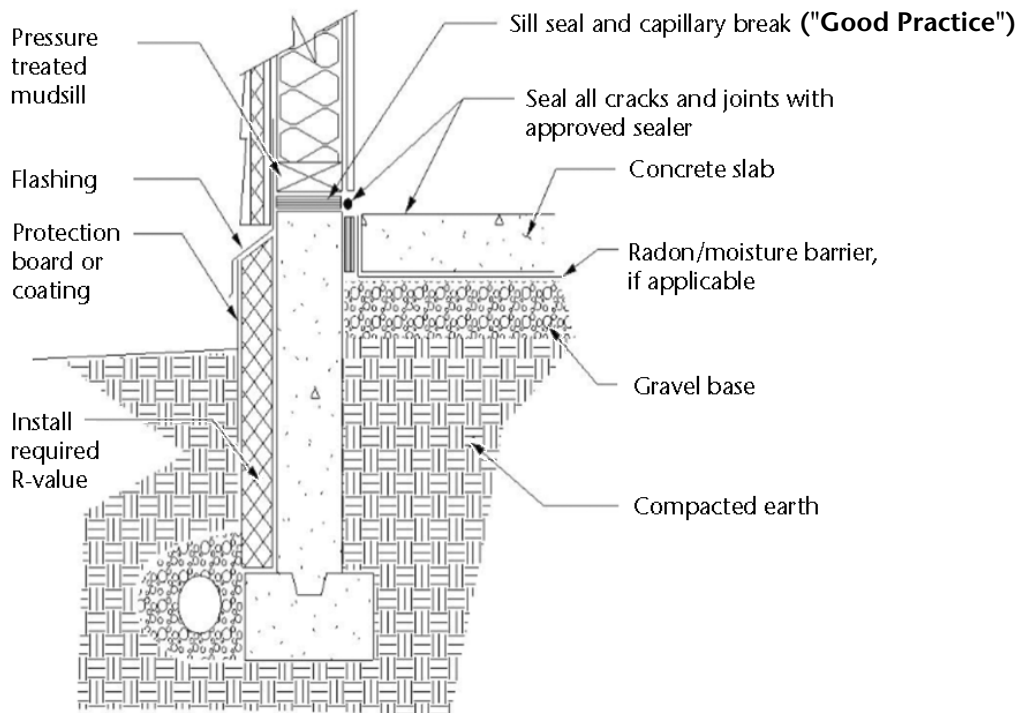


Figure 2-7

Note: See VIAQ 503.2.4 for membrane requirements in radon counties.

Possible Slab Insulation Details

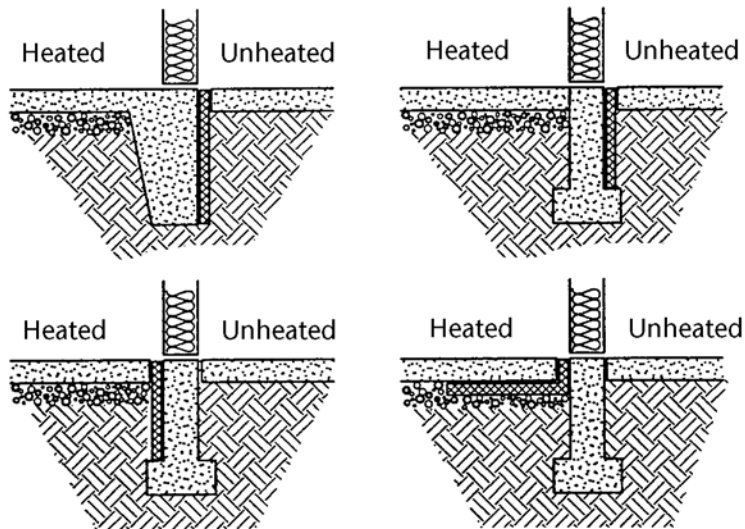
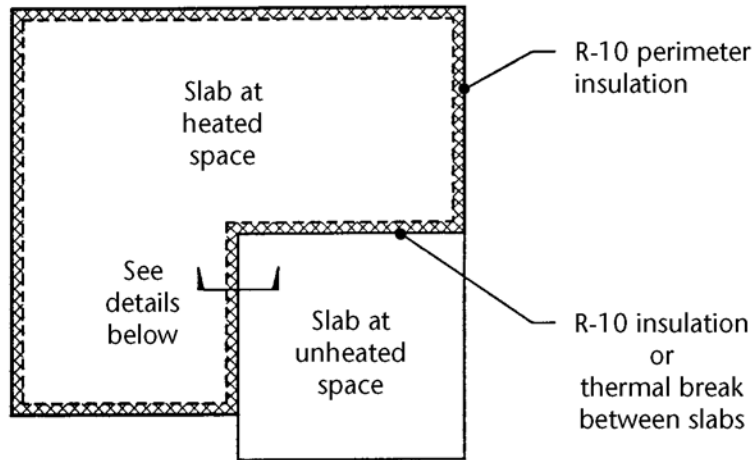


Figure 2-8

Non-Bearing Slab Thermal Break

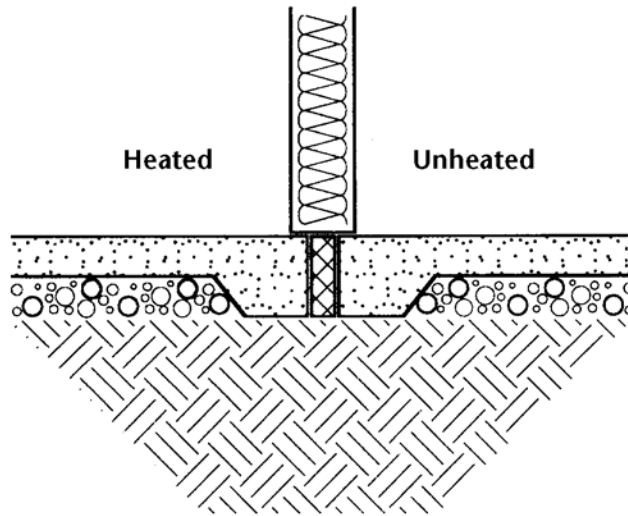
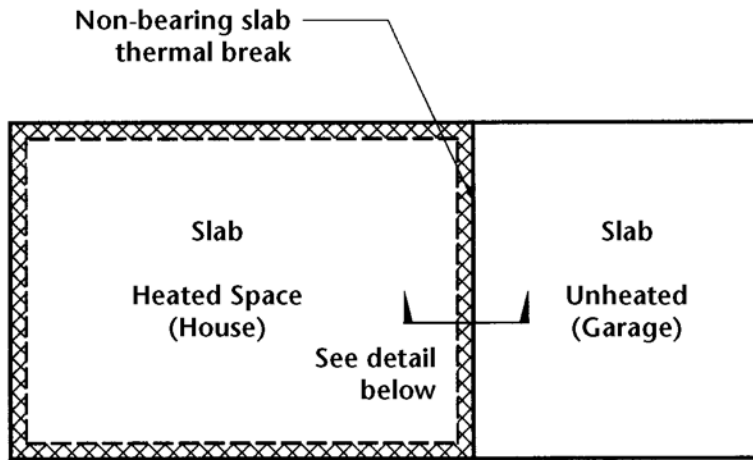


Figure 2.9

Basements

Any basement with a heat source must have insulated walls. For a basement to be considered unheated and not require wall insulation, there must be no heat supplied. An unheated basement must be thermally isolated from adjoining conditioned spaces. This would include:

- Ceiling insulation (i.e. the floor above).
- Insulated stairwell walls.
- A weatherstripped access door.
- Insulated and sealed ducts and pipes.

[502.1.4.10]

Below-Grade Walls. For the purposes of the Energy Code, wall sections that extend 24 inches or less above grade may be considered below-grade walls.

Insulation:

- May be placed on either the interior or the exterior of the wall.
- The minimum required R-value is determined by the compliance path chosen.

Exterior insulation must:

- Be approved for below-grade installation.
- Extend from the top of the below-grade wall to the top of the footing.
- Be protected where it extends above grade (see Figure 2-10).

Interior insulation must:

- Extend from the top of the below-grade wall to the top of the below-grade floor (see Figure 2-11).

Daylight Basement. Pay attention to corner details when insulating a daylight basement (see Figures 2-12 and 2-13 for examples). Anywhere the slab in a daylight basement is within 24 inches of the finish grade, perimeter slab insulation is required.

[V501]

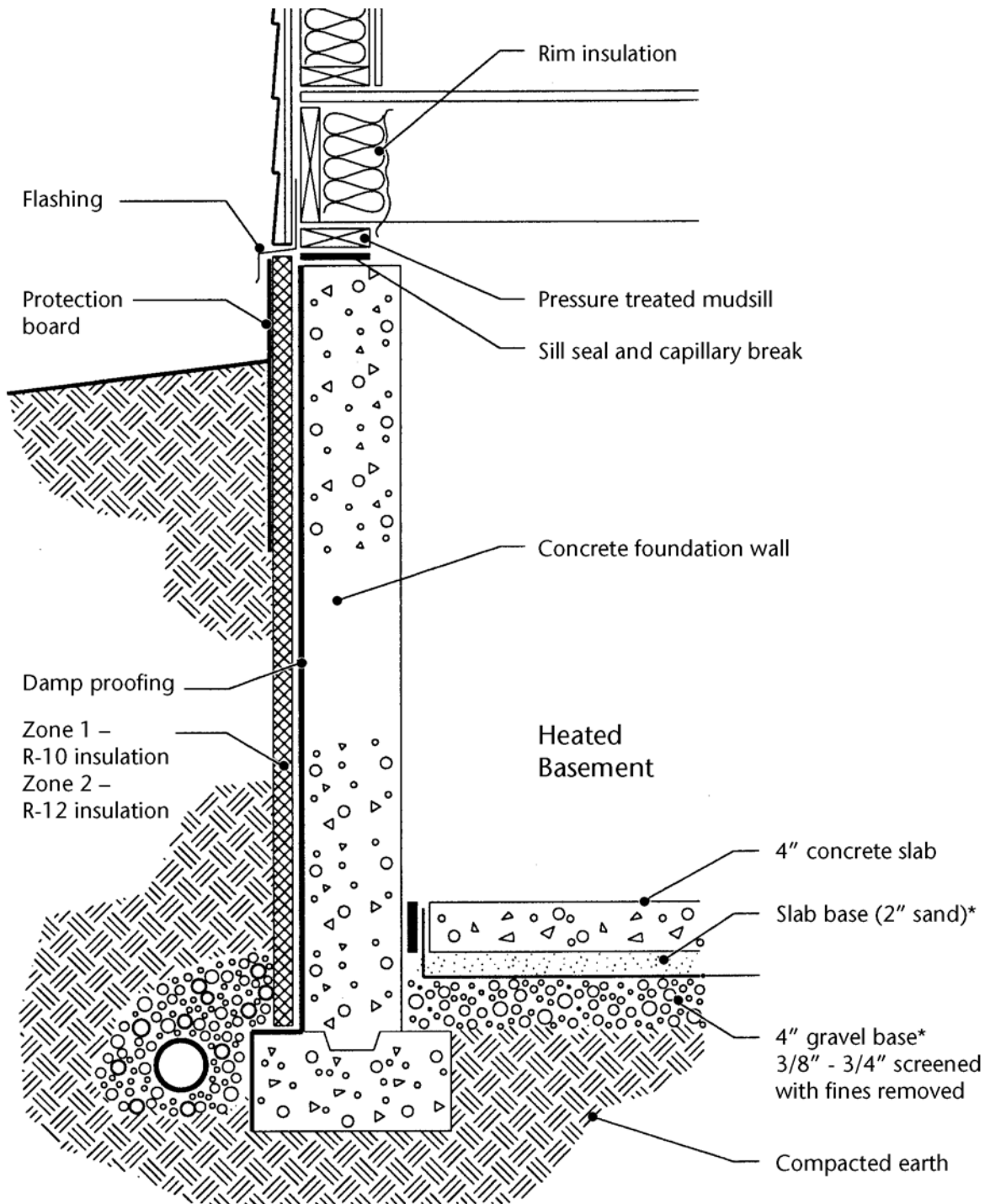
Higher Risk Radon Areas. Basement slabs in higher risk radon counties (see list, p.1-20) must be poured over 4 inches of aggregate and a soil gas retarder membrane. Slab penetrations must be sealed, and a radon vent installed (see Radon, p. 2-18, and Figure 2-14).

See IRC Appendix F and VIAQ 503.2.4 for requirements in radon counties.

Note:

Ducts and pipes in the slab and combustion air requirements are the same for heated basements as they are for slab-on-grades. Unheated basements require R-8 duct insulation. Any hot water pipes buried under a slab must be insulated to as noted in Table 5-12. (R-3.6 for > 2" pipe, R-5.4 for >= 2", see Note, p. 2-5).

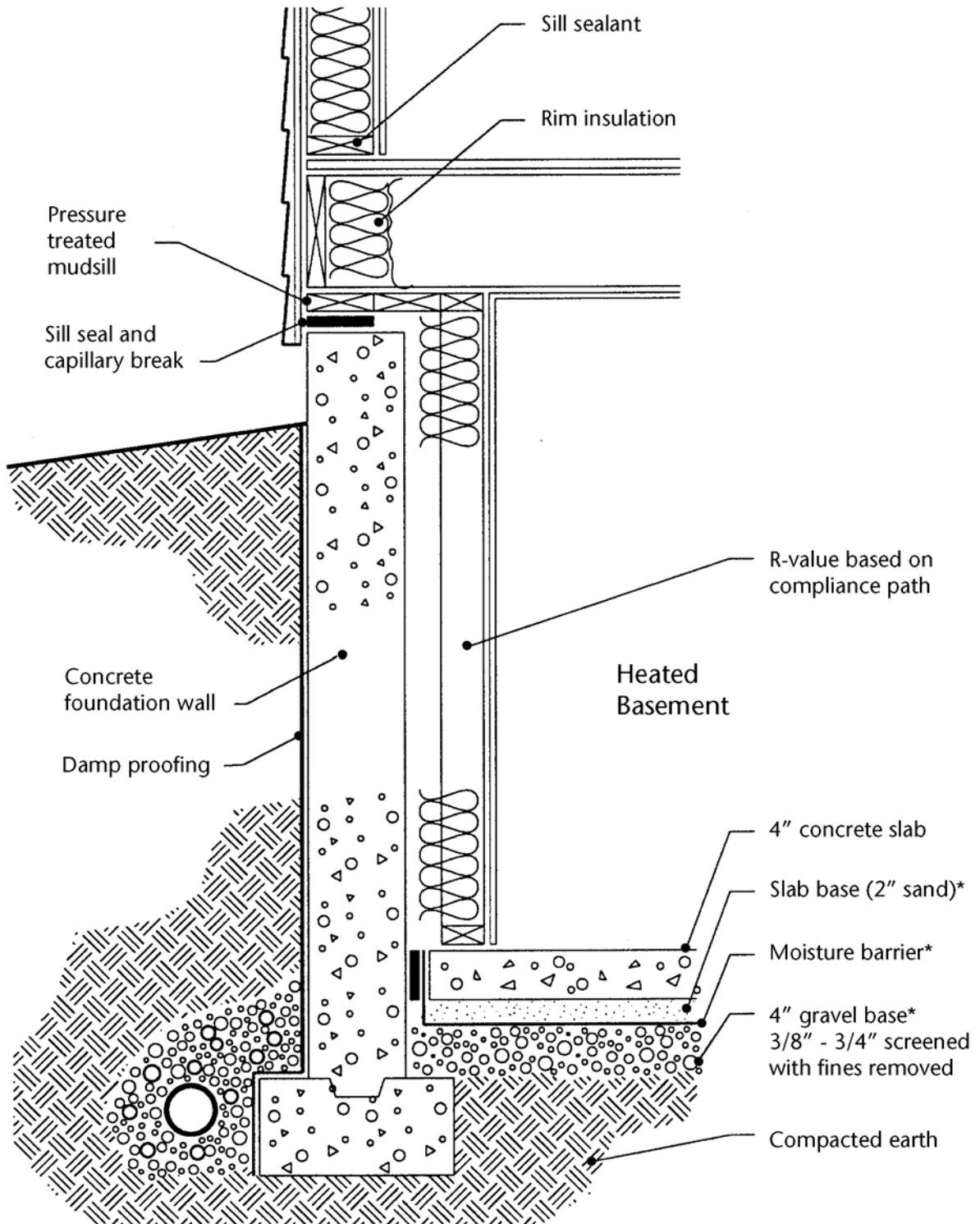
Heated Basement: Exterior Insulation



* Good practice: required only in higher risk radon counties.

Figure 2-10

Heated Basement: Interior Insulation



* Good practice: required only in higher risk radon counties

Figure 2-11

Heated Daylight Basement: Exterior Insulation

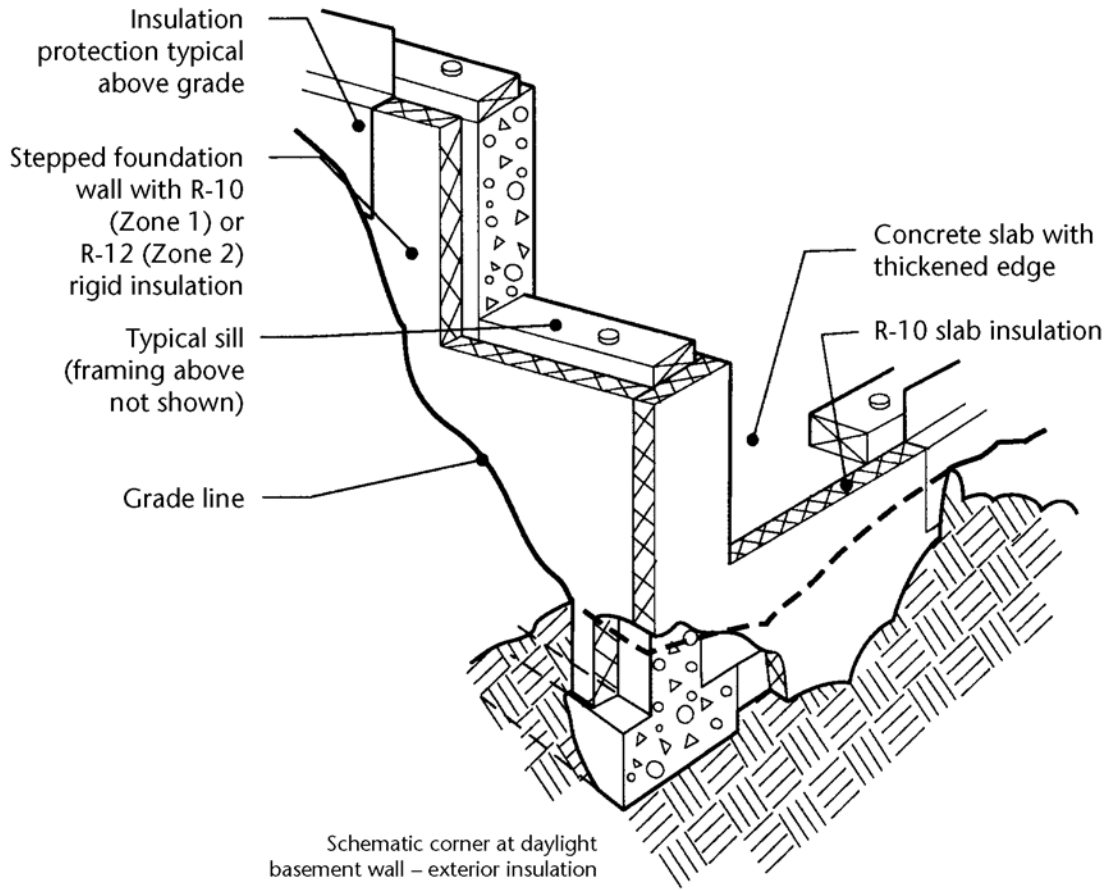


Figure 2-12

Heated Daylight Basement: Interior Insulation

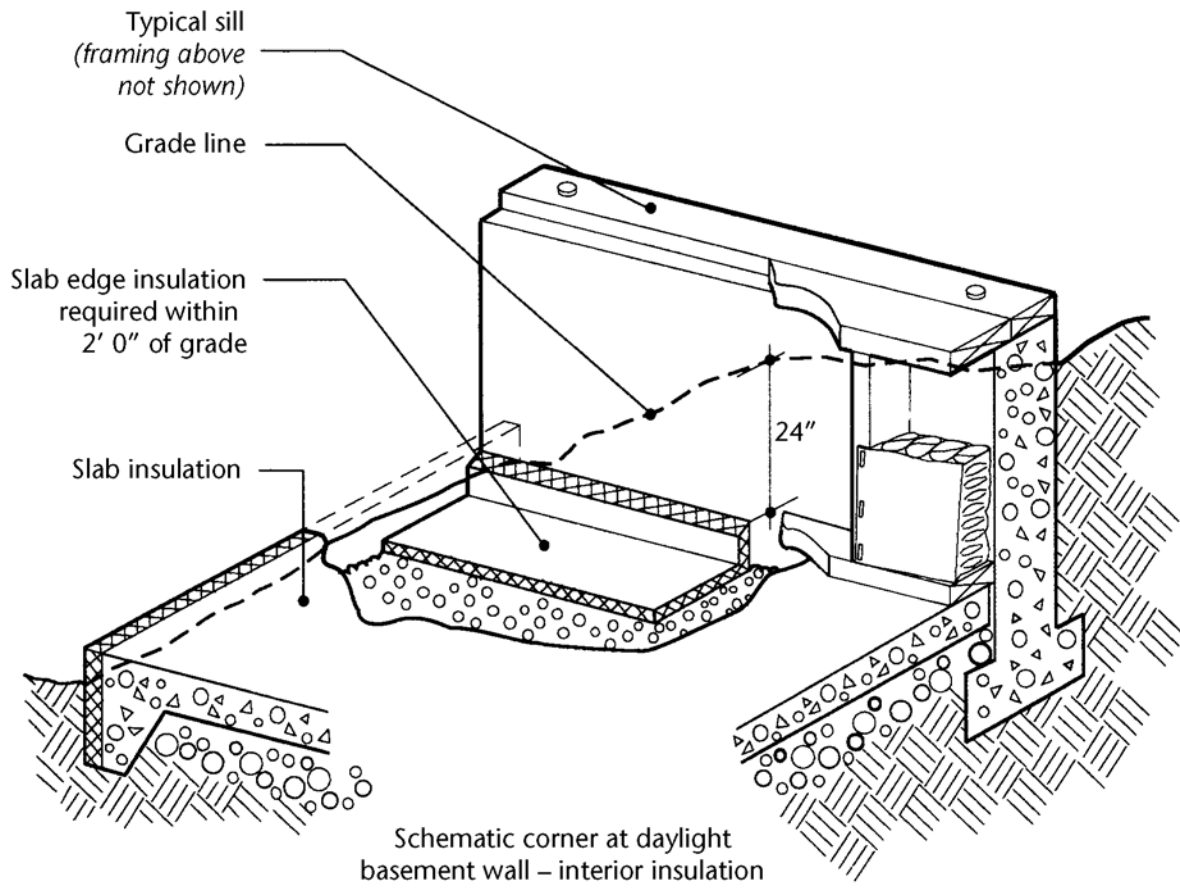


Figure 2-13

Radon

Radon is a colorless, odorless, naturally occurring, radioactive soil gas. The U.S. Environmental Protection Agency (EPA) estimates that radon causes over 20,000 lung cancer deaths each year. To reduce this risk, the IRC Appendix F and VIAQ Code require additional measures in some counties for types of construction that may increase occupant exposure.

[V503.2.6]

Radon Vent. Radon vents are required by the VIAQ Code in some crawlspaces and for all concrete slabs within living spaces in higher risk radon areas (see Crawlspaces, p. 2-1 and list of radon counties, p. 1-13).

A radon vent is a pipe that keeps unwanted gases out of the home by evacuating them to the outdoors, much as a plumbing vent removes sewer gas.

When a radon vent must be installed, the Code requires a continuous sealed pipe that runs from beneath the ground cover in the crawlspace or the soil gas retarder membrane under a slab to a point outside the building (see Figure 2-14). The radon vent must:

- Have a minimum 3-inch diameter.
- Be constructed of PVC schedule 40, ABS, or approved equivalent smooth walled pipe.
- Terminate no less than 12 inches above the eaves.
- Terminate more than 10 feet horizontally from chimneys or operable windows.
- Be sloped to drain.
- Be visibly labeled “Radon Vent.”
- Be located within the thermal envelope to the extent practicable (see Figures 2-16 and 2-17 for additional details).

The radon vent may be eliminated if an approved alternative active depressurization system is installed.

Radon Fan. Vent installation must provide a location for the possible future installation of an in-line fan. This includes:

- Isolation of the fan and any downstream piping from indoor air.
- Electrical outlet.
- Access to the location.

[V502.1.3] The Code requires installation of the fan only when the crawlspace is used as a supply air plenum.

[V503] **High Risk Area Prescriptive Requirements.** The provisions of this section *apply only to the designated higher risk counties*: Clark, Ferry, Okanogan, Pend Oreille, Skamania, Spokane, and Stevens (see Figure 1-5, p. 1-13).

Concrete Slabs. Concrete slabs in contact with the ground and within residential living space including unheated basements must be:

- Placed over a minimum 4-inch thick layer of graded aggregate.
- Placed directly on top of a soil gas retarder membrane or placed over the gravel bed with at least 2 inches of fine sand or pea gravel installed between the concrete and membrane.
- The soil gas retarder membrane shall be overlapped by 12 inches or more at all seams and sealed at all penetrations to limit the entry of soil-gas into indoor air.
- Connected directly to a radon vent. The vent must meet the same specifications listed on p. 2-18; installation of a fan is not required.

Note: These requirements don't apply to garages.

[V503.2.2]

Aggregate. The aggregate used under the slab must meet one of the following gradation specifications:

- ASTM standard C-33 and be No. 67 size aggregate or larger as listed in Table 2 “Grading Requirements for Concrete Aggregates.”
- Washington State Department of Transportation specification 9-03.1(3) “Course Aggregate for Portland Cement Concrete.” Aggregate size shall be Grade 8 or larger.
- Screened and washed consistent with ASTM Standard C-33 with 100% of the gravel passing a 1/2-inch sieve and less than 5% passing a No. 16 sieve.

[V503.2.8]

Separate Aggregate Areas. Aggregate areas should be as continuous as possible. Where areas are separated by footings or other barriers, two options are available:

- A separate radon vent must be installed for each distinct area.
- Separate areas may be considered a single area if a minimum 3-inch diameter connection joining the areas is provided for every 30 feet of barrier (see Figure 2-14).

[V503.2.5]

Below-Grade Sealing. All penetrations in the slab and joints in the slab or other floor systems and below-grade walls must be sealed.

Concrete block walls in below-grade areas are considered unsealed surfaces. Block walls and any penetrations must be sealed to create a continuous air barrier to limit the transport of soil-gas into the indoor air.

[V102.1]

Alternative Methods. The VIAQ Code allows alternative methods of construction. The alternative must:

- Meet the intent of the Code.
- Be at least equivalent to the prescribed practice in suitability, effectiveness, safety, and indoor air quality.
- Be approved by the Building Official.

This provision has been used by a number of jurisdictions to approve alternative methods for radon control. Check with your local jurisdiction.

Radon Requirements

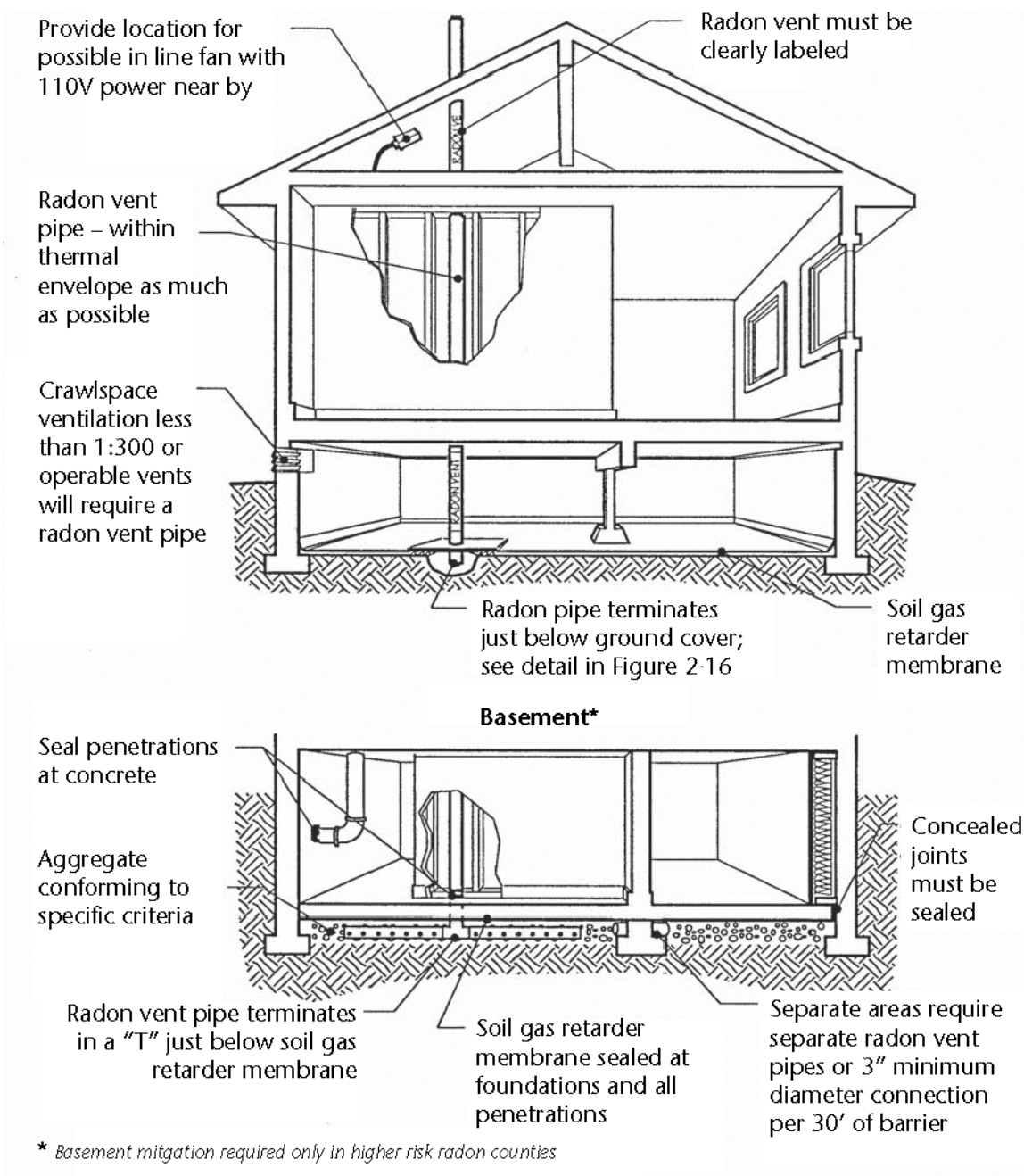


Figure 2-14

Note: See IRC Appendix F and VIAQ 503.2.4 for requirements in radon counties.

Crawlspace Used as a Supply Air Plenum Activated System

[V502.1.4]

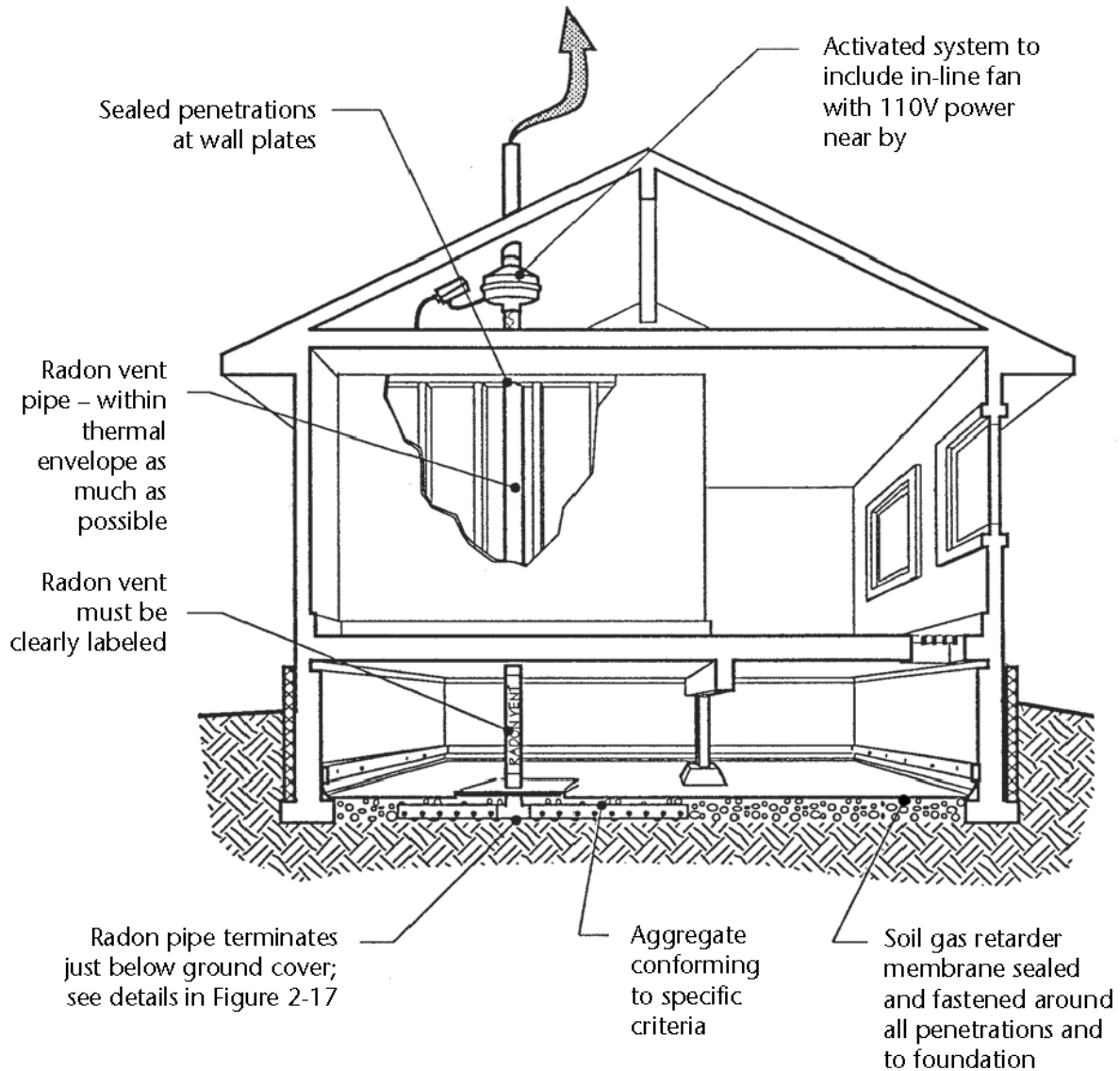


Figure 2-15

Suggested Radon Details

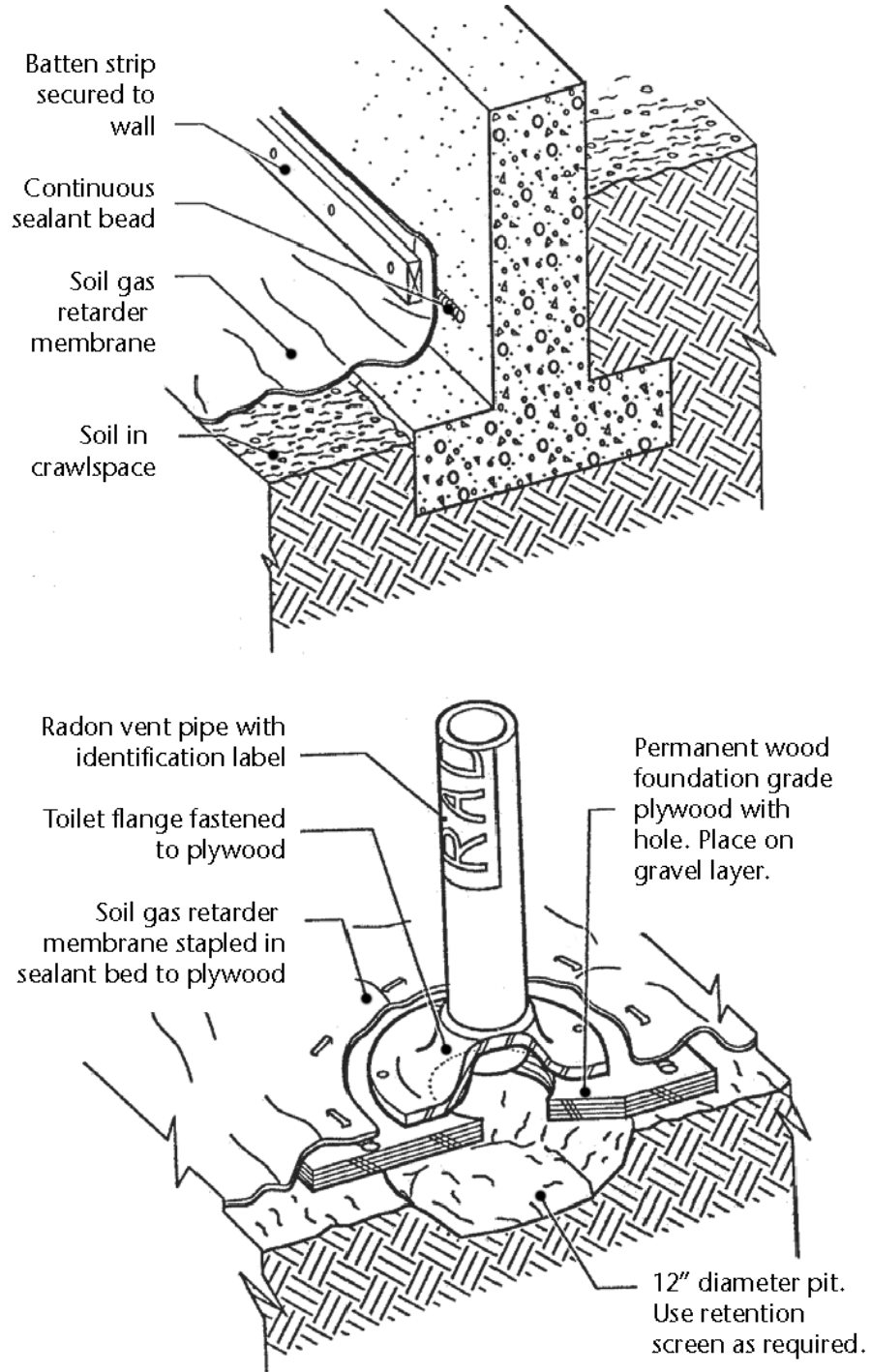


Figure 2-16

Required Sub-Slab Detail High Risk Radon Counties

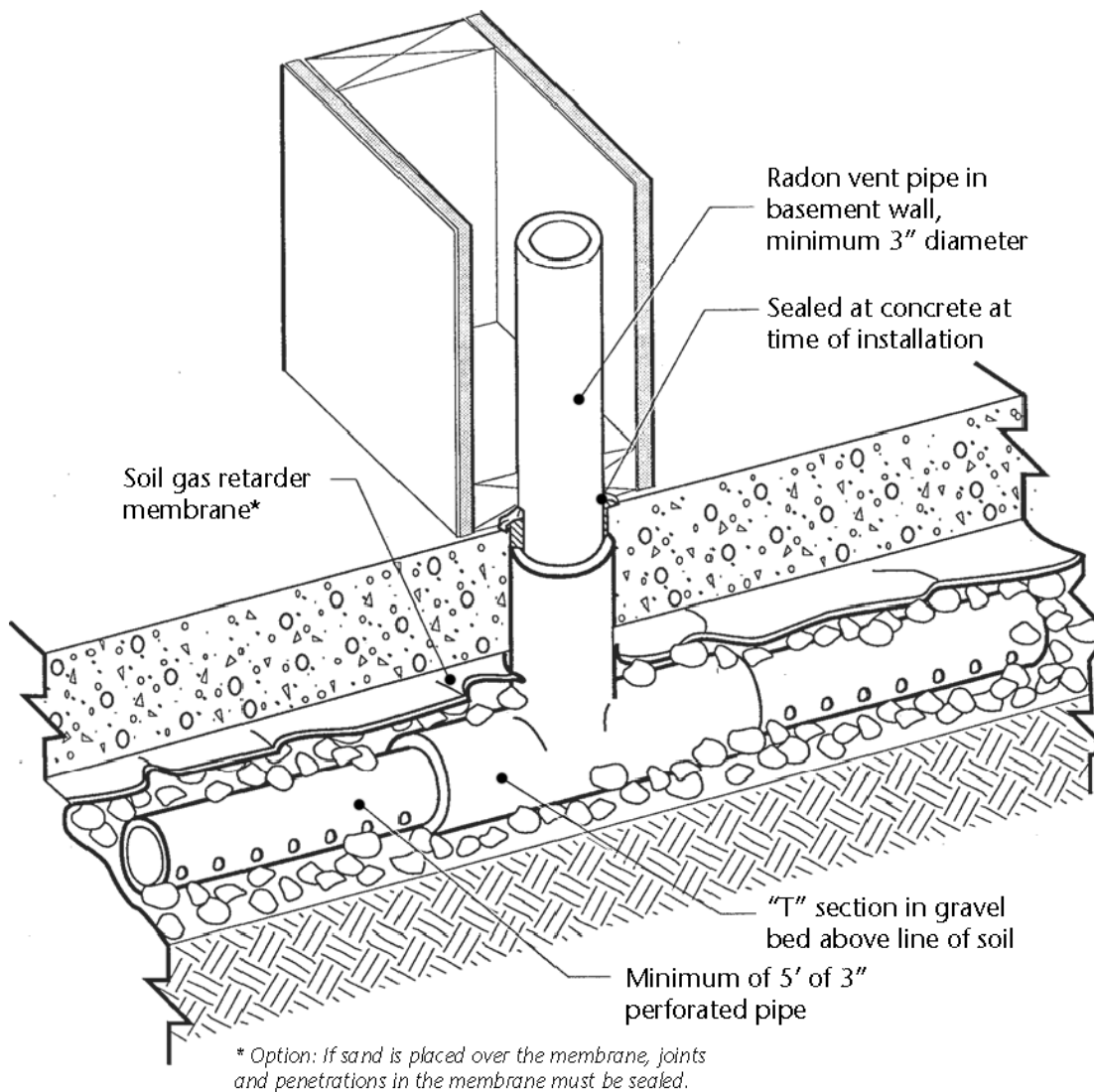


Figure 2-17

Note: See IRC Appendix F and VIAQ 503.2.4 for requirements in radon counties.

Chapter 3: Framing

Special Materials May Be Needed

[V401.1]

Structural Panels With Low Formaldehyde Ratings.

Sheathing or panels (plywood, waferboard, strandboard, etc.) within the conditioned space of the building must be marked with one of the following grade stamps:

- Exposure 1
- Exterior Grade
- HUD-Approved

These stamps indicate the material will release relatively small amounts of formaldehyde.

Eliminating formaldehyde-bearing products from the home is an example of “source control” – keeping indoor air pollutant sources out of the home.

Intermediate Framing Materials. In Zone 2, several prescriptive options require intermediate wall framing. Credit for the added thermal efficiency gained by advanced framing is also allowed if a project follows the component performance or systems analysis approach. To meet the requirements of intermediate wall framing, installation of foam insulation for headers is required (see Figure 3-14).

Advanced Framing Materials. If you’re planning to do advanced wall framing, be sure to order sheathing, siding, and wallboard rated for a 24-inch on-center framing.

The Washington State Energy Code (WSEC) does not require advanced framing for walls, but will credit the added thermal efficiency gained by advanced framing if your project follows a component performance or systems analysis approach (see pages 1-7 and 1-11).

Special Trusses. The WSEC requires “advanced” roof/ceiling framing for some prescriptive paths, and will credit the added thermal efficiency gained by advanced framing if your project follows the component performance or systems analysis approach.

Windows. Before you order or install windows, make sure the windows meet Code requirements (see Chapter 1).

Heat loss through windows, per square foot, is very high compared to most other building envelope components. Decisions about window type, glazing area, and orientation can be the most important energy performance choices you make for the home.

U-Factors are a measure of window energy performance. The lower the U-factor, the lower the rate of heat transfer, and the better the energy performance of the window. The total window area and the area weighted U-factor (see page 1-4) for all windows must meet the compliance path chosen. Always check with your building jurisdiction before adding additional windows or changing window type. Unapproved changes may result in unnecessary construction delays while compliance is reverified.

All windows and skylights should be tested to establish U-factors. Only National Fenestration Rating Council (NFRC) Standard 100-2004 test results from a certified laboratory will be acceptable. NFRC Residential Model Size must be used. If a test result is not available, you must use the appropriate default U-factor listed in the Code for Compliance (see WSEC Table 10-6A and Table 10-6B).

Solar heat gain coefficient (SHGC) will also be needed if a Systems Analysis Approach is being utilized.

For more information on NFRC labeling, visit the Efficient Windows Collaborative web site.
www.efficientwindows.org/nfrc.html

<p>Note: The Code considers sliding glass doors as windows.</p>

Some windows may require special jamb extensions because of added wall thickness needed to accommodate required insulation levels.

Some homes may use ventilation slots built into the window frame to meet air inlet requirements of the VIAQ Code. Check the type of ventilation system being used in

the house before ordering windows (see Chapter 8).

Exterior Doors. The following doors must meet the chosen compliance path required U-factor for exterior doors:

[502.1.5.2,
Exception 3]

- Entry doors.
- Garage passage doors.
- Interior doors to unheated basements.
- Doors joining any heated space with an unheated space.
- One swinging door of not more than 24 square feet may be exempted from the door U-factor requirement.

If a tested value for the door assembly you plan to use is not available, then use the default values in WSEC Table 10-6C.

Note: The area of glazing that is part of any swinging door is included in the total glazing area of the house as determined for prescriptive compliance. The U-factor of this door glazing, however, is counted as part of the doors overall U-factor (see WSEC Table 10-6D).

Skylights. Skylights are included in the total glazing percentage for the home. Skylights must meet U-factor requirements specific to overhead glazing. Default U-factors for overhead glazing are listed in WSEC Table 10-6E.

Walls

Intermediate and Advanced Framing. In Climate Zone 2, several prescriptive options require intermediate wall framing. Credit for the added thermal efficiency gained by intermediate framing is also allowed if a project follows the component performance or systems analysis approach. The requirements of intermediate wall framing include:

- Two stud corners instead of three (see Figure 3-12);
- Partition wall intersections with exterior are framed to accommodate insulation of the exterior wall (see Figure 3-13);

- All headers must be insulated to R-5 or better (see figure 3-14).

The reduced wood surface area and increased insulation area in advanced framing will improve thermal performance. If component performance or systems analysis compliance paths are used, this improved performance will help qualify the house.

Advanced framing is different from standard framing (see Figure 3-1). It is defined within the Code as:

- Studs on 24-inch centers.
- Headers insulated with R-10 material (wherever structurally possible).
- Headers supported without cripples.
- Fully insulated corners.
- Interior/exterior wall intersection fully insulated.
- Double top plate is allowed.

[502.1.4.6]

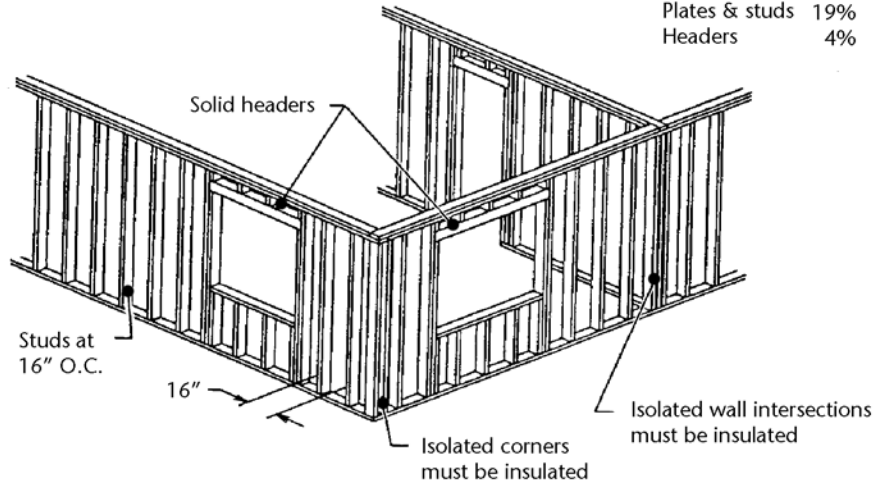
In either case, all wall cavities must be filled with insulation, including cavities isolated during framing.

Standard, Intermediate, and Advanced Framing

Standard Framing

Framing placed at 16" on center

Standard Framing	
Cavity	77%
Plates & studs	19%
Headers	4%



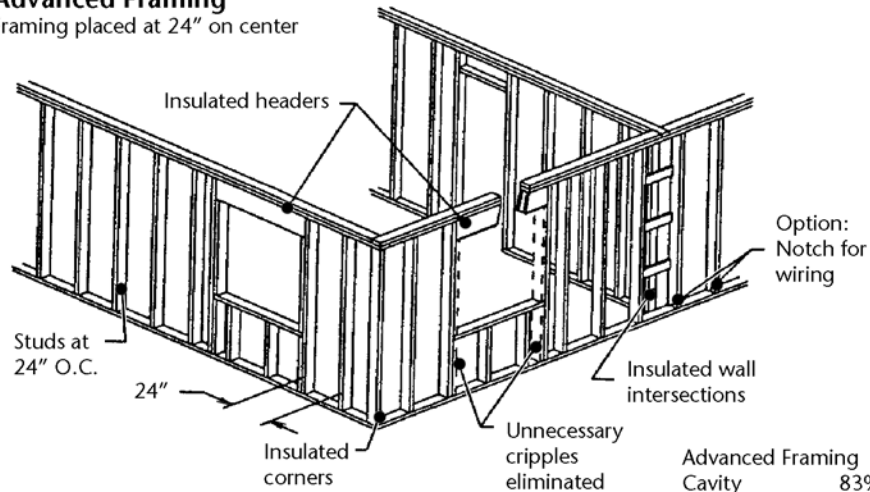
Intermediate Framing

Framing placed at 16" on center
Insulated headers, corners and intersections

Intermediate Framing	
Cavity	78%
Plates & Studs	18%
Headers	4%

Advanced Framing

Framing placed at 24" on center



Advanced Framing	
Cavity	83%
Plates & Studs	13%
Headers	4%

Note: Approximately 25% less wood in advanced frame walls.

Figure 3-1

Energy-Efficient Floor Framing

Framed floors over unconditioned space must be able to accommodate the levels of insulation required (see Chapter 4 for insulation details).

[502.4.3] **Sealing Air Leaks.** The WSEC requires that all openings, joints, and penetrations in the thermal envelope of the building must be sealed, caulked, gasketed, or weather-stripped to limit air leakage.

The first floor rim joist area over a basement and the rim joist area between floors may require special attention during framing (see Figures 3-2, 3-3 and Chapter 5, Air Leakage and Moisture Control).

[502.1.6.2] **Vapor Retarders.** Floors over unconditioned space must include a vapor retarder. Manufactured flooring materials (plywood, etc.) with exterior grade glues meet this requirement. Flooring systems such as 2x6 decking that don't include plywood or similar materials must use kraft paper, poly sheathing, or some other rated material as a vapor retarder (see Figure 3-4).

Basement Rim Air Barrier

[502.4.3]

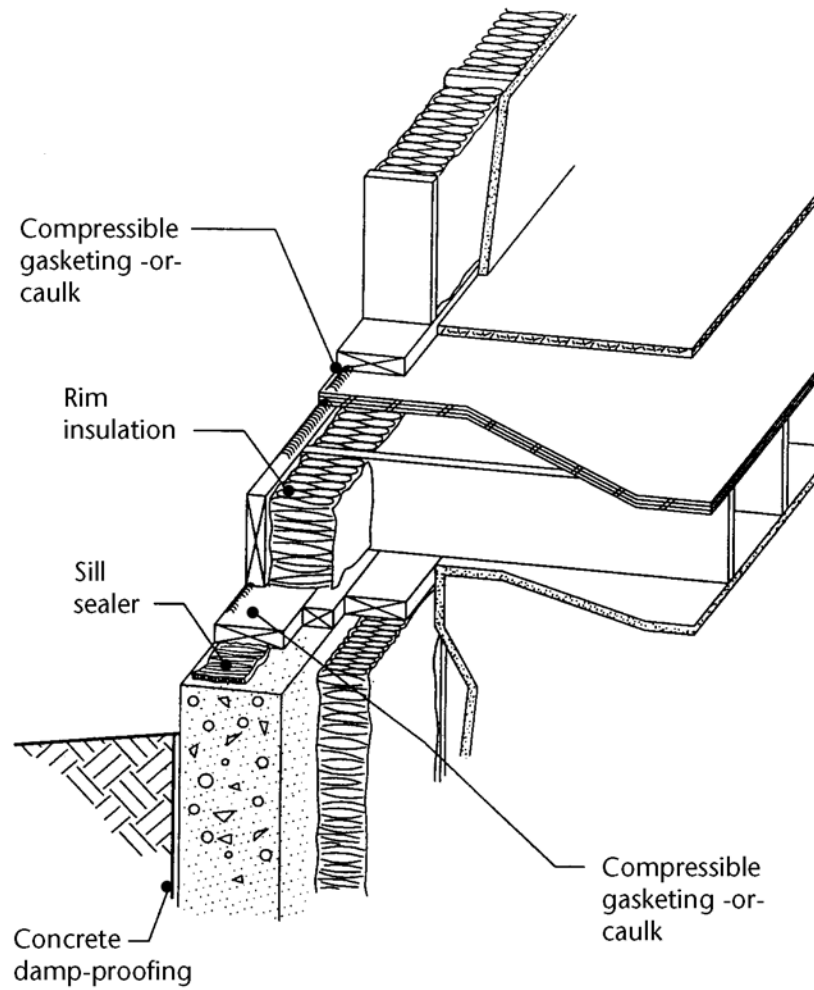


Figure 3-2

Standard Rim Air Barrier

[502.4.3]

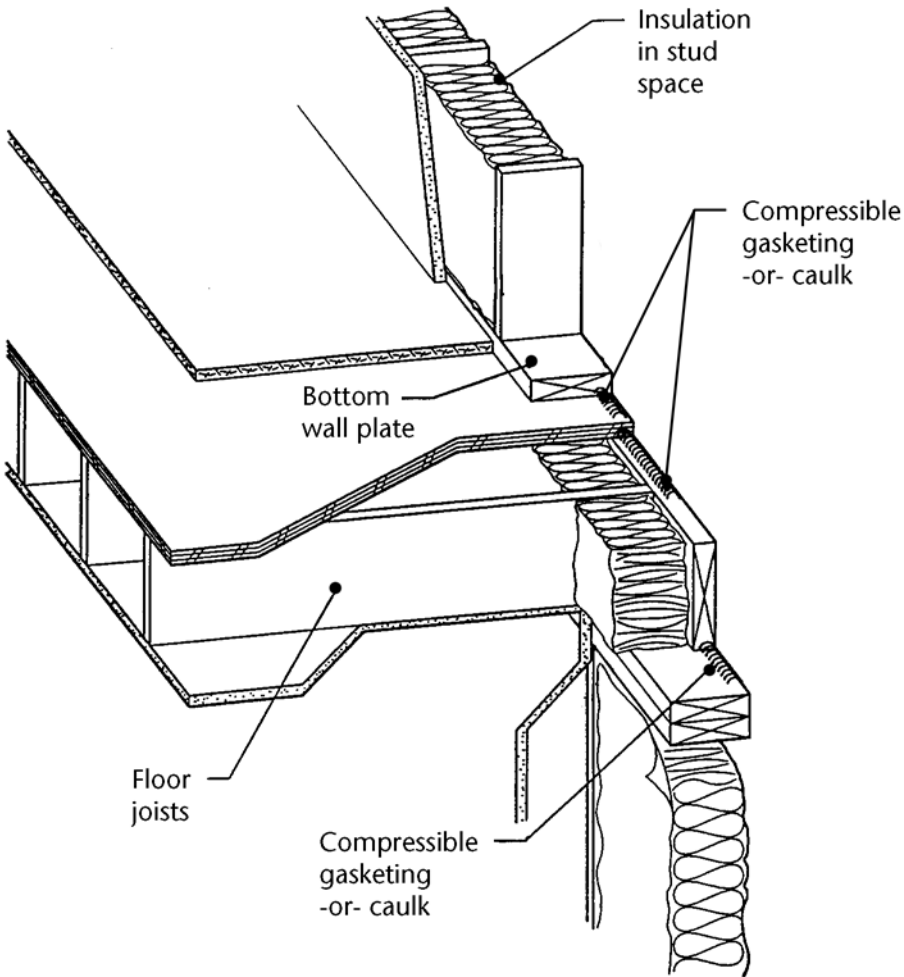


Figure 3-3

Post and Beam Air Sealing

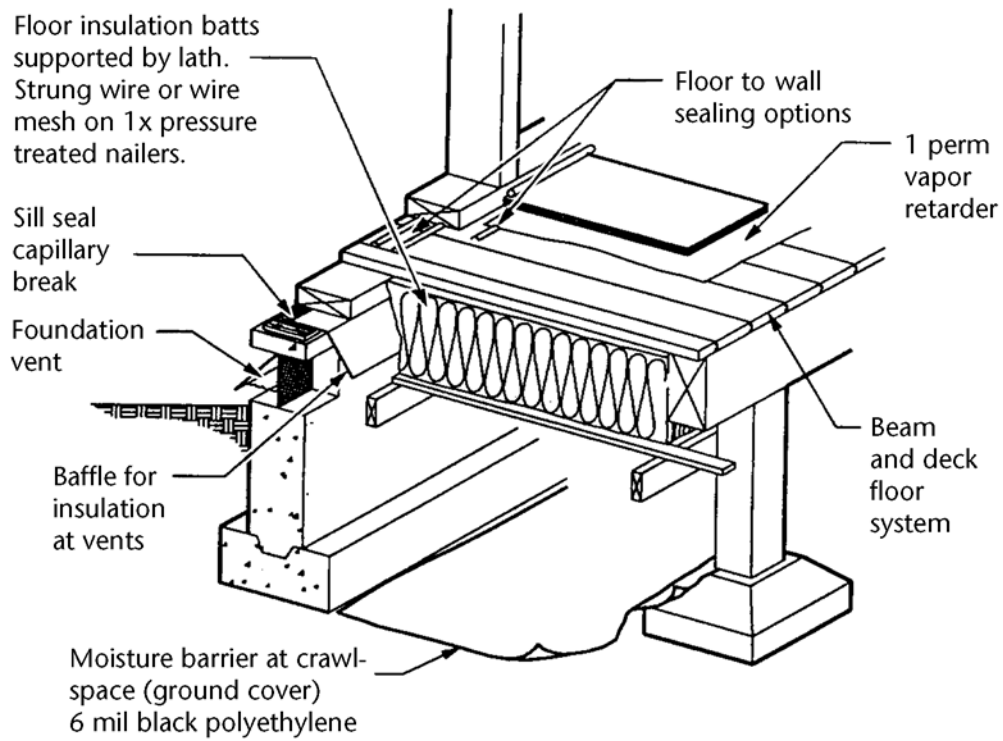


Figure 3-4

Energy-Efficient Wall Framing

You may use any wall detail that has an insulation nominal R-value equal to or exceeding your chosen compliance path (see Figure 3-5 and Chapter 1).

[502.1.4.6] **Wall Details.** The prescriptive approach identifies two alternatives as equivalent to the nominal R-21 wall (see Figure 3-6). In addition, the component performance and systems analysis approaches credit the use of higher R-value walls (see Figure 3-7). The use of double framed walls or stressed-skin panels are among other options that may work (see Figure 3-8).

Insulated Sheathing. Insulated sheathing may be used to increase the R-value of a wall. Insulated sheathing is required in Prescriptive Path V in Table 6-2. If the insulated sheathing is used in place of structural sheathing, additional wall bracing will be required. Consult the *International Residential Code* for bracing requirements in your area.

Rigid foam insulation may be applied to either the interior or exterior surface of the exterior wall (see Figures 3-9, 3-10 and 3-11). Applying foam to the exterior is the preferred option.

Additional references, prepared by the APA Engineered Wood Association, may also be useful. Check the various resources available on the APA website: www.apawood.org

Insulation. Code requires all cavities in the thermal envelope of the building be filled with insulation. Corners and wall intersection can easily be filled during the normal placement of wall insulation using certain details (see Figures 3-12 and 3-13). These details, while not required by Code, help prevent creating isolated areas during framing.

Headers. Headers must always be properly sized to meet loading conditions. Any remaining wall cavity space adjacent to the structural header must be filled with insulation. Figure 3-14 illustrates possible details for maximizing header insulation when intermediate or advanced framing is used.

Installing Through-the-Wall Air Intake Vents. Some ventilation options require these vents (see Chapter 7, Ventilation). When required, one must be placed in each bedroom and other habitable rooms of the house. Installation is easiest while the wall cavities are still open (see Figure 3-15).

Acceptable R-21 Walls

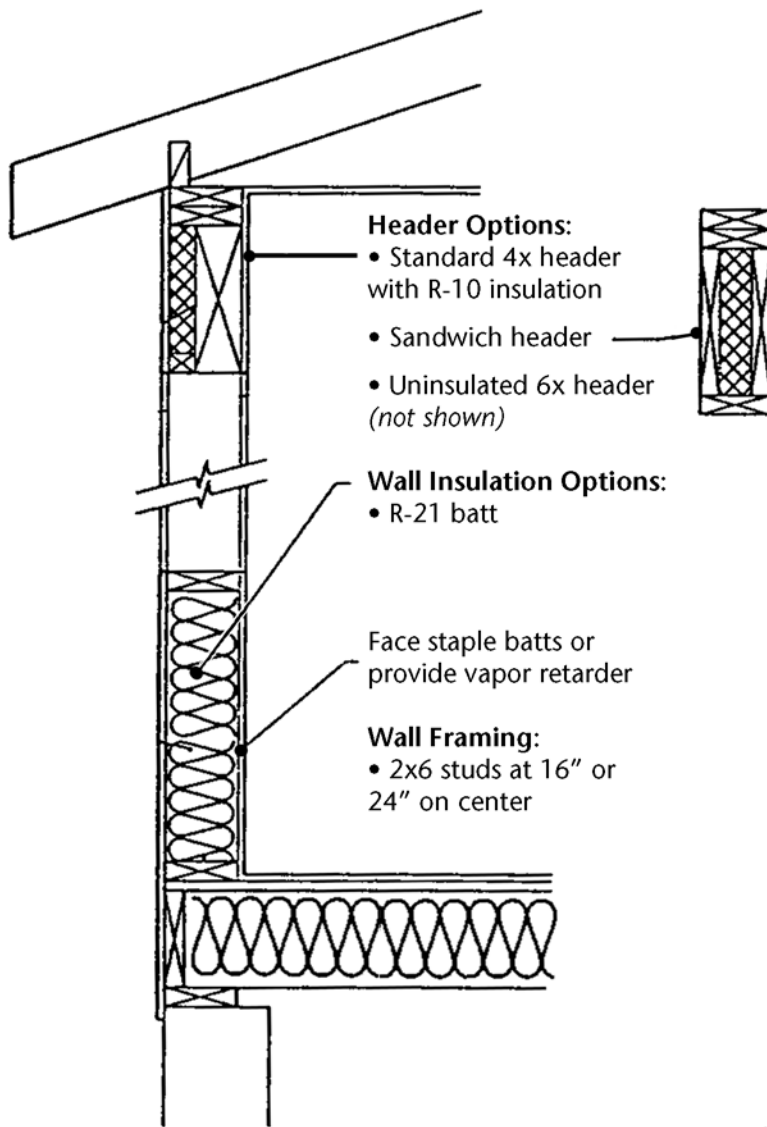


Figure 3-5

Acceptable Prescriptive Substitutes for R-21 Walls

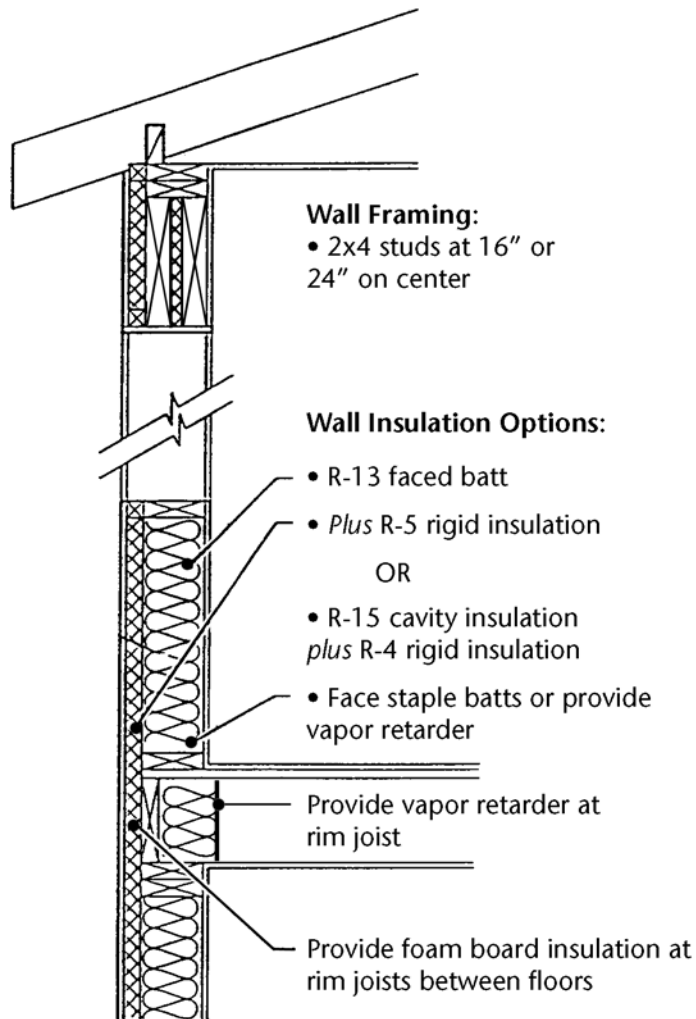


Figure 3-6

R-24 & Above Walls

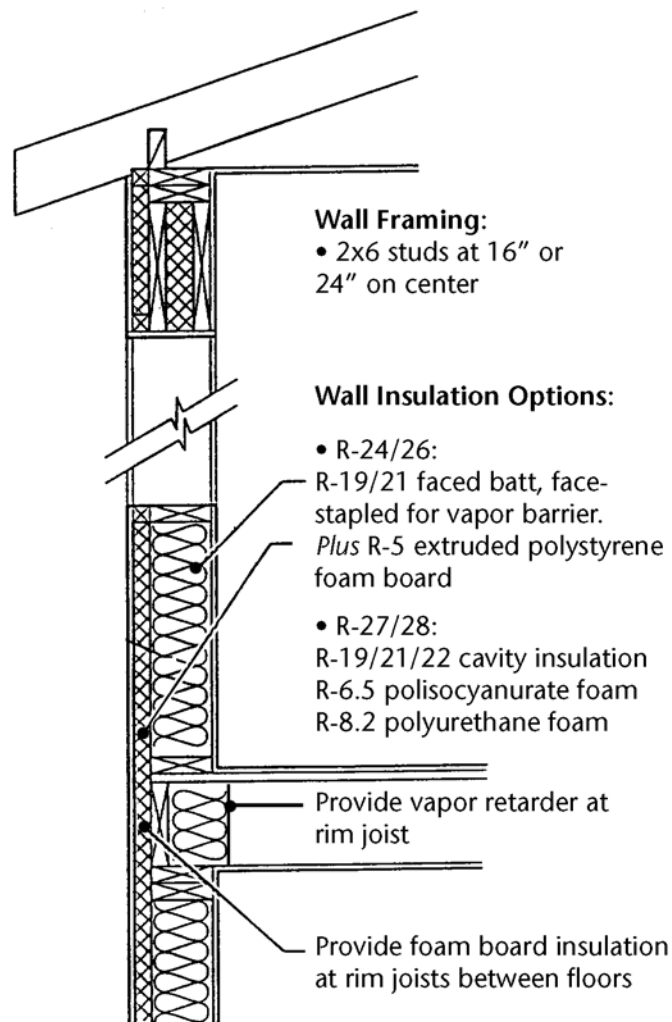


Figure 3-7

Double Wall

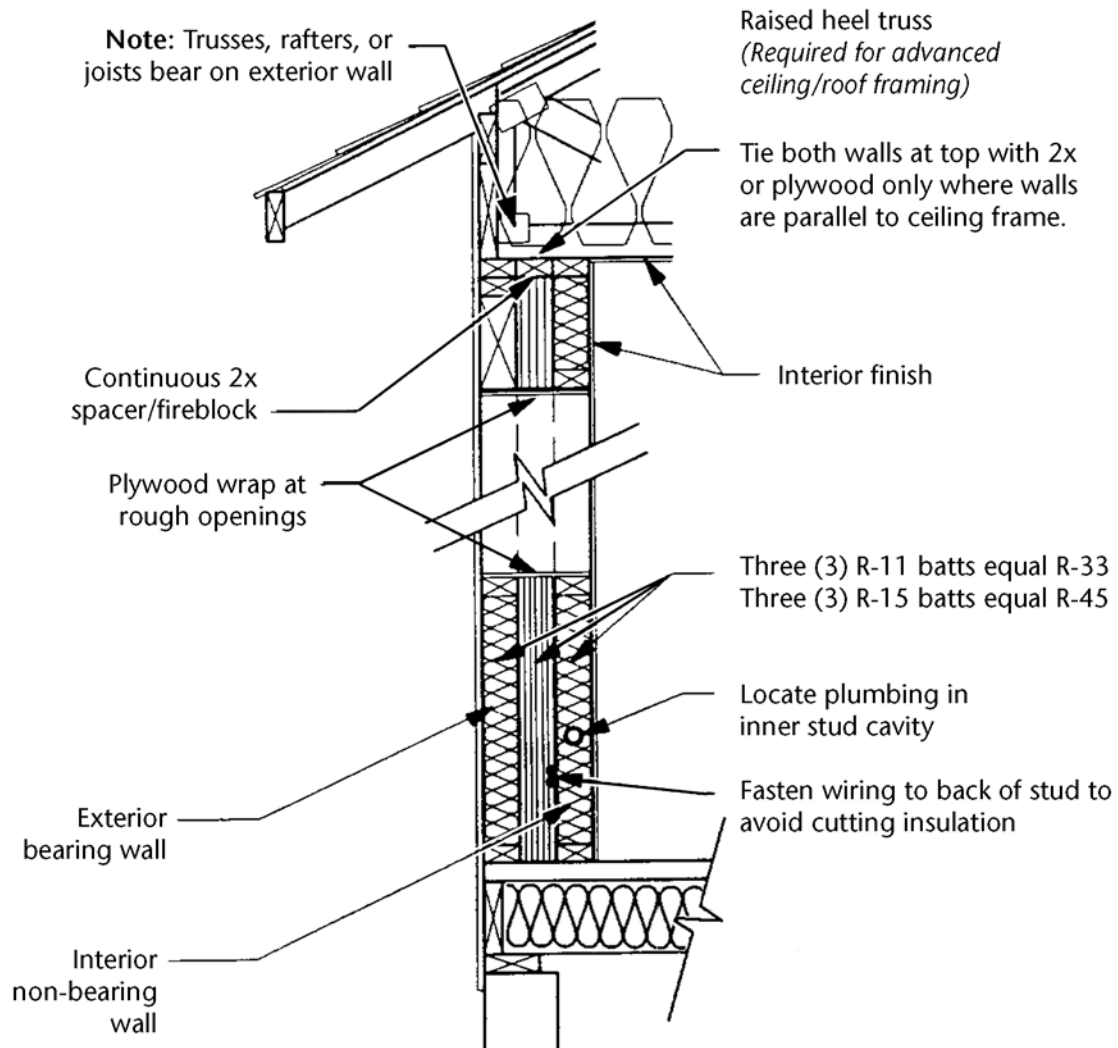


Figure 3-8

Above-Grade Wall: Interior Rigid Insulation

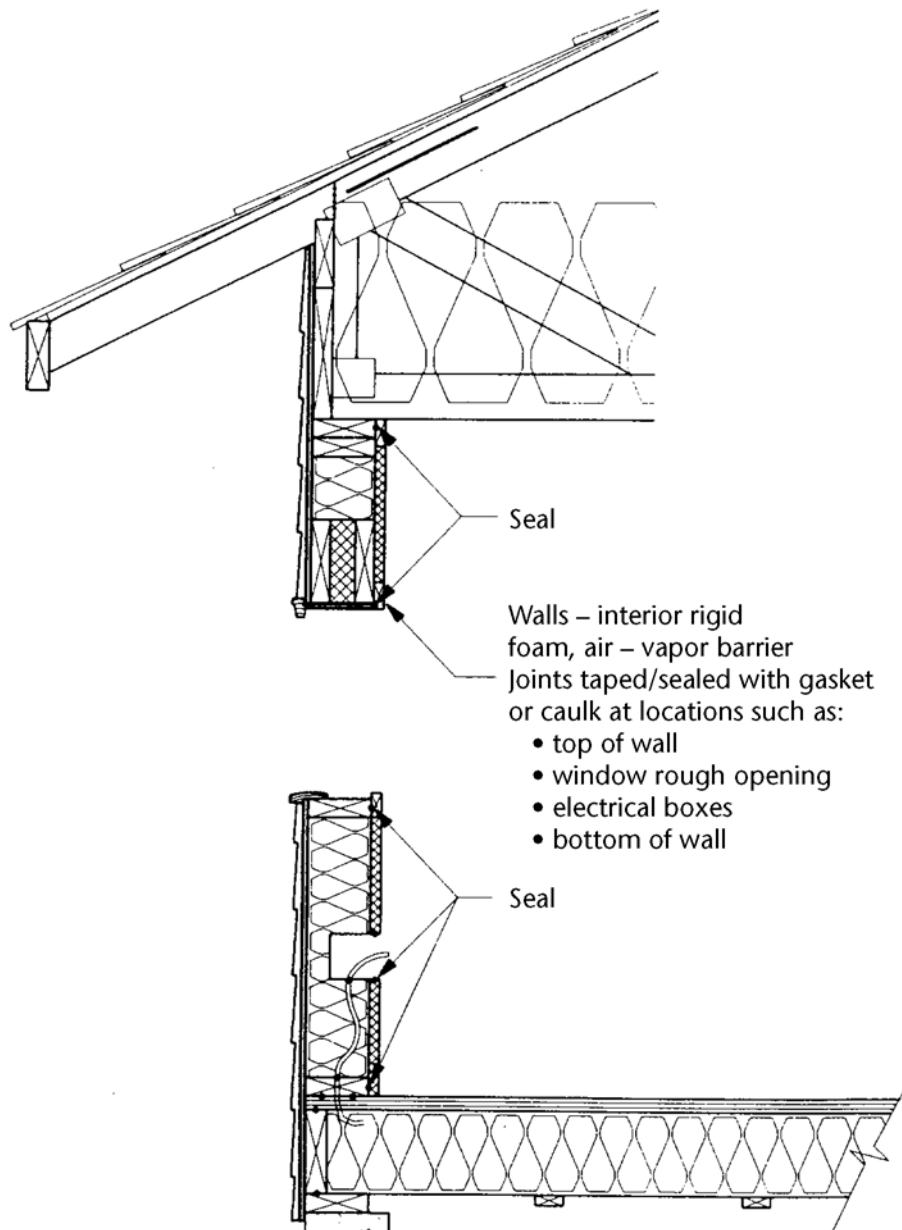


Figure 3-9

Interior Rigid Foam Framing Details

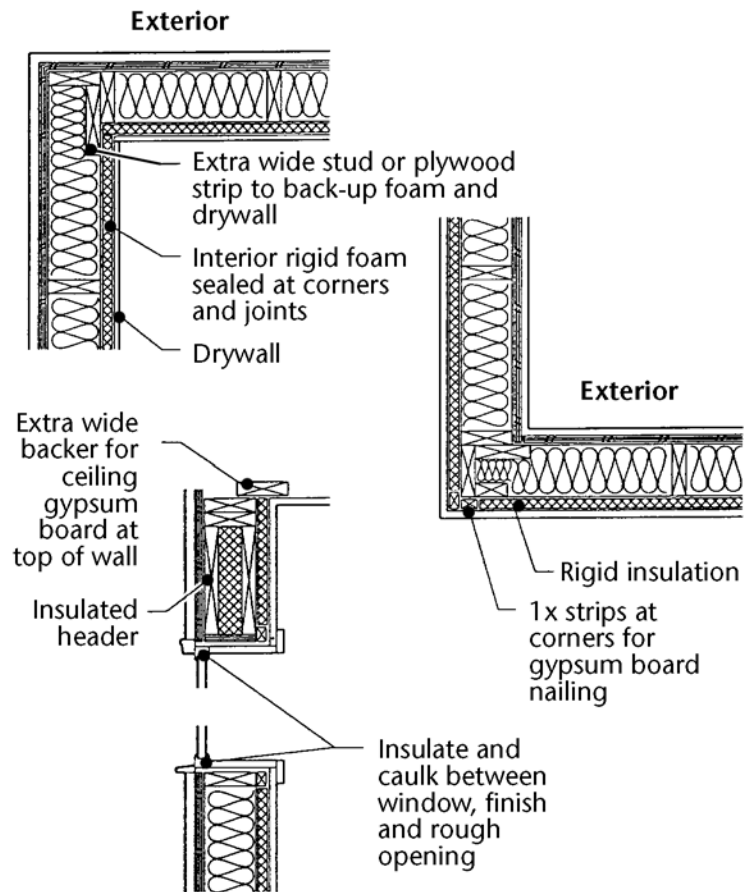


Figure 3-10

Corner Trim Detail for Exterior Rigid Insulation

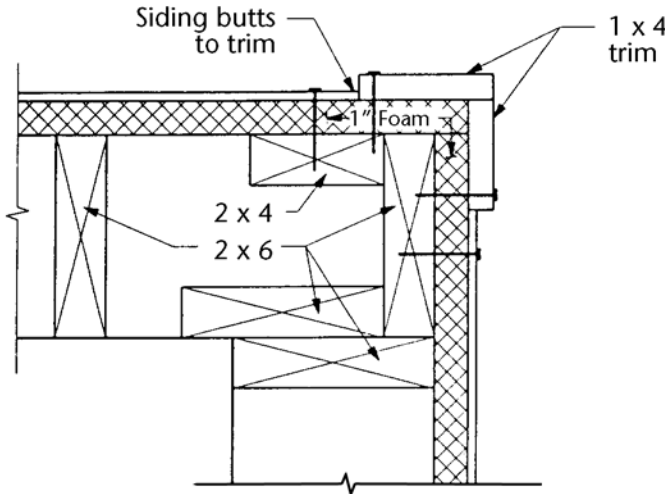


Figure 3-11a

Door Reinforcement for Exterior Rigid Insulation

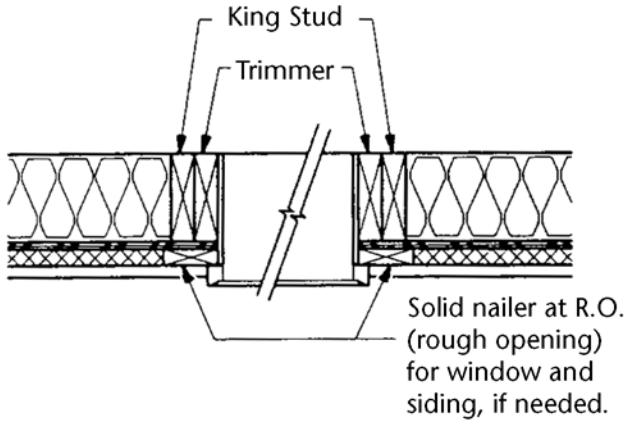
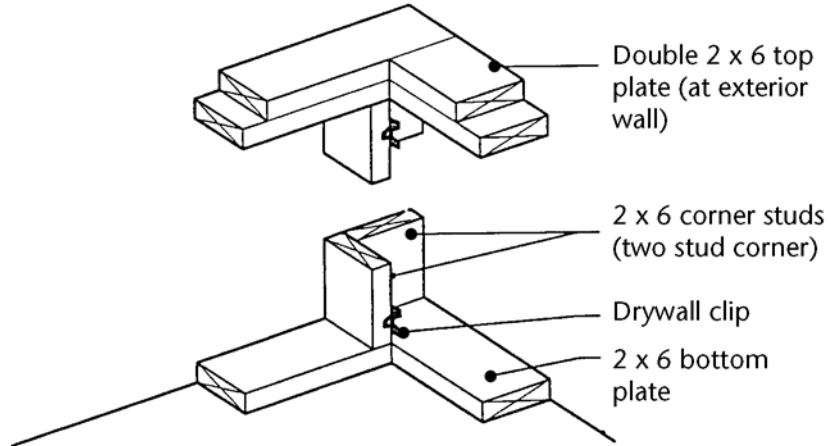


Figure 3-11b

Optional Details Allowing Easy Placement of Insulation - 1

Two Stud Corner – Preferred Option



Three Stud Corner

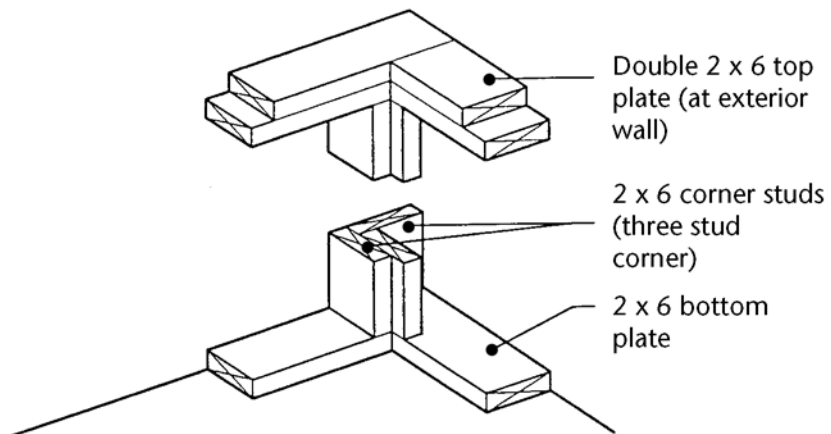
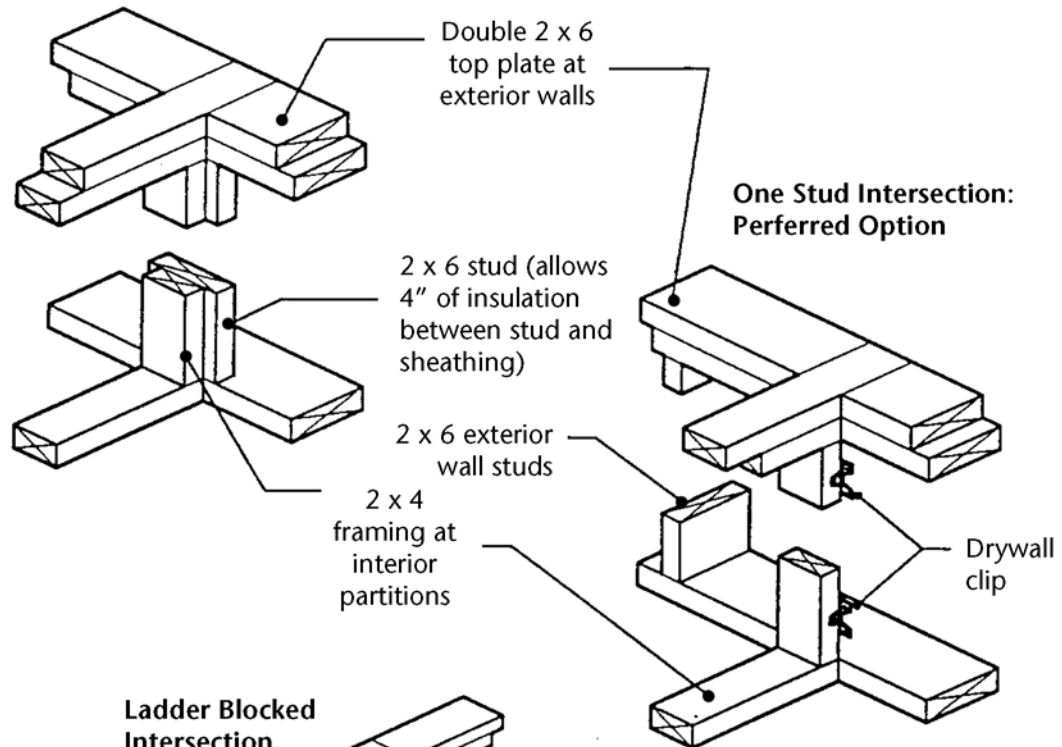


Figure 3-12

Optional Details Allowing Easy Placement of Insulation - 2

Flat Stud Intersection



Ladder Blocked Intersection

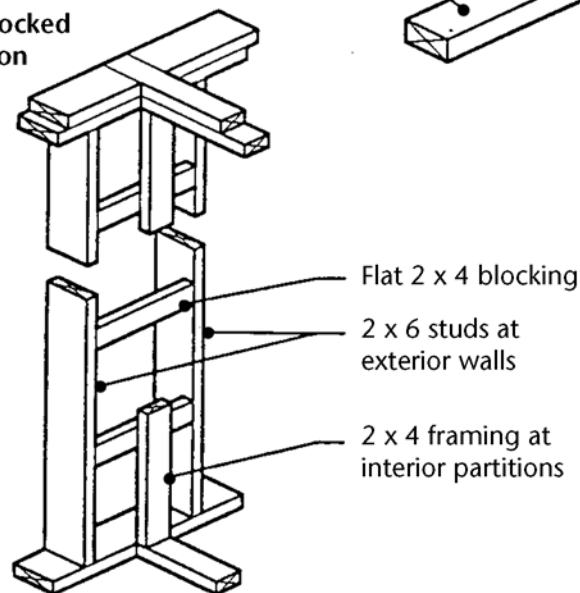
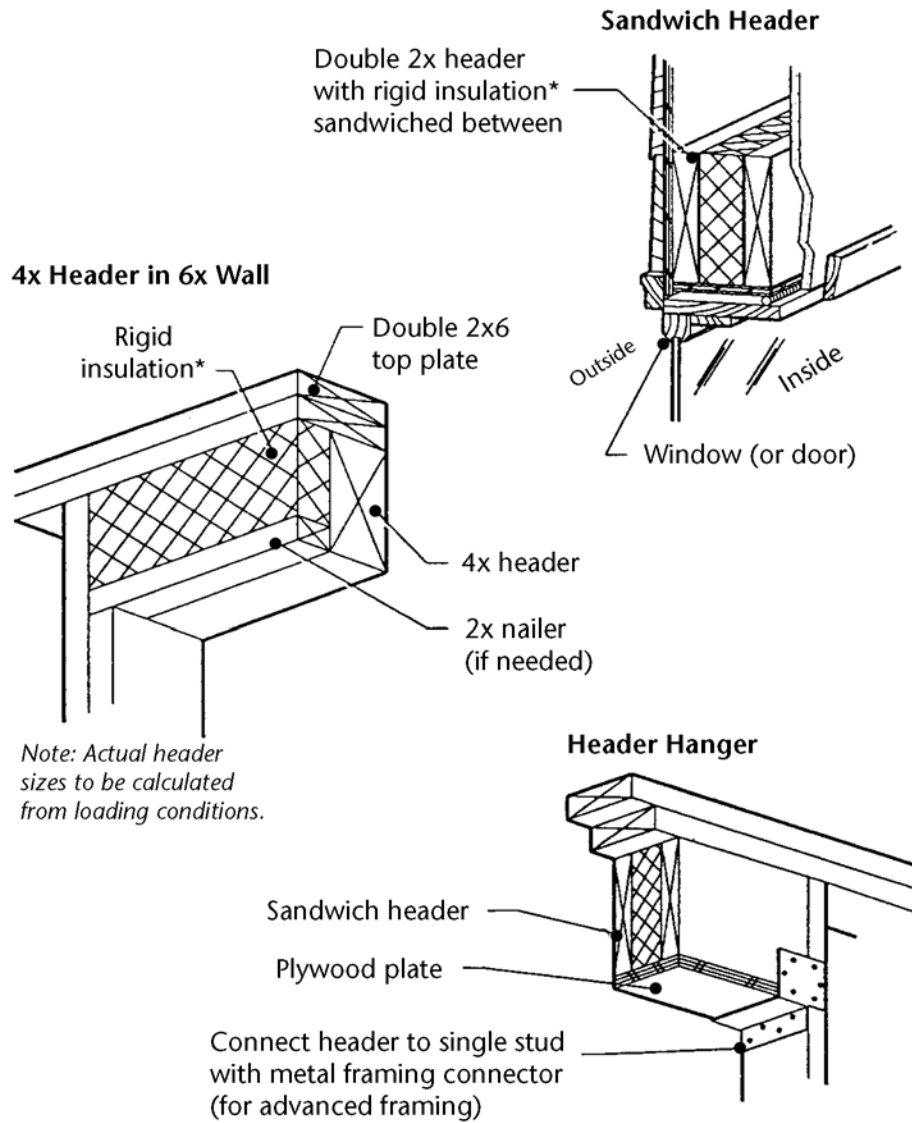


Figure 3-13

Header Details (Required for Intermediate and Advanced Framing)



* Rigid insulated headers (R-10) required for intermediate and advanced framing.

Figure 3-14

Air Intake Vent Installation Detail

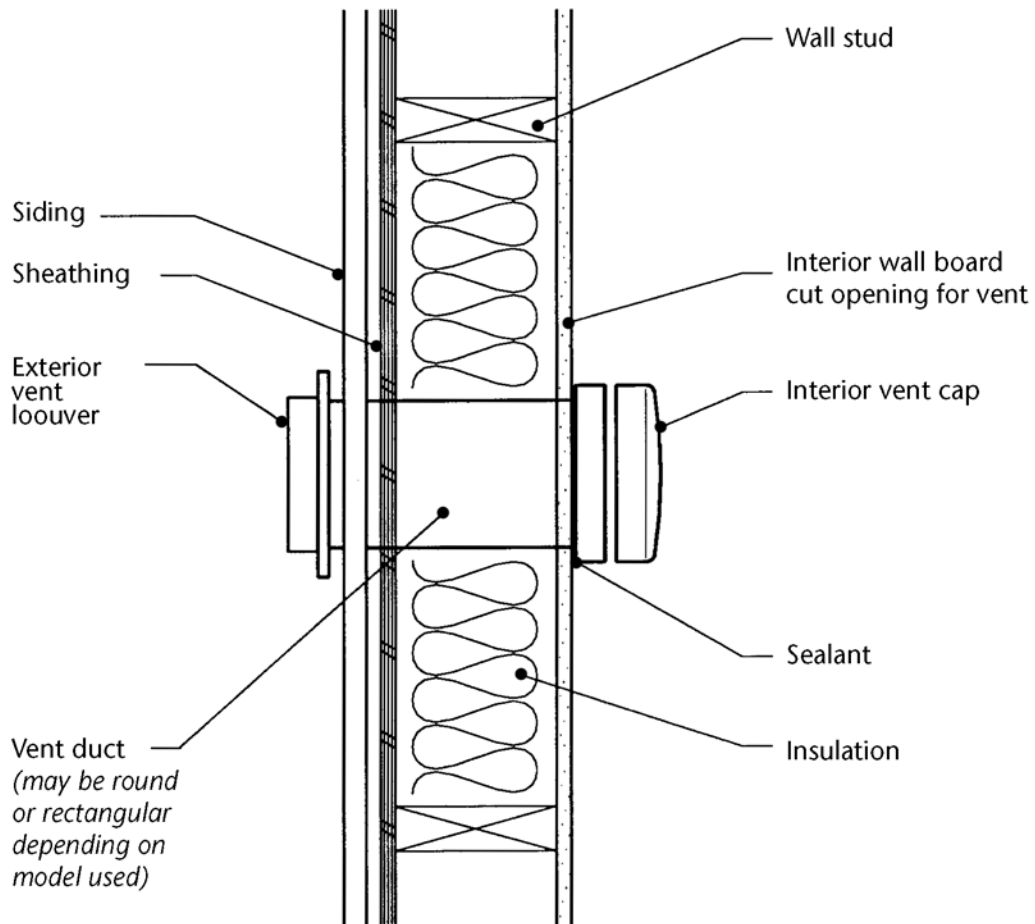


Figure 3-15

Energy-Efficient Ceiling/Roof Framing

Advanced Framing. An oversized or raised heel truss replaces the standard truss to avoid compressing insulation at the exterior wall (see Figure 3-16).

[502.1.4.3,
502.1.4.5]

Attic Venting. Venting must meet IRC requirements. When venting is placed at the eaves, special consideration must be given to baffling the insulation in order to maintain a minimum 1 inch of free area for air movement from the vent into the attic (see Figure 4-4).

Vaulted Ceilings*. Following some prescriptive paths, single rafter vaults may only require R-30 insulation. Component performance compliance may allow less than R-30 if another component makes up the difference (see Chapter 1). Various options for framing vaulted ceilings to obtain high levels of insulation are available (see Figure 3-17).

[502.1.6.3]

Vault Cavity Ventilation. Most ceilings with insulation beneath the structural sheathing, including vaults, must provide a minimum one-inch air space above the insulation (see Figure 3-18).

* A vaulted ceiling is defined as a ceiling where enclosed joist or rafter space is formed by ceilings applied directly to the underside of roof joists or rafters. A sloped ceiling of a scissor truss is not considered a vaulted ceiling.

Options to Maintain Full Heel Insulation (Advanced Frame Ceiling)

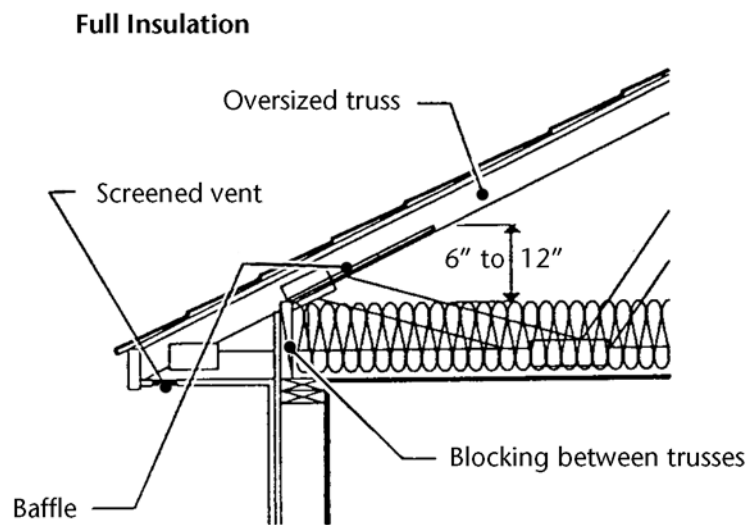
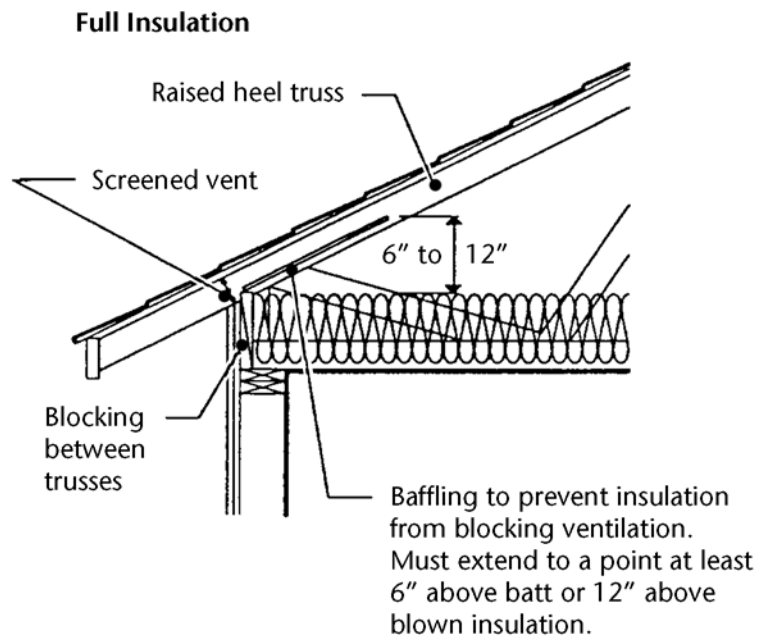
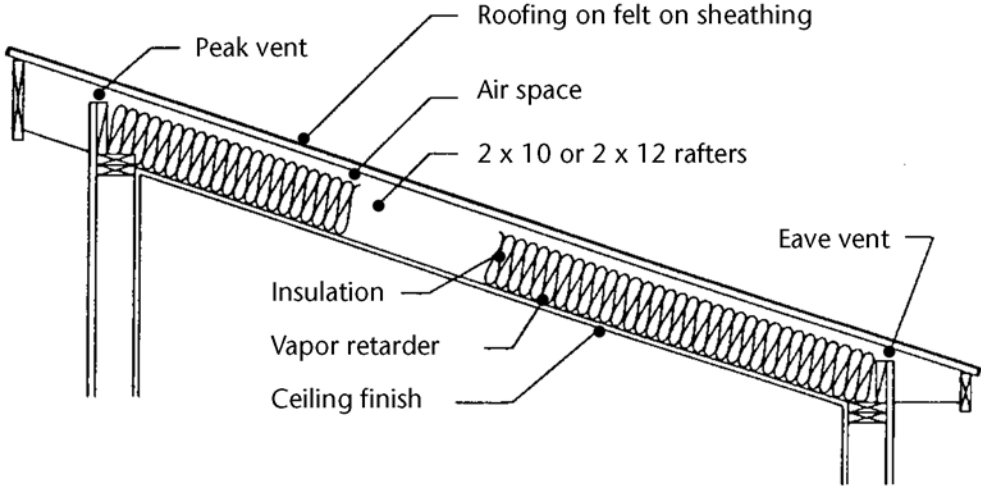


Figure 3-16

Vaulted Ceilings

Stick Frame (R-30/R-38)



Flat Truss (R-38/R-60)

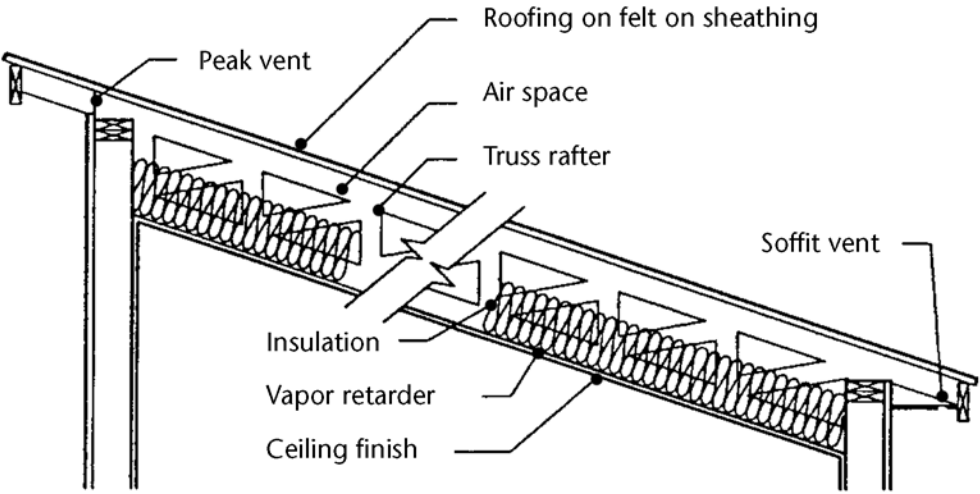
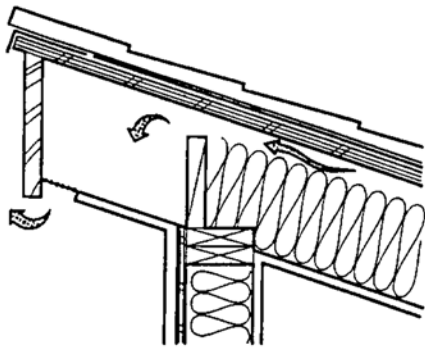
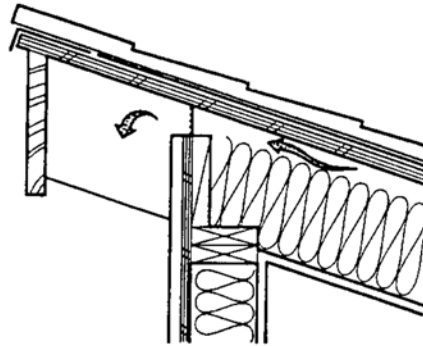


Figure 3-17

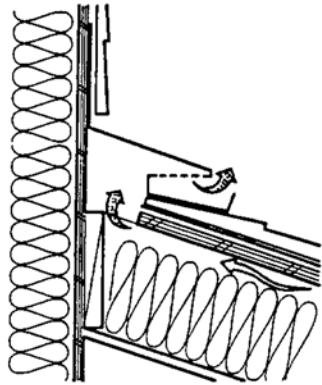
Venting Vaulted Ceilings



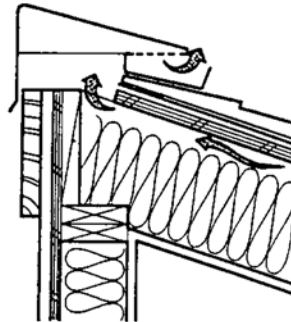
Shed Peak With Soffit



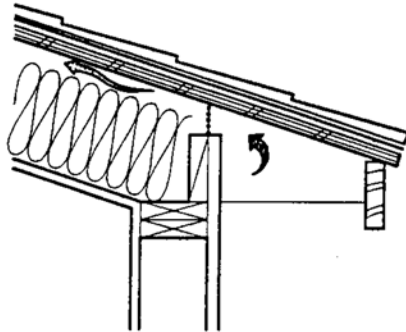
Shed Peak Without Soffit



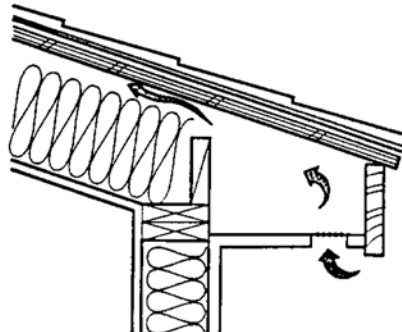
Shed Roof at Wall



Shed Peak: No Overhang



Eave Without Soffit



Eave With Soffit

Figure 3-18

Chapter 4: Insulation

Insulation levels expressed in R-values are determined by the compliance path as explained in Chapter 1, Compliance. For below-grade walls and slab-on-grade insulation details see Chapter 2, Foundations. For above-grade wall construction and insulation details, see Chapter 3, Framing. General insulation requirements, regardless of compliance path, are outlined in this chapter.

Installing the proper amount of insulation is important, but correct installation techniques are of equal importance to achieve specified R-values.

[502.1.4.6]

Completely Fill All Exterior Wall Cavities. Exterior wall cavities are considered to be any wall separating a heated from an unheated space. Areas that are sometimes overlooked are:

- Behind shower or bathtub enclosures (see Figure 4-1).
- Where interior and exterior walls meet.
- Corners.
- Stairwells to unheated basements.
- Skylight chases through attics.

Exception: Framed cavity can be empty or partially filled, provided:

- The wall assembly calculations are performed along with a completed performance calculation for the whole building; and
- Insulation installed in partially filled cavities is not included in the performance calculation.

Tub Enclosure on Exterior Wall

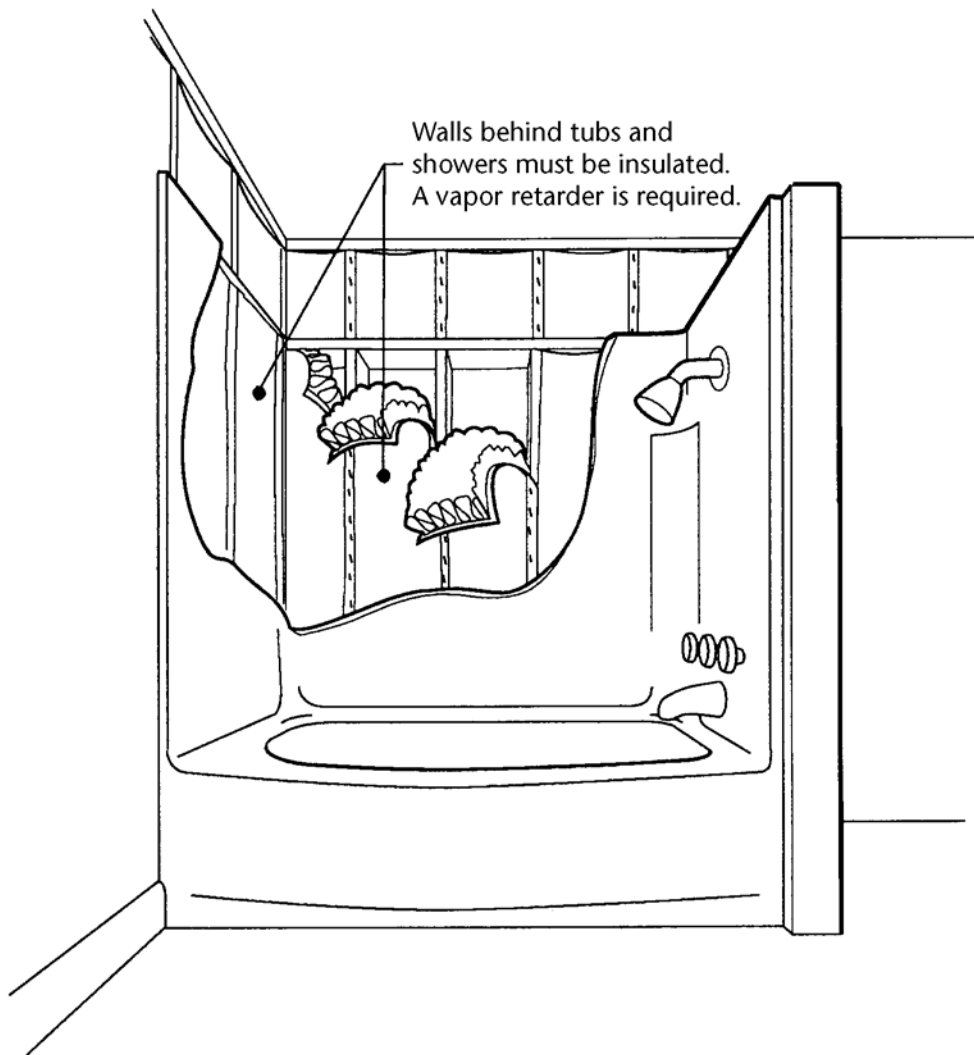


Figure 4-1

[502.1.4.1]

Don't compress the insulation. Compression of insulation will cause it to be less efficient. For example, if you compress an R-19 batt in half, you reduce the R-value by almost 50%. Common areas of compression are:

- Behind outlet and switch boxes.
- Behind plumbing pipes and wiring.

Compression problems can be avoided in these situations by cutting and fitting insulation around outlet and switch boxes (see Figure 4-2). Slicing about halfway through a batt will allow it to fit around a wire or pipe.

Electrical Box Insulation Details

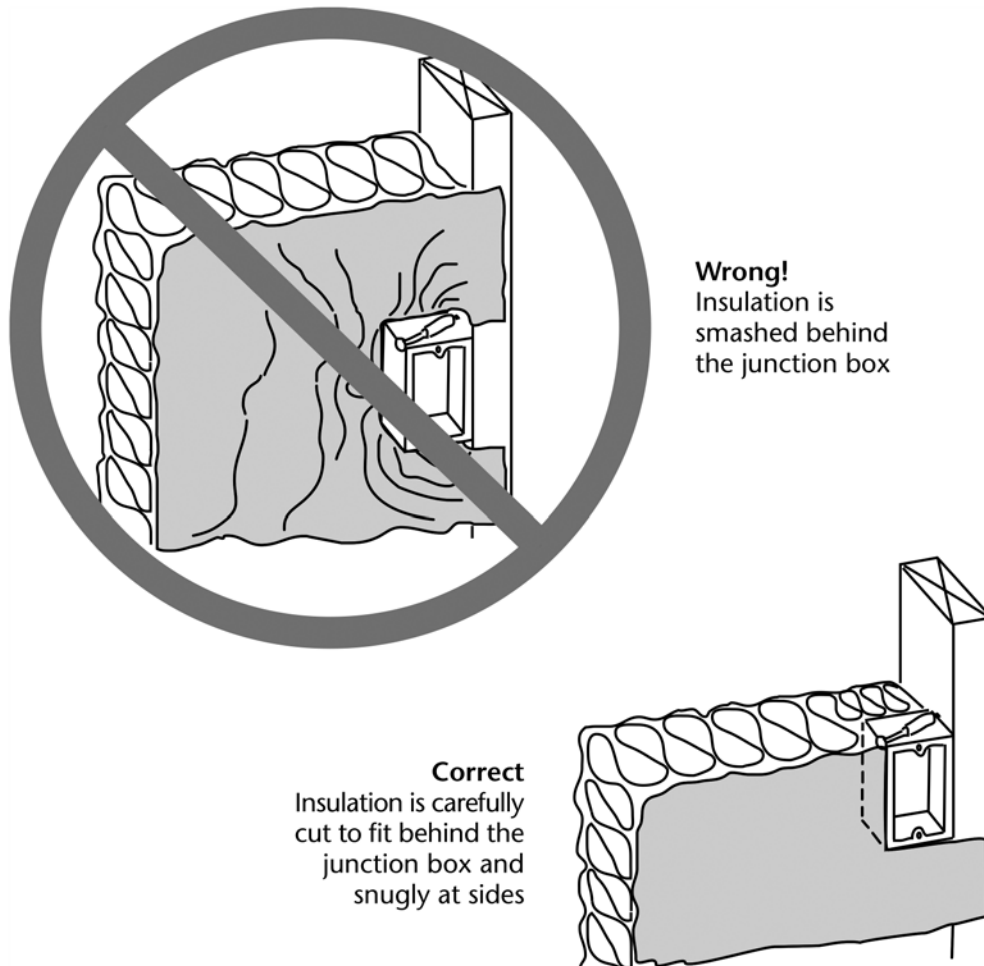


Figure 4-2

[502.1.4.6]

Inset Stapling Faced Batts is not Allowed. If faced batts are used (kraft paper or foil facing material) and if they have a stapling tab, they must be stapled directly to the face of the stud. Stapling to the side of the stud compresses the insulation and creates a convective air channel that reduces the effectiveness of the insulation (see Figure 4-3).

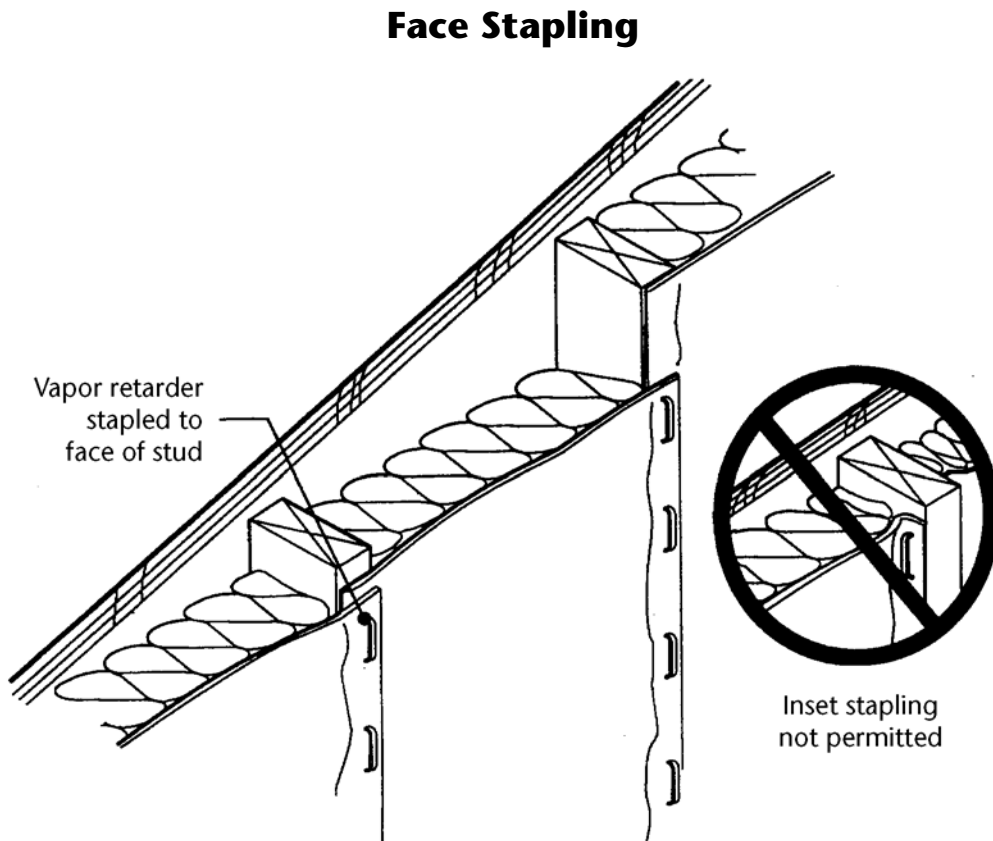


Figure 4-3

[502.1.4.5]

Attic Baffles. Baffles are necessary to maintain an airspace between the insulation and the roof sheathing when soffit or birdblock venting is used (see Figure 4-4). This promotes cross-ventilation of the attic, helping to remove unwanted moisture. It minimizes potential rot problems, and ice damming in winter.

Baffles are made of weather resistant material, typically wax-impregnated cardboard. Baffles must extend:

- 6 inches (vertically) above non-compressed batt type insulation.
- 12 inches (vertically) above full depth blown-in insulation.

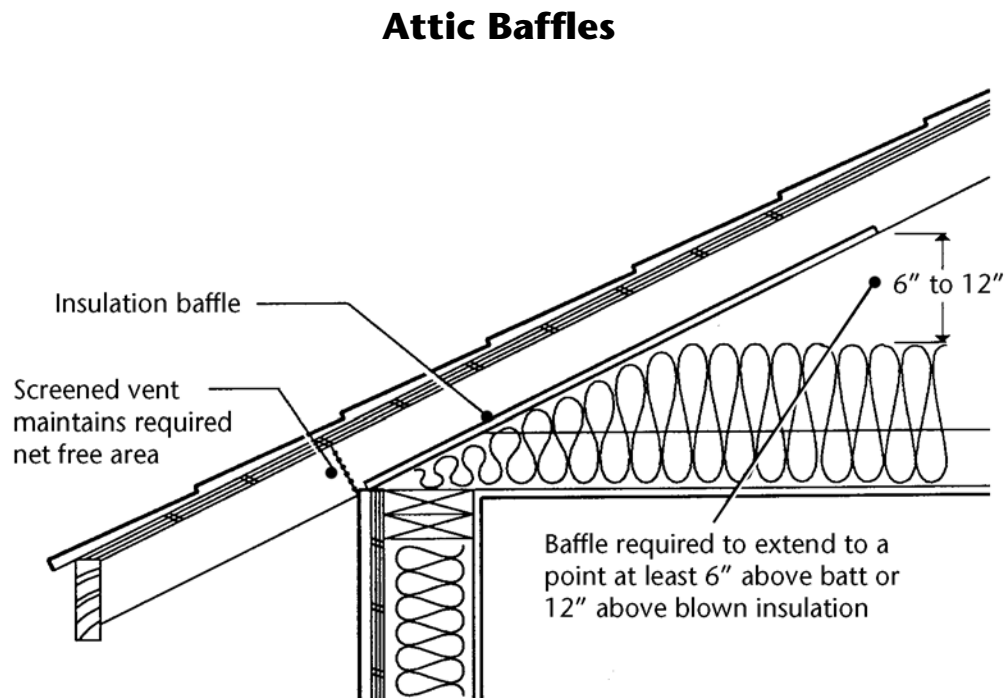


Figure 4-4

[502.1.4.4]

Attic Access. A baffle or dam around attic access hatch is also required when loose-fill or blown-in insulation is installed (see Figure 4-5). Requirements for access hatches and doors are:

- Wood frame, or equivalent, baffle installed around the opening. Cardboard is not acceptable.
- The hatch must be insulated to the same R-value as the surrounding ceiling with batt or rigid insulation.
- The hatch must be weatherstripped to stop air leakage between the attic and the interior.

Attic Hatch

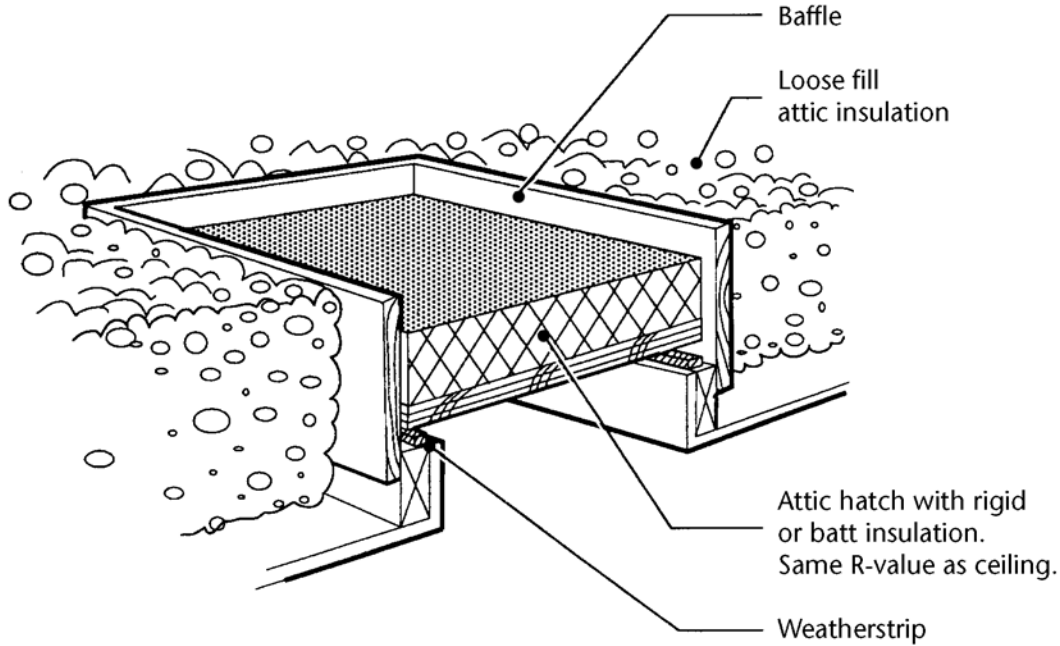


Figure 4-5

[502.1.4.1,
502.1.4.7]

Floor Insulation Supports. Floor insulation must be installed in a permanent manner and in substantial contact with the surface being insulated (see Figure 4-6 or 4-7). Insulation can be held in place using:

- Polyethylene twine.
- Lath.
- Chicken wire.
- Other approved material.

Supports are required to be a maximum of 24 inches apart. If the insulation thickness is more or less than the depth of the joist, hangers are available to hold the insulation to the floor surface without compressing it. Metal rods or other supports that compress the insulation are not acceptable.

Floor Insulation Supports Insulation Fills the Cavity

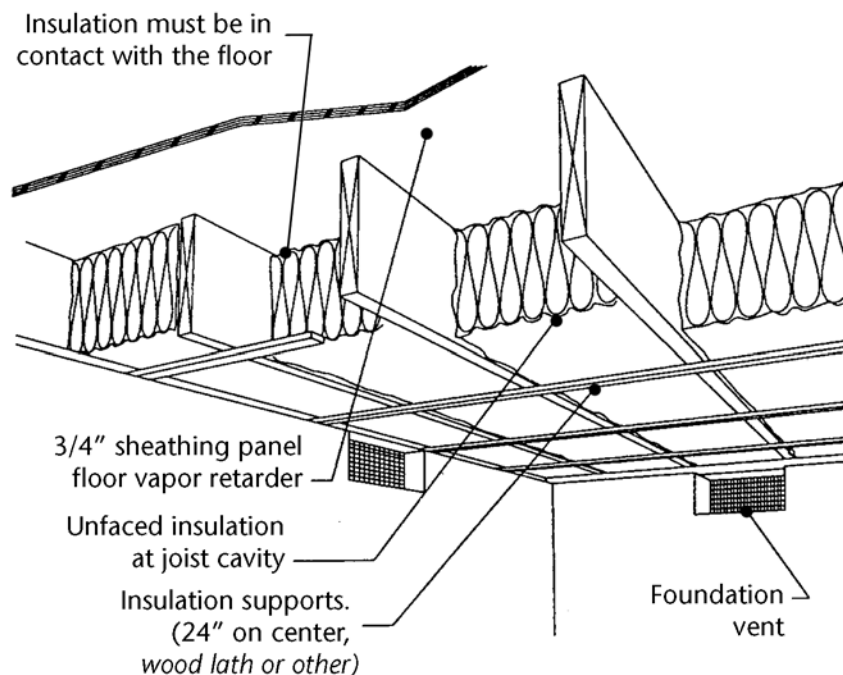


Figure 4-6

Post and beam floors require a different insulation attachment approach. The insulation is supported by lath and supports are attached to the posts and foundation wall (see Figure 4-7).

Post and Beam Insulation Supports

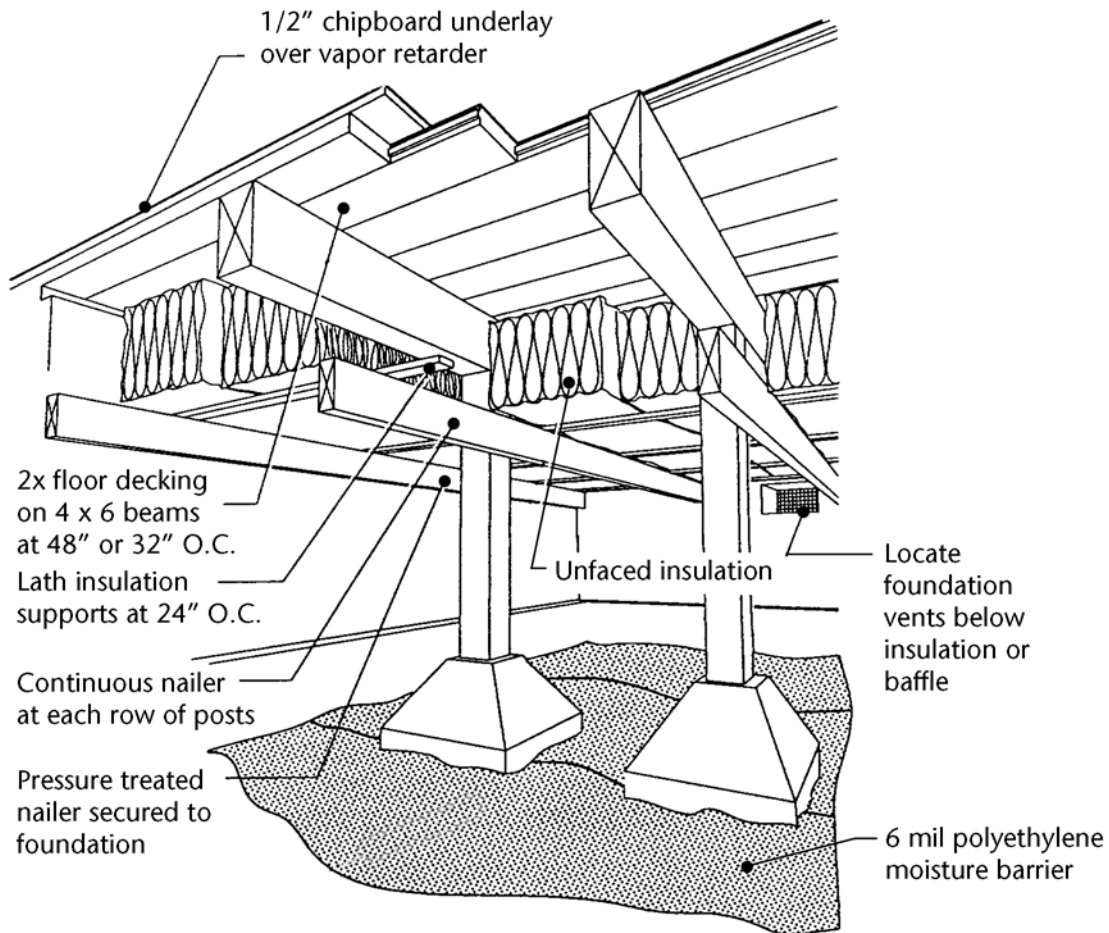


Figure 4-7

[502.1.4.7, Exception]

In either type of floor, when insulation butts against a foundation vent, a baffle must be installed to deflect the incoming air below the insulation level. These baffles are typically made of plywood installed at a 30° angle (refer back to Figure 2-2).

[502.1.4.7]

Loose-Fill Insulation. Loose-fill or blown-in insulation is commonly installed in ceilings (see Figure 4-8). The following requirements apply when using loose-fill insulation:

[502.1.4.1]

- The ceiling pitch must be 3-in-12 or less.
- Code-approved baffles must be installed.
- There must be minimum of 30 inches of clear distance from the bottom chord of the truss to the sheathing at the ridge.
- The insulation material must comply with the IBC for flame spread and smoke density requirements.
- R-value markers must be installed every 300 sq. ft.

Loose Fill Insulation Requirements

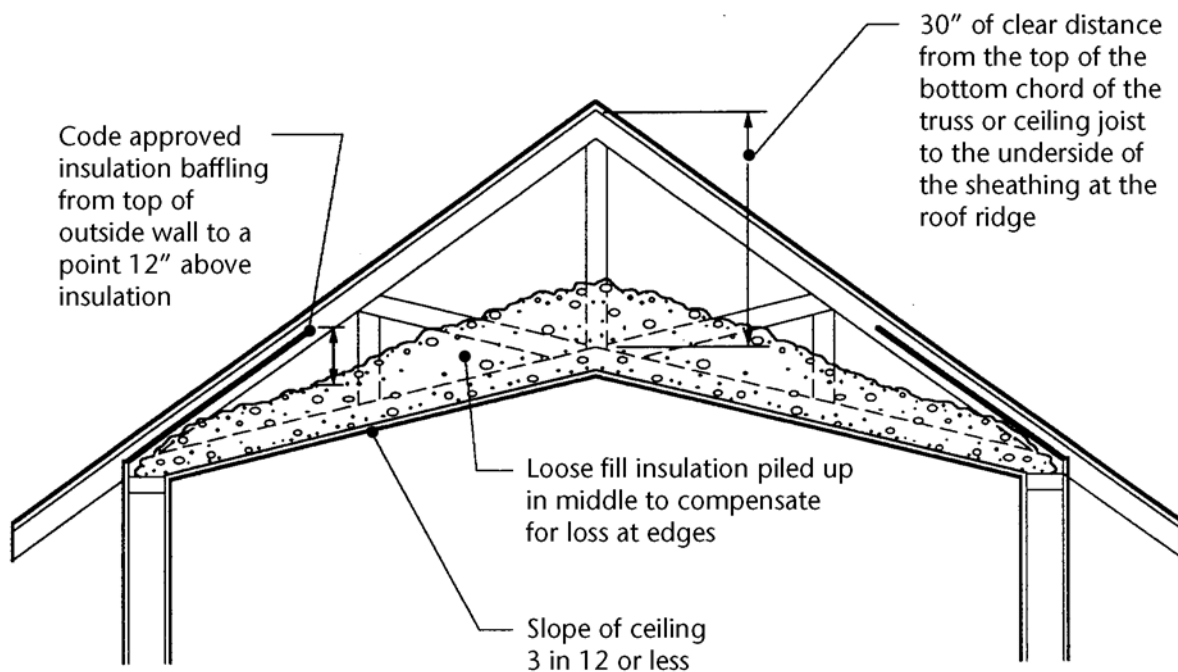


Figure 4-8

[502.1.4.4]

If areas of the attic need to be accessible for equipment maintenance, a catwalk should be constructed and supported above the loose-fill insulation (see Figure 4-9).

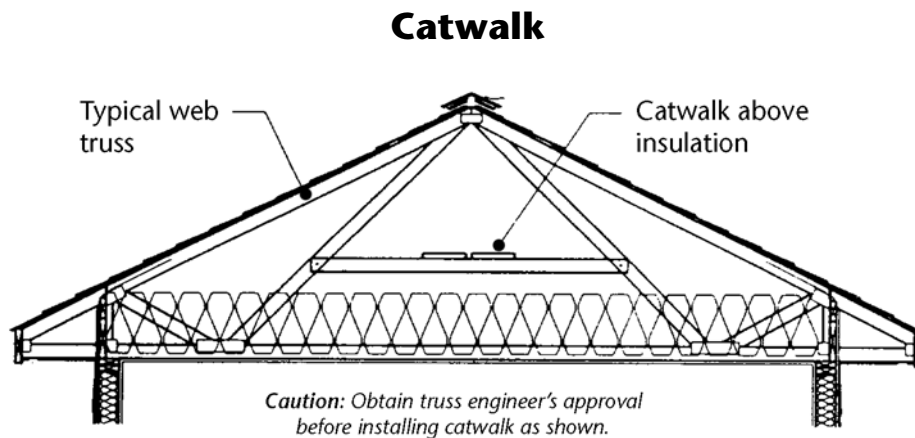


Figure 4-9

Skylight Walls. Skylight walls are insulated to the same level as the other walls in the house. Due to construction methods and close proximity of roof trusses, these walls are more difficult to insulate than a standard exterior wall.

A common skylight wall insulation technique is to tack insulation batts on the outside of the framed walls and secured in place with twine. *Remember, a vapor retarder is required.* The vapor retarder faces the inside, or warm side, as explained in Chapter 5, page 5-1.

Chapter 5: Air Leakage and Moisture Control

[502.1.6] **Vapor Retarders.** A vapor retarder is a material placed to minimize vapor movement through the diffusion process. Types of vapor retarders include:

- Kraft paper or foil facings on insulation.
- 4-mil or thicker polyethylene.
- Vapor retarder rated paint.

To meet Code, vapor retarders need to be rated at 1 perm dry cup or less. This is a rating of how permeable to vapor movement a given material is (see Table 5-1 for perm ratings).

Components of the house requiring a vapor retarder are:

- Floors between heated and unheated spaces.
- Walls – on the inside (warm side in winter).
- Ceilings averaging less than 12 inches of ventilated area above the insulation.

[502.1.6.2.] **Floors.** Floors that separate a heated from an unheated space are required to have an installed vapor retarder. Sometimes the floor decking itself meets the perm rating and qualifies as a vapor retarder. Three-quarters inch (3/4") tongue-and-groove exterior plywood and exterior grade OSB both meet the vapor retarder requirements. Floors with obvious gaps and holes call for a vapor retarder such as polyethylene or 15 lb. felt paper.

[502.1.6.6] **Walls.** All walls separating heated from unheated spaces must have a vapor retarder. Vapor retarders need to be installed on the inside of the wall, or the warm side in the winter.

[502.1.6.3] **Ceilings.** All roof/ceiling assemblies must have an installed vapor retarder when the ventilation space averages less than 12 inches. This is an average amount of ventilation space from the top of the insulation to the underside of the roof sheathing.

Table 5-1

Permeance Values for Common Building Materials*

Materials	Permeance
Polyethylene (4 mil)	0.08
Latex Primer/Sealer	6.28
Vapor Retarder Paint	0.45
Polyvinyl Acetate Latex (PVA)	5.5
Kraft Paper (Asphalt Impregnated)	0.03
15 lb. Asphalt Felt Paper	1.0
Gypsum Wall Board (3/8")	50
Plywood (1/4" with exterior glue)	0.7

*2005 ASHRAE Handbook of Fundamentals

Materials must be applied in accordance with manufacturer's instructions to achieve specified permeance ratings.

Air leakage control is an important but commonly misunderstood component of the energy efficient house. Tightening the structure with caulking and sealants has several positive impacts. A tight house will:

- Have lower heating bills due to less heat loss.
- Have fewer drafts and be more comfortable.
- Reduce the chance of mold and rot because moisture can't enter and become trapped in cavities.
- Have a better performing ventilation system.

Critical Areas for Air Leakage Control

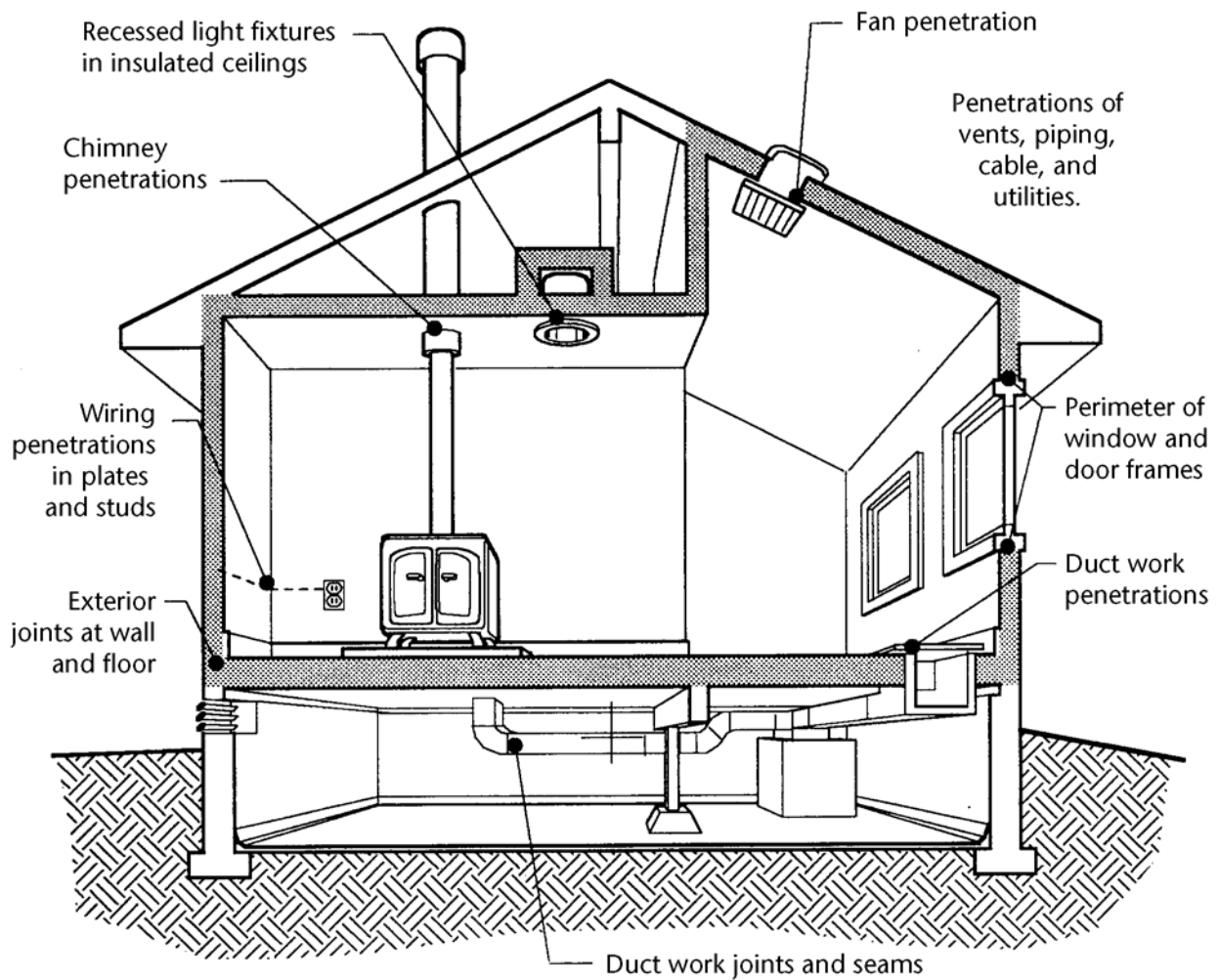


Figure 5-1

[502.4.1]

WSEC states specific locations in buildings requiring sealing. Air leakage must be controlled where outdoor ambient conditions are separated from interior spaces that are heated or mechanically cooled (see Figure 5-2).

The type of sealing material used varies with the size of the gap. For example:

- Caulk and low expansion foam should be used for small holes and cracks (less than 1/8" [one-eighth]).
- A combination of caulking and backer rod (foam rope) should be used for wider gaps (greater than 1/8" [one-eighth]).
- Polyethylene, rubber, or neoprene material should be used for large openings (greater than 1").

Window Sealing

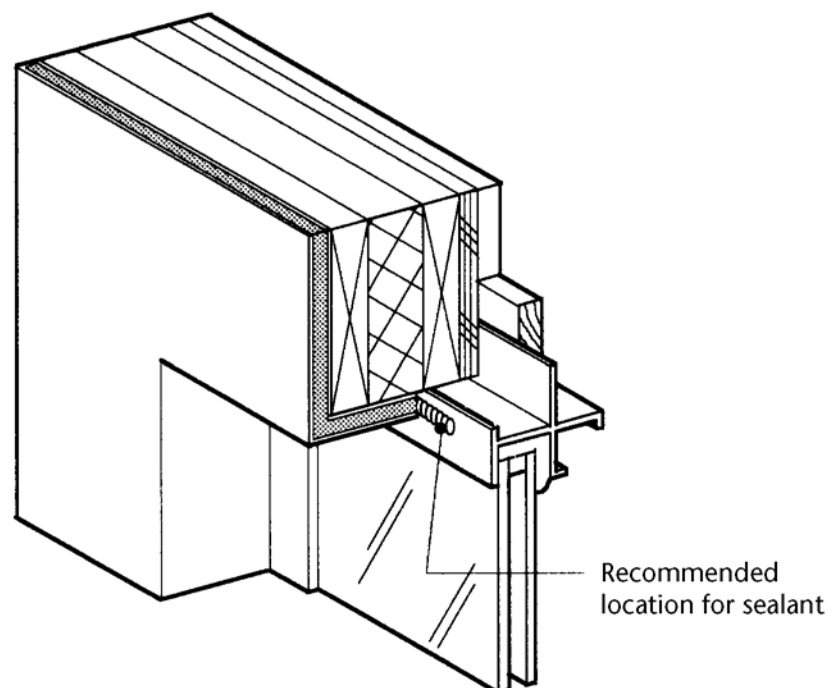


Figure 5-2

Fiberglass, loose cellulose, and rockwool insulation are not suitable air sealing materials; they do not stop air movement.

[502.4.3]

Windows and Doors. All windows and doors in exterior walls must be sealed between the frame and the rough opening framing material (see Figure 5-2).

Wiring and Plumbing Penetrations. Holes drilled in top and bottom plates (between heated and unheated spaces) need to be sealed. Plumbing penetrations often leave large holes requiring sealing (see Figure 5-3).

Plumbing Bypass

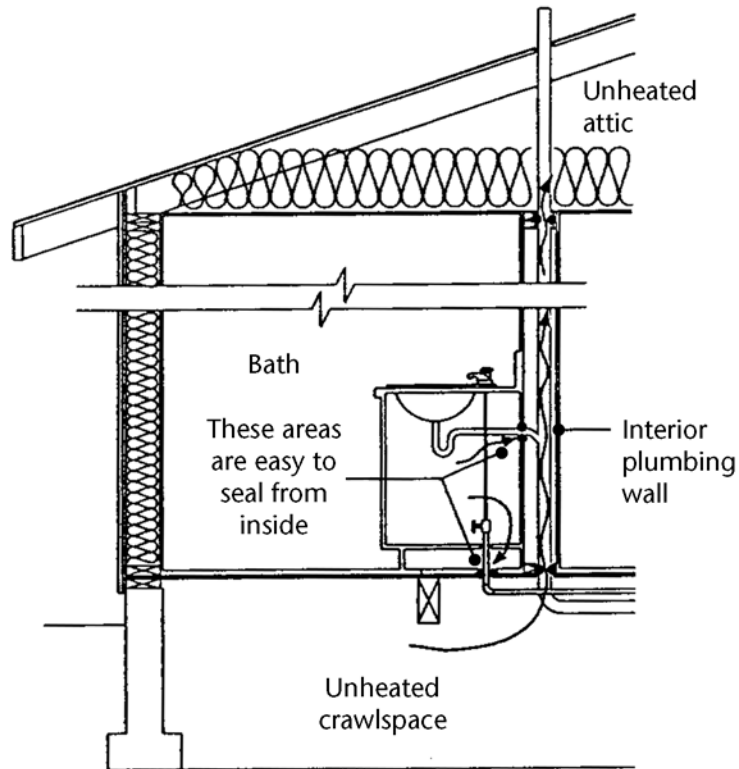


Figure 5-3

[502.4.3]

Drain traps penetrating floors over unconditioned spaces are often overlooked, but must be sealed (see Figure 5-4).

Holes drilled where interior and exterior walls intersect also need to be sealed.

Electrical boxes are considered holes in the envelope and call for sealing. A typical sealing technique is to caulk where the wire enters the box. Make sure that a latex or non-petroleum based caulk is used. A silicone type caulk may corrode the insulation on the wiring and expose the wire.

Gasket at Tub Penetration

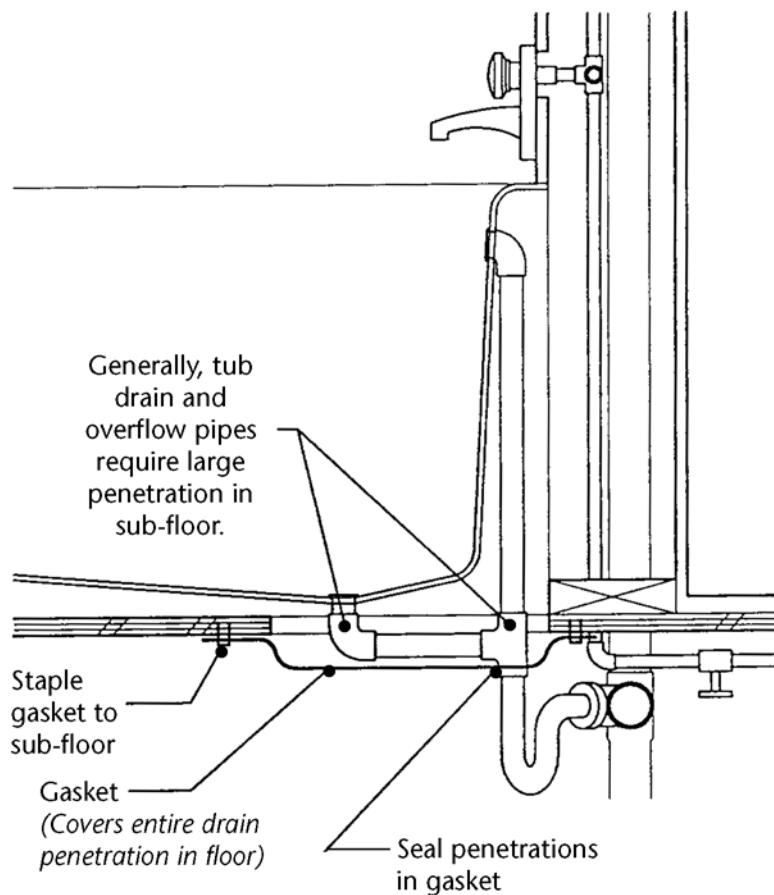


Figure 5-4

Outlet and switchplate gaskets are always recommended, but should always be installed if there are gaps between the box and wallboard.

Recessed Lighting Fixtures. Leaky recessed lighting fixtures, when installed in the building envelope, can be a major source of heat loss and moisture movement. WSEC does not limit the number of recessed lights that can be installed, but does give specific installation specifications.

[502.4.4]

To meet Code, a recessed fixture must be IC-rated (insulation cover) and installed in a way that limits air leakage (see Figure 5-5):

- Type IC rated, tested using ASTM E283 method. Certified and labeled to meet the WSEC air leakage requirements.

Note: Many recessed lighting fixtures only meet the air sealing requirement when a specific trim kit is used. Check with your supplier for details.

Recessed Lighting Fixtures

Type IC rated fixture, certified tested 2.0 CFM maximum air movement

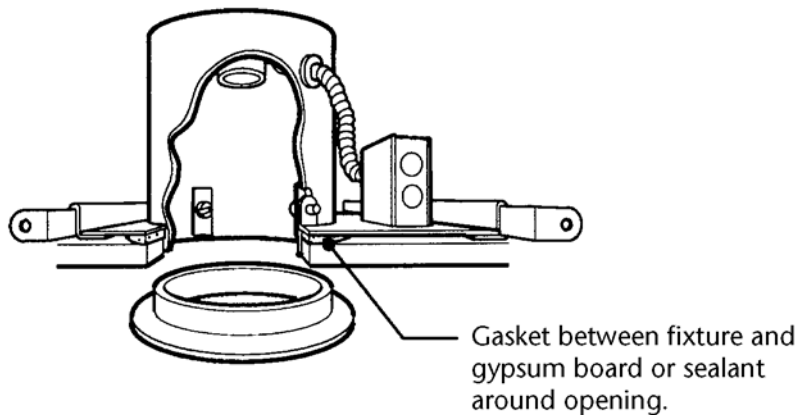


Figure 5-5

[502.4.3a]

Other Building Penetrations. Additional areas of potential air leakage that require sealing are:

- **Sole Plates.** Sealing sole plates to subfloors is commonly done after the house is framed and dried in. The caulking is applied at the point where the sole plate meets the subflooring. This method works well because the caulk can be applied to a clean, dry surface for a better bond and the building inspector can easily see that it has been done.
Alternative methods are to seal the sole plate on the bottom when it is erected or by using a plate gasket product (see Chapter 3, Figures 3-2 and 3-3).
- **Rim Joists.** Rim joists between floors can be sealed either on the interior side with caulking or on the exterior side. Exterior sealing approach requires sealing the house wrap at the rim joist to create an air barrier.
- **Mud Sills.** These are treated the same as sole plates. Mud sills are usually placed on a sill sealer that stops both air leakage and moisture wicking.
- **Flues.** Chimney penetrations are typically sealed where the support or collar meets the ceiling. Observe all fire rating restrictions.

Chapter 6: Plumbing

The Washington State Energy Code (WSEC) sets standards that minimize heat loss and conserve water (see Figure 6-1).

Plumbing Requirements

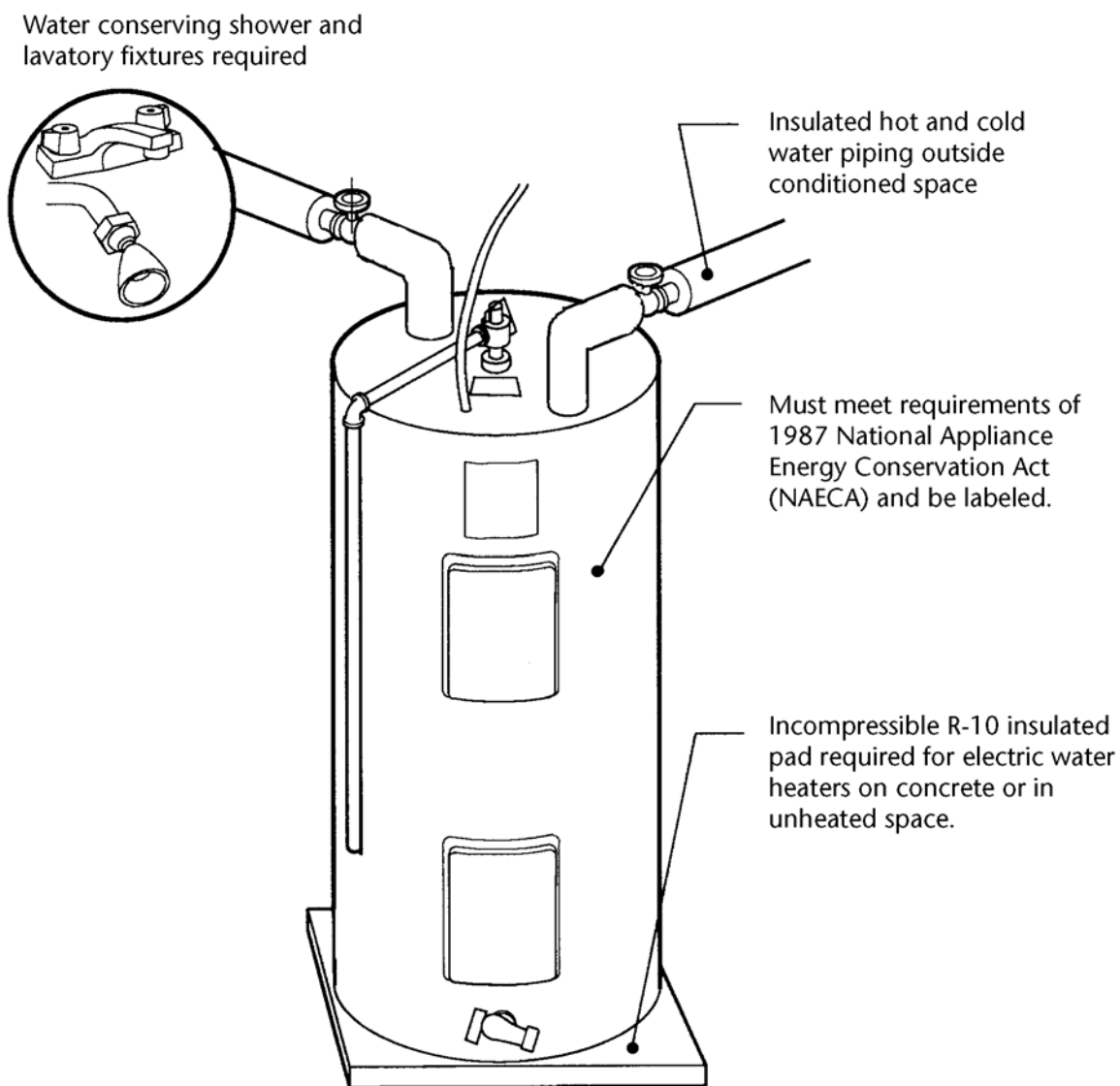
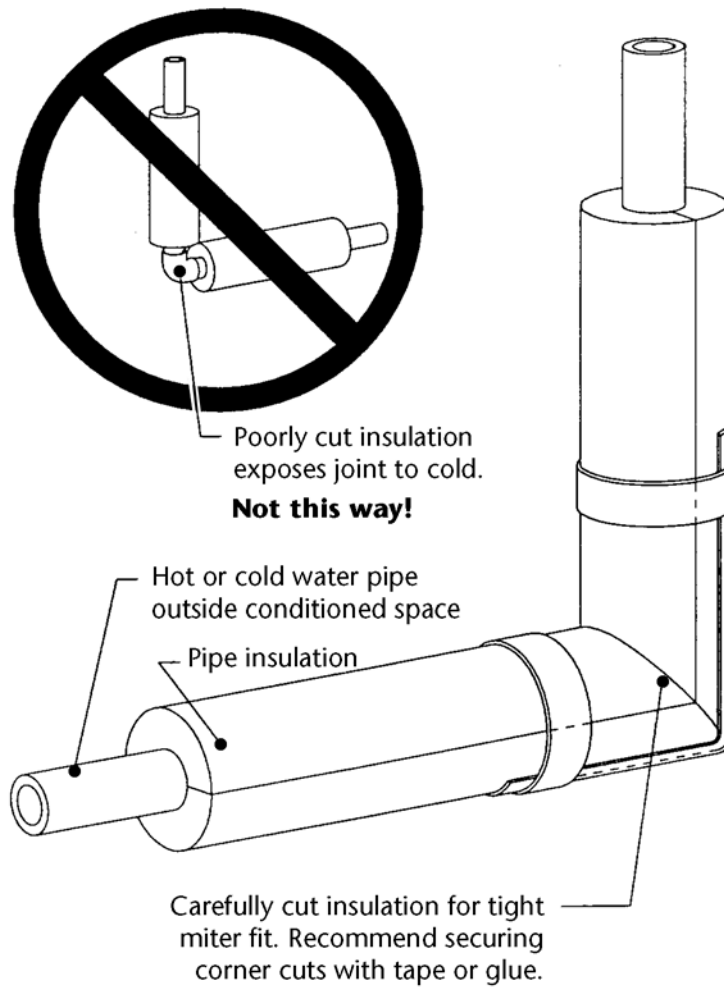


Figure 6-1

- [504.8.1] **Water Conservation.** Flow rates for shower heads and lavatories are limited by the Washington Administrative Code. These flow rates are set at 2.5 gpm or less for shower heads and 1.6 gpm for lavatories.
- [504.2.1] **Water Heaters.** All water heaters must meet the performance efficiency requirements of the 1987 National Appliance Energy Conservation Act (NAECA). All currently manufactured units should meet this standard. Also:
- [504.3] Residential water heaters must be set to a maximum 120°F.
- [504.4] Each water heater must have a separate shut-off switch or valve.
- All electric water heaters in unheated spaces or on concrete floors must be placed on an incompressible insulated surface with minimal thermal resistance R-10.
- [504.2.1] Storage water heaters used for combination space heating and water heating must meet the efficiencies listed in Table 504.2.1.
- [503.11] **Pipe insulation.** Hot and cold water pipes outside the conditioned envelope of the building must be insulated to the level specified in WSEC Table 5-12 (R-3.6 for < 2" pipe, R-5.4 for > 2").
- Swimming Pools.** Heated swimming pools must meet the following requirements:
- [504.5.2] Have a pool cover approved by the Building Official.
- [504.5.1] All pool heaters must have an accessible ON/OFF switch to shut off the heater without adjusting the thermostat.
- [504.5.1] Pool thermostats must be adjustable to a minimum 65°F setting.

Pipe Insulation



Note: Polyethylene foam will provide approximately R-3.6 per inch of thickness.

Figure 6-2

Chapter 7: Heating and Cooling Systems

Design Conditions

The Washington State Energy Code sets the following conditions for heating system design and equipment sizing:

- [302.2.1] • Indoor Design Temperature: 70°F heating - 78°F cooling.
- [302.1] • Outdoor Design Temperature: Based on local weather data taken from Puget Sound Chapter of ASHRAE publication “Recommended Outdoor Design Temperatures for Washington State.”
www.pugetsoundashrae.org/interest.htm
- Recommended Air Infiltration Rate for equipment sizing: 0.6 air changes/ hour.

Design Heat Load (DHL) Calculation

[503.2.1] Heating and cooling design loads for the purpose of sizing the heating and/or cooling equipment must be calculated in accordance with accepted engineering practice, including infiltration and ventilation.

- [503.2.2] **System Sizing Limit.** The Code limit is set at 150% of designed heating or cooling load. Exceptions are made for:
- Equipment providing both heating and cooling in one packaged unit; compliance need only be demonstrated for the heating or cooling system size.
 - Gas or oil heating equipment with a total rated output less than 40,000 Btu/hr. are exempt from the sizing limit. Gas or oil heating equipment that exceeds 40,000 Btu/hr. may be 250% of the DHL if the annual fuel utilization efficiency (AFUE) is 90% or greater.

Alternate methods to calculate HVAC system sizes are:

- Air Conditioning Contractors of America (ACCA) Manual J; or
- Prescriptive Path and Component Performance Worksheets located at www.energy.wsu.edu/code/

Electric Resistance Heating Systems

System efficiency. No requirement. Electric resistance heating is considered 100% fuel efficient (see Figure 7-1)

[503.8]

Controls. Thermostat, which must provide:

- Heating only 55°F to 75°F with Cooling 55°F to 85°F.
- Adjustable deadband of not less than 10°F between hot and cold.
- Manual or automatic setback.
- Zonal Control – at least one thermostat for each separate system.

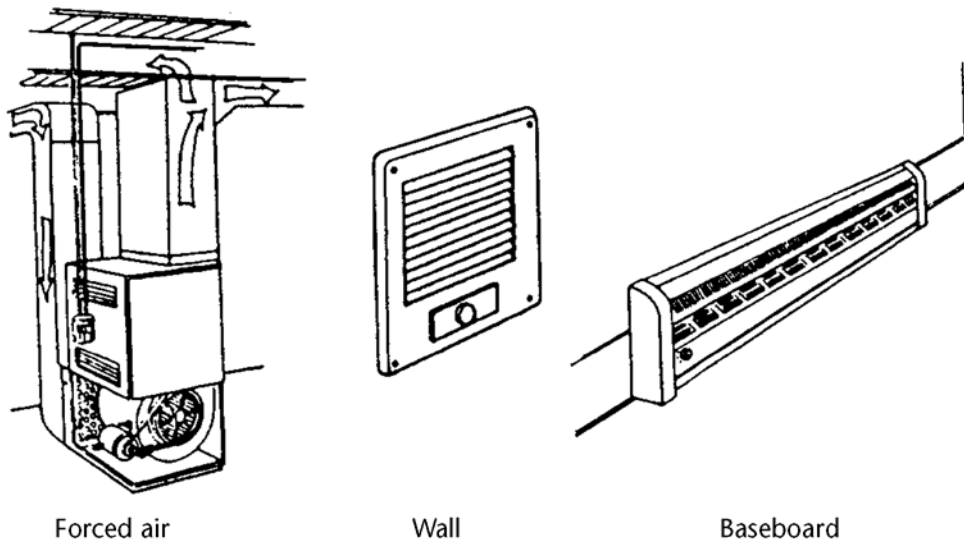


Figure 7-1

Other Fuel Heating Systems (Combustion)

[503.4]

System efficiency. Minimum 78% AFUE.

Oil, gas, or propane space heater requires intermittent ignition or must meet 1987 NAECA efficiency requirement.

Credit for increased efficiency by Systems Analysis approach.

Controls: Same as Electric Resistance.

Combustion Heating Systems

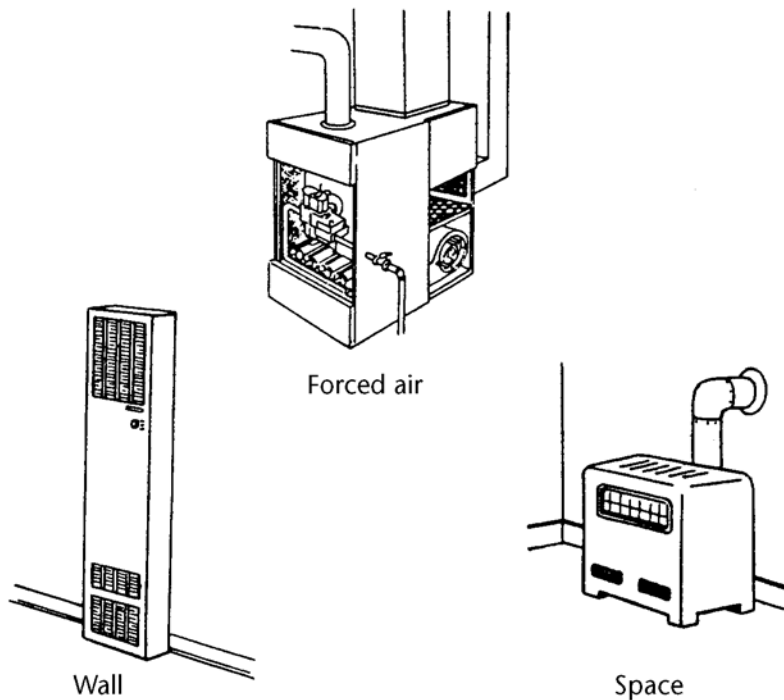


Figure 7-2

Other Fuel Heating Systems (Heat Pumps)

[503.4]

System efficiency. Varies depending on source of heat.

Air Source

- For Split System, a minimum of 7.7 HSPF (Heating Seasonal Performance Factor). (See WSEC Table 14-1B.) (See Figure 7-3.)
- For Single Package, a minimum of 6.6 HSPF.

Ground Source

- Minimum COP (Coefficient of Performance) = 3.6 @ 50°F.

Split Package Heat Pump

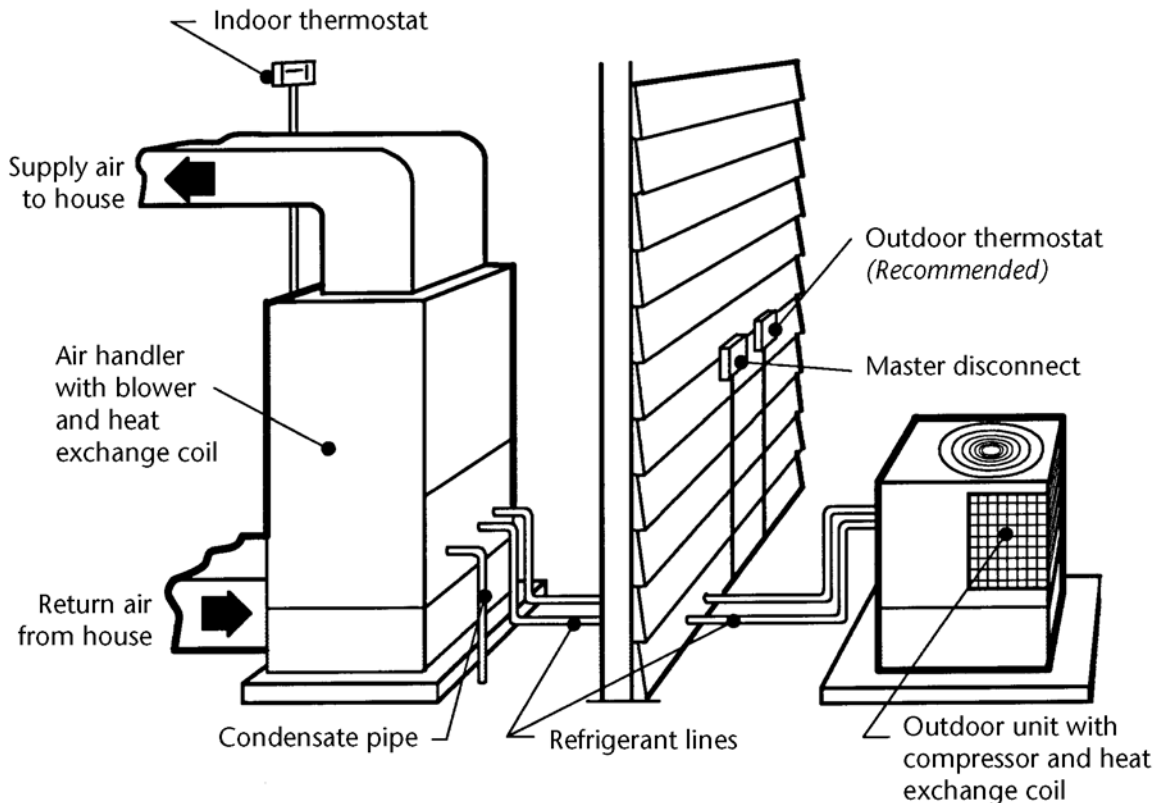


Figure 7-3

Duct Systems

[503.9]

Ducts, plenums, and enclosures outside conditioned space must be insulated to R-8 in Climate Zone 1 and R-10 in Climate Zone 2 (R-5 in slabs or in the ground in both climate zones).

Exceptions:

- Within the HVAC equipment.
- Supply or return ducts installed in unvented crawlspaces with insulated walls.

Duct Fasteners

Ducts must be fastened in accordance with the International Mechanical Code (IMC). For small sheet metal ducts, a minimum of three screws per connection equally distributed around the duct, or equivalent is required. For flex duct, and duct board, you must follow instructions developed by the Sheet Metal & Air Conditioning Contractors National Association (SMACNA), noted in the IMC. More information can be found at:

www.smacna.org/

Duct Sealing

All supply and return ducts that may communicate air to the exterior of the building must be sealed. This includes ductwork and building cavities used to transport air.

Primary sealants approved for ducts include welds, gaskets, mastic, or mastics with embedded fabric systems. Tapes may be used if specific installation procedures provided by the manufacturer are followed.

Tapes must be installed in accordance with manufacturer's instructions, or in the case of UL 181 sealants, in accordance with the product listing. If the product does not have instructions specific to material or application it is being applied to, it does not meet the intent of the code. For example, if tape is used to seal sheet metal, instructions published by the manufacturer must include notes

on application to sheet metal. If the sheet metal needs to be cleaned, the manufacturer's instructions must provide specific instructions on cleaning. These instructions must be followed by the installer.

Building cavities used to transport air may be sealed using drywall, tape and mud. It must be installed with a continuous air barrier.

For additional information on duct sealing, see the *Builder's Field Guide's Supplement A, "Improving Forced Air Heating Systems,"* included in this guide.

Duct Insulation and Sealing

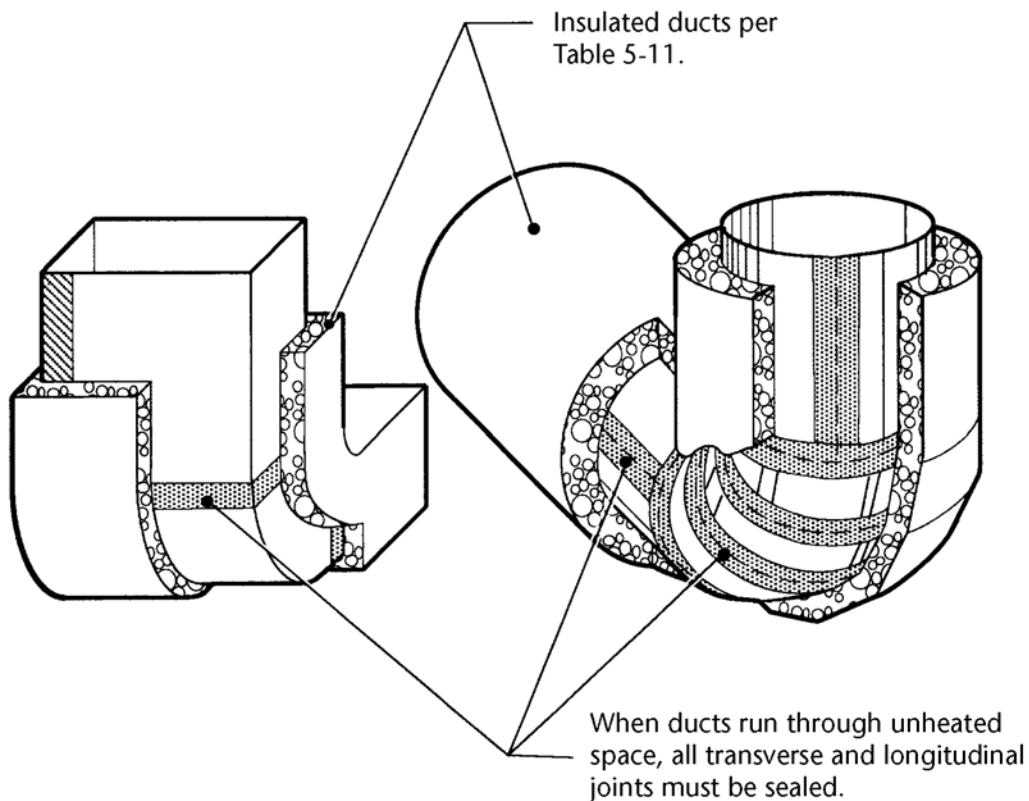
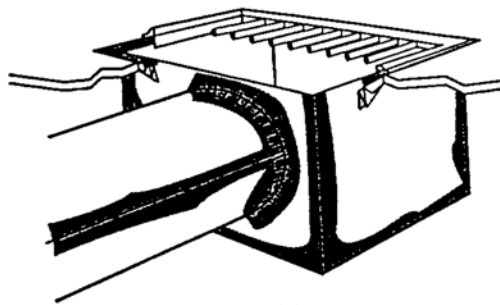
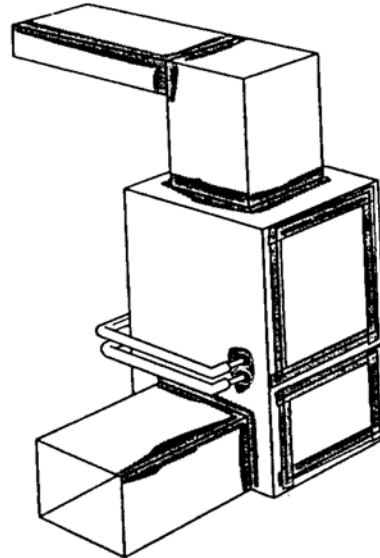


Figure 7-4

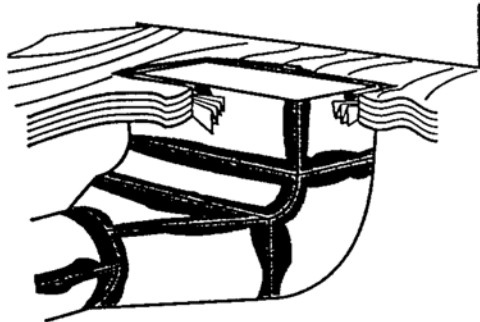
Sealing Ducts



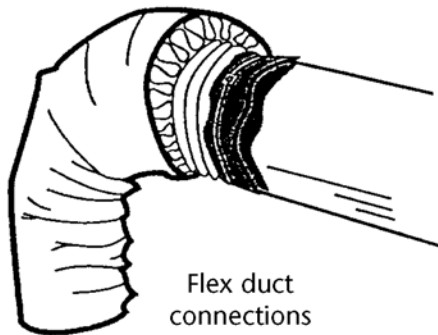
Transitions



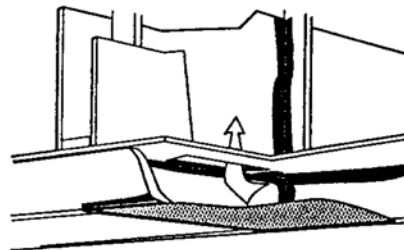
Air handler



Register boot



Flex duct connections



Building cavities
(Not Recommended)

Figure 7-5

Chapter 8: Ventilation

Definitions of terms used in this chapter:

ACH stands for "air changes per hour." It is a measure of the ventilation rate of a room or whole structure. If half the volume of air in a room is exchanged for fresh air in one hour, then the room is being ventilated at the rate of 0.5 ACH.

CFM (or **cfm**) stands for "cubic feet per minute" and is used to measure the volume of ventilation air required or the capacity of a fan to move air.

Fan capacity ratings are given in terms of the volume of air (in cfm) that the fan can move against a given static pressure (in inches of water gauge). For prescriptive compliance, the VIAQ Code requires that all fan capacities be rated at .25 inches of water gauge.

Fan Capacity Rating Example

Static Pressure; Inches of Water	0.0	0.1	0.125	0.250	0.375
CFM	98	94	93	84	52

Static pressure is a measure of the resistance of air movement through a duct system. Often used as a basis for the design and sizing of duct systems. The static pressure of duct system is essentially a back pressure the fan must overcome to achieve air movement through the duct.

Water gauge (or *water column*) is a scale used to show pressure differences. When you suck on a straw in a glass of water, the water rises in the straw because the pressure in the straw is reduced. The height that the water rises is a measure of the pressure difference inside and outside the straw. The height of a 1 inch diameter column of water is frequently used to describe the static pressure in a duct system. The static pressure of a residential ventilation duct system might typically be .15 inches of water.

Mechanical Ventilation Systems Required

The Washington State Ventilation and Indoor Air Quality Code (VIAQ) requires new residential structures be provided with both source-specific and whole-house ventilation systems. There are two methods for meeting this code. Section 302 provides requirements for residential ventilation systems using performance or design qualification methods. Section 302 will most likely be used by mechanical engineers on complex projects and systems designed for continuous operation. Section 303 provides prescriptive direction for spot ventilation and four prescriptive options for intermittent operation whole house ventilation systems. This guide will only cover the Section 303 prescriptive paths.

Prescriptive Paths Include:

- [V303.3] • Source Specific Ventilation (all prescriptive paths)
- [V303.4.1] • Whole House Ventilation Using Exhaust Fans
- Whole House Ventilation Integrated with a Forced Air Heating System
- [V303.4.2] • Whole House Ventilation Using a Supply Fan
- [V303.4.4] • Whole House Ventilation Using a Heat Recovery Ventilation System

Source-Specific Ventilation

[V303.3] Source-specific or spot ventilation (see Figure 8-1) is required in specific rooms of the house, including:

- Kitchens
- Bathrooms
- Water closets
- Laundry room
- Indoor swimming pools or spas
- Other rooms where excess water vapors or cooking odors are produced

VIAQ Table 3-1 lists minimum ventilation rates for source-specific fans according to their location.

VIAQ Table 3-1

Source Specific Ventilation Capacity Requirements

Mode of Operation	Bathrooms	Kitchens
Intermittently Operating	50 cfm	100 cfm
Continuous Operation	20 cfm	25 cfm

[V303.3.2] VIAQ Table 3-1 shows two exhaust rates, expressed in Cubic Feet per Minute (CFM). A lower CFM rate is required for continuously operating systems than for intermittently operated systems. Fan CFM are to be rated at 0.25 inches water gauge. This rating is included on the manufacturers fan curve. The CFM rating on the fan carton is usually the rating at the lower pressure of 0.10 and does not necessarily meet the requirements of the VIAQ.

Source Specific Fan Controls

[V303.3.3] Switches, dehumidistats, or timers that are readily accessible to the occupant are required.

Source Specific Ventilation

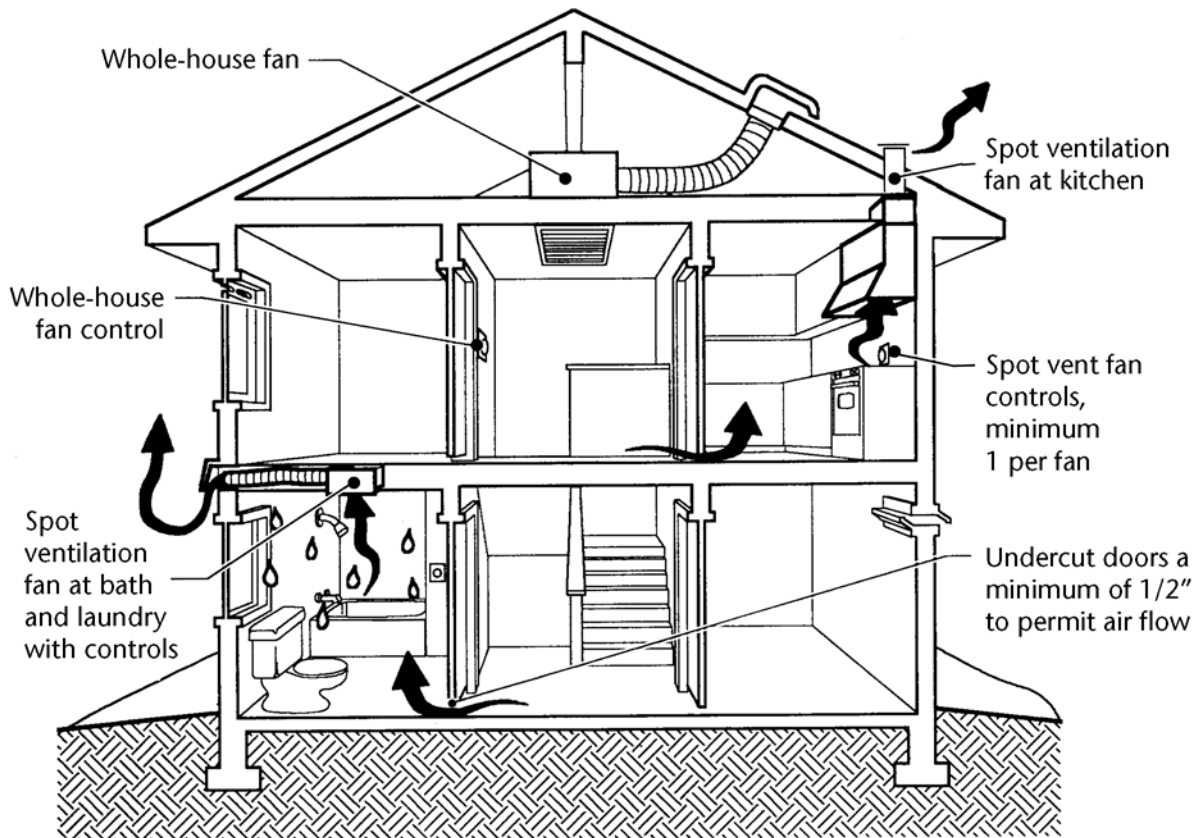


Figure 8-1

Source Specific Ventilation Ducts

[V303.3.4]

- Must be sized as per VIAQ Table 3-3.
- Must terminate outside the structure.
- Must be insulated to at least R-4 outside the heated space.
- Terminal elements must be screened and sized to be greater than or equal to the net free area of the duct.

Whole-House Ventilation Systems

[V303.4]

VIAQ requires that in addition to source-specific ventilation fans, a whole-house ventilation system must be installed. Prescriptive whole-house ventilation system provides fresh air for the occupants on a timed basis. For continuously operating systems you must comply with section 302.

All Whole house ventilation systems must be capable of providing the minimum ventilation rate specified in VIAQ Table 3-2. The maximum CFM is the maximum rate allowed without a heat recovery ventilation system. Heat recovery ventilation systems do not need to comply with the maximum values.

VIAQ Table 3-2 lists prescriptive whole-house fan sizes based on conditioned floor area and number of bedrooms. The prescriptive approach requires no calculations.

VIAQ Table 3-2

Ventilation Rates (CFM) for all Group R Occupancies Four Stories

Floor Area, ft ²	Bedrooms													
	2 or less		3		4		5		6		7		8*	
	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.
<500	50	75	65	98	80	120	95	143	110	165	125	188	140	210
501-1000	55	83	70	105	85	128	100	150	115	173	130	195	145	218
1001-1500	60	90	75	113	90	135	105	158	120	180	135	203	150	225
1501-2000	65	98	80	120	95	143	110	165	125	188	140	210	155	233
2001-2500	70	105	85	128	100	150	115	173	130	195	145	218	160	240
2501-3000	75	113	90	135	105	158	120	180	135	203	150	225	165	248
3001-3500	80	120	95	143	110	165	125	188	140	210	155	233	170	255
3501-4000	85	128	100	150	115	173	130	195	145	218	160	240	175	263
4001-5000	95	143	110	165	125	188	140	210	155	233	170	255	185	278
5001-6000	105	158	120	180	135	203	150	225	165	248	180	270	195	293
6001-7000	115	173	130	195	145	218	160	240	175	263	190	285	205	308
7001-8000	125	188	140	210	155	233	170	255	185	278	200	300	215	323
8001-9000	135	203	150	225	165	248	180	270	195	293	210	315	225	338
>9000	145	218	160	240	175	263	190	285	205	308	220	330	235	353

**For residences that exceed 8 bedrooms, increase the minimum requirement listed for 8 bedrooms by an additional 15 CFM per bedroom. The maximum CFM is equal to 1.5 times the minimum.*

Fan Controls

[V302.3.2]

All whole-house ventilation systems must have a control with the capability of continuous operation, manual and automatic control. Twenty-four hour timers with a manual switch are the most common control.

At the time of the final inspection, the ventilation system is required to be set for a minimum of 8 hours per day. It is recommended that the fan control setting alternate between 10 minutes on and 20 minutes off.

Fan controls must have a label that reads:

Whole-House Ventilation
(See Operating instructions)

Operating Instructions

[V101.4]

Installers shall provide operating instructions. Sample operating instructions are posted at www.energy.wsu.edu/code/

Whole-House Ventilation Using Exhaust Fans

[V303.4.1] In addition to the requirements listed above, whole-house ventilation using exhaust fans must comply with requirements for fan ratings, sound control, duct sizing, insulation, and outdoor air inlets (see Figure 8-2).

Fan Rating

[V303.4.1.1] VIAQ Table 3-2 shows two exhaust rates, expressed in Cubic Feet per Minute (CFM). Fan CFM must be rated at 0.25 inches water gauge. This rating is included on the manufacturer's fan curve. The CFM rating on the fan carton is usually the rating at the lower pressure of 0.10 and does not meet the requirements of the VIAQ.

To identify products that meet the VIAQ standards, use the Home Ventilating Institute's Directory of Certified Products. The directory is certified monthly, and can be obtained from www.hvi.org

Fan Noise

[V303.4.1.2] The whole-house fan must be quiet when operating. Fan noise is rated in "sones." The VIAQ allows a 1.5 sone maximum when the fan motor is installed within 4 feet of the interior pick-up grille. Remote-mounted fans (more than 4 feet from the pick-up grille) are exempt from the sound rating requirement (see Figures 8-3 and 8-4).

Whole-House Exhaust Ventilation

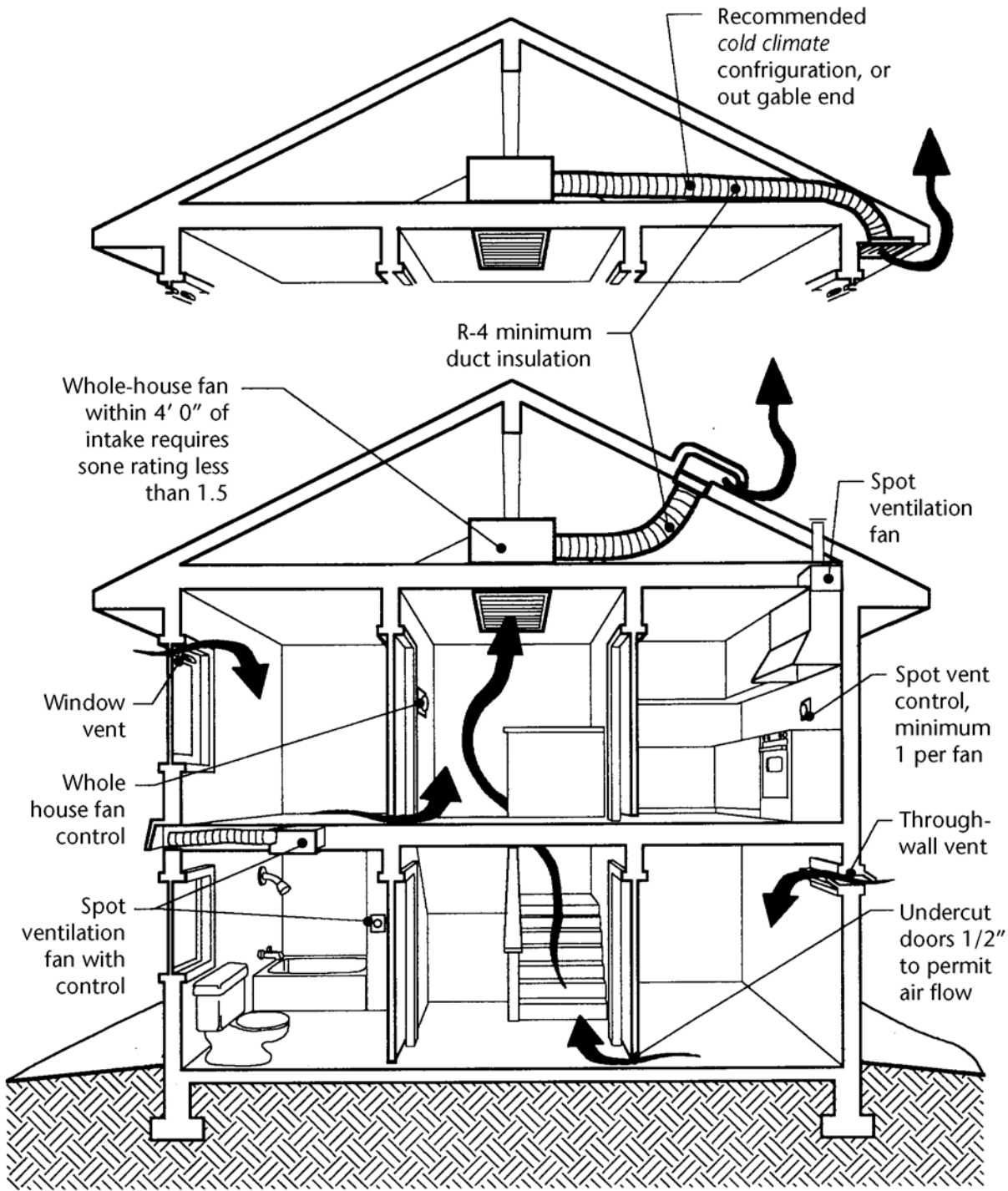
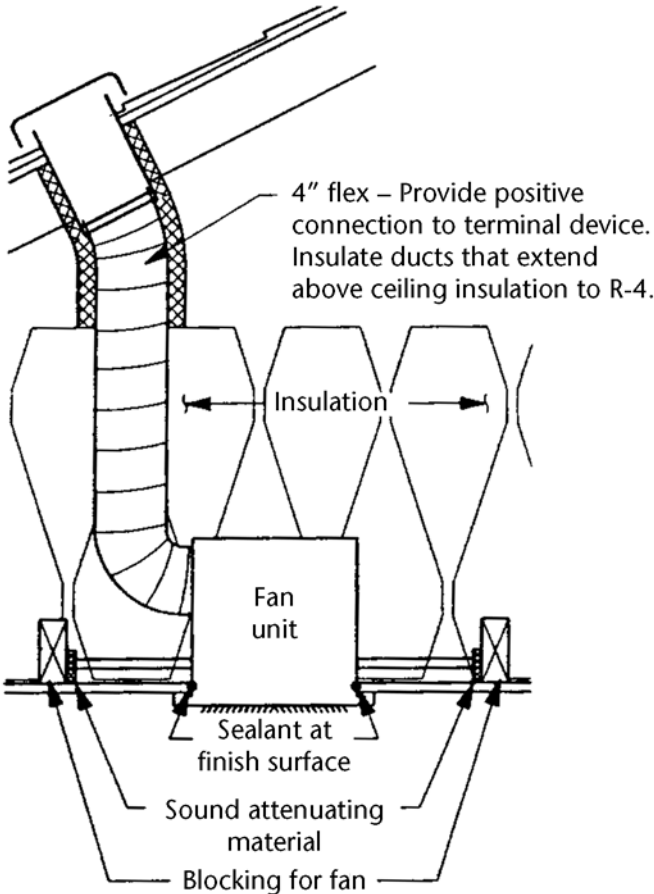


Figure 8-2

Sound Attenuation for Surface Mounted Fans



Note: Remember, the noise rating applies to whole-house ventilation fans, not source-specific fans.

Figure 8-3

Exhaust Fans

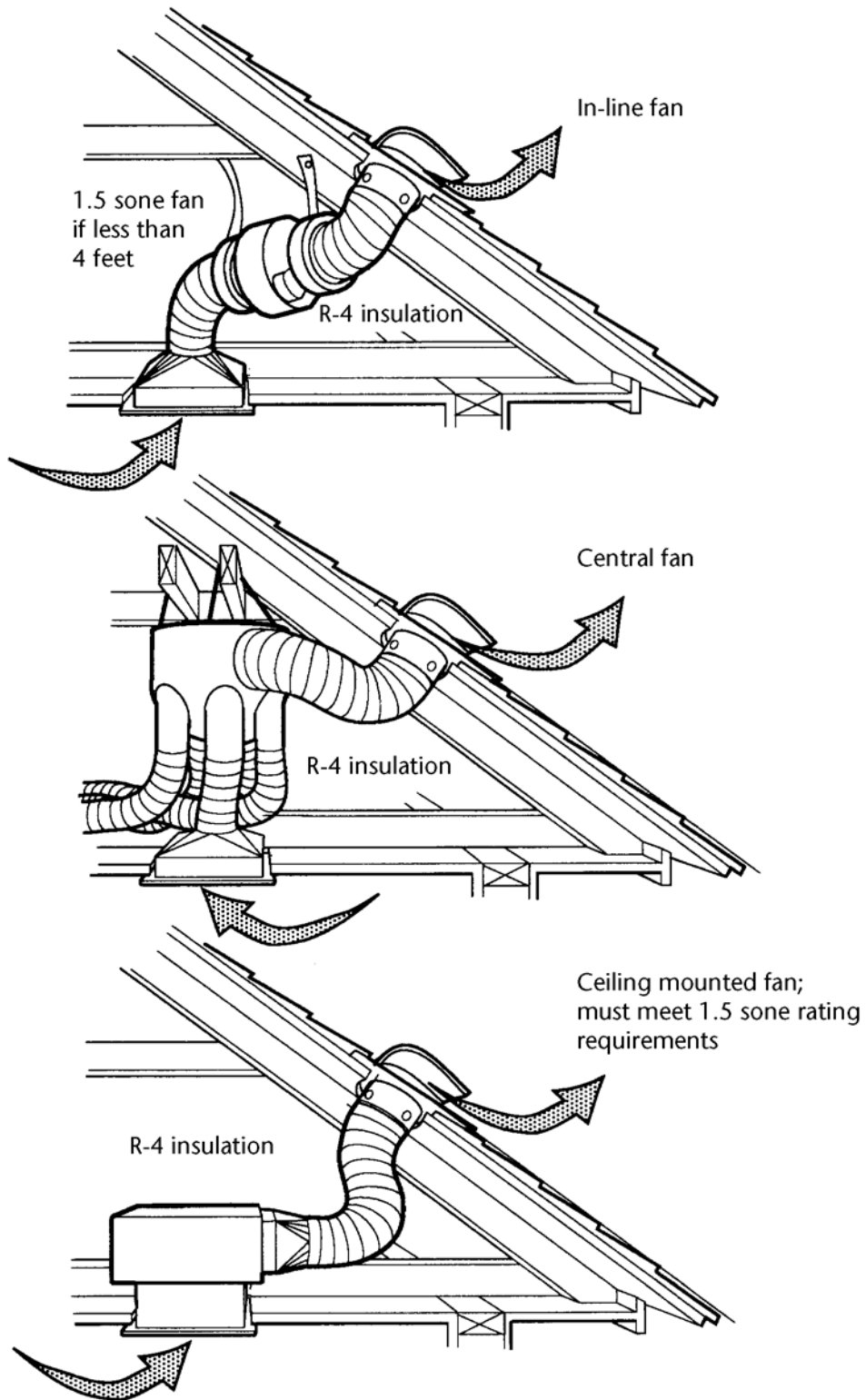


Figure 8-4

Exhaust Ducts

[V303.4.1.4]

Prescriptively installed ventilation systems have specific ductwork requirements to ensure adequate air flow, minimize condensation, and exhaust moisture and pollutants to the outside. Exhaust ducts must:

- Be sized and installed according to VIAQ Table 3-3.
- Have a backdraft damper.
- Be insulated to R-4, if run in an unheated space.
- Terminate outside the building.

VIAQ Table 3-3 gives minimum duct sizes, length of run, and number of elbows (90° bends) based on the size of the fan. The table applies to smooth wall and flexible ducts.

VIAQ Table 3-3

Prescriptive Exhaust Duct Sizing

Fan Tested CFM @ 0.25" W.G.	Minimum Flex Diameter	Maximum Length Feet	Minimum Smooth Diameter	Maximum Length Feet	Maximum Elbows ¹
50	4 inch	25	4 inch	70	3
50	5 inch	90	5 inch	100	3
50	6 inch	No Limit	6 inch	No Limit	3
80	4 inch ²	NA	4 inch	20	3
80	5 inch	15	5 inch	100	3
80	6 inch	90	6 inch	No Limit	3
100	5 inch ²	NA	5 inch	50	3

1. For each additional elbow subtract 10 feet from length.
 2. Flex ducts of this diameter are not permitted with fans of this size.

Outdoor Air Inlets

[V303.4.1.5]

Each habitable space of the building must be provided with outdoor air. Outdoor air distribution is accomplished through the use of outdoor air inlets (see Figure 8-5).

These openings must:

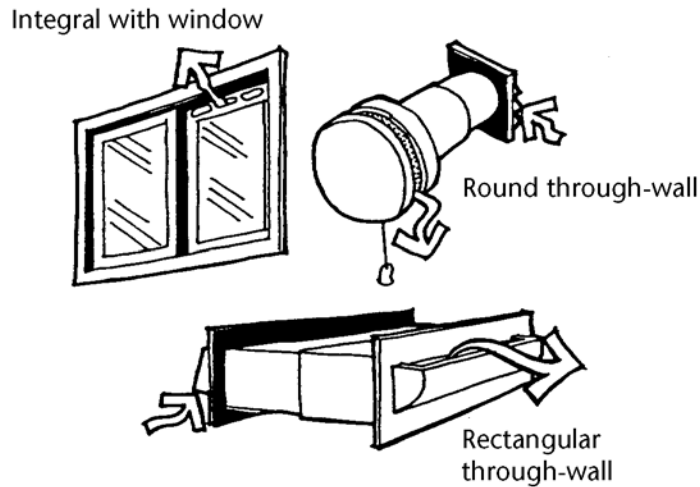
- Have controllable and secure openings.
- Be sleeved when installed through a wall or window frame.
- Have a minimum of 4 square inches of net free area or provide a minimum of 10 CFM @ 10 pascals tested by HVI.

If a door separates a fresh air inlet from an exhaust point, airflow can be ensured by either:

- Undercutting doors a minimum of 1/2-inch above the finish floor material.
- Or installing distribution ducts, grilles, or transoms.

Exception: Exhaust only ventilation systems do not require outdoor air inlets if the home has a ducted forced air heating system that communicates with all habitable rooms and the interior doors are undercut to a minimum of 1/2 inch above the surface of the finish floor covering.

Outdoor Air Inlets



(See Figure 3-15 for installation detail.)
Double duty spot/whole-house ventilation system.

Figure 8-5

Types of Whole-House Ventilation Using Exhaust Fans

Double-Duty Spot/Whole-House: A common whole-house ventilation strategy is to combine a source-specific and whole-house ventilation fan. If possible, choose a bathroom or laundry room with a centrally located spot fan for the double-duty system. To prescriptively size the fan, use VIAQ Table 3-2. Don't add both spot CFM rates and whole-house rates together to determine the fan size. Use the larger of the two rates (see Figure 8-2 for a typical spot/whole-house system set-up).

This type of ventilation system includes:

- A 1.5 sone (or less) rated fan.
- Automatic and manual controls.

- Undercut doors (or other means) for air distribution.
- Proper duct sizing, length, and insulation (when outside the conditioned space).
- Fresh air supplied to habitable spaces.

Separate Spot/Whole-House: Another ventilation strategy is installing a dedicated whole-house fan in addition to the spot ventilation fans. An advantage to this system is the ability to centrally locate the whole-house fan and have it operate independently of the spot ventilators. This system may be a good choice in large houses where there are no centrally located spot fans. CFM rates, controls, air distribution, and duct requirements for the double-duty system also apply to this system.

Central Ducted Whole-House: A central ducted system is typically installed in the attic and ducted to individual areas of the house, bathrooms, kitchen, laundry room, or any room where ventilation is required or desired. Advantages to this system include: replacement of individual spot ventilation fans, quiet operation, and better overall ventilation of the structure. This system can also be operated continuously, which eliminates the need for controls.

[V303.4.2]

Integrated Ventilation System: If a forced air heating system is installed, fresh air may be ducted into the system to meet ventilation requirements (see Figure 8-6). An integrated system consists of:

- A fresh air duct, connected to the furnace return plenum, sized per VIAQ Table 3-5.
- A damper allowing the proper amount of outside air to the system.
- A clock timer set to appropriate ventilation periods.

Integrated Ventilation

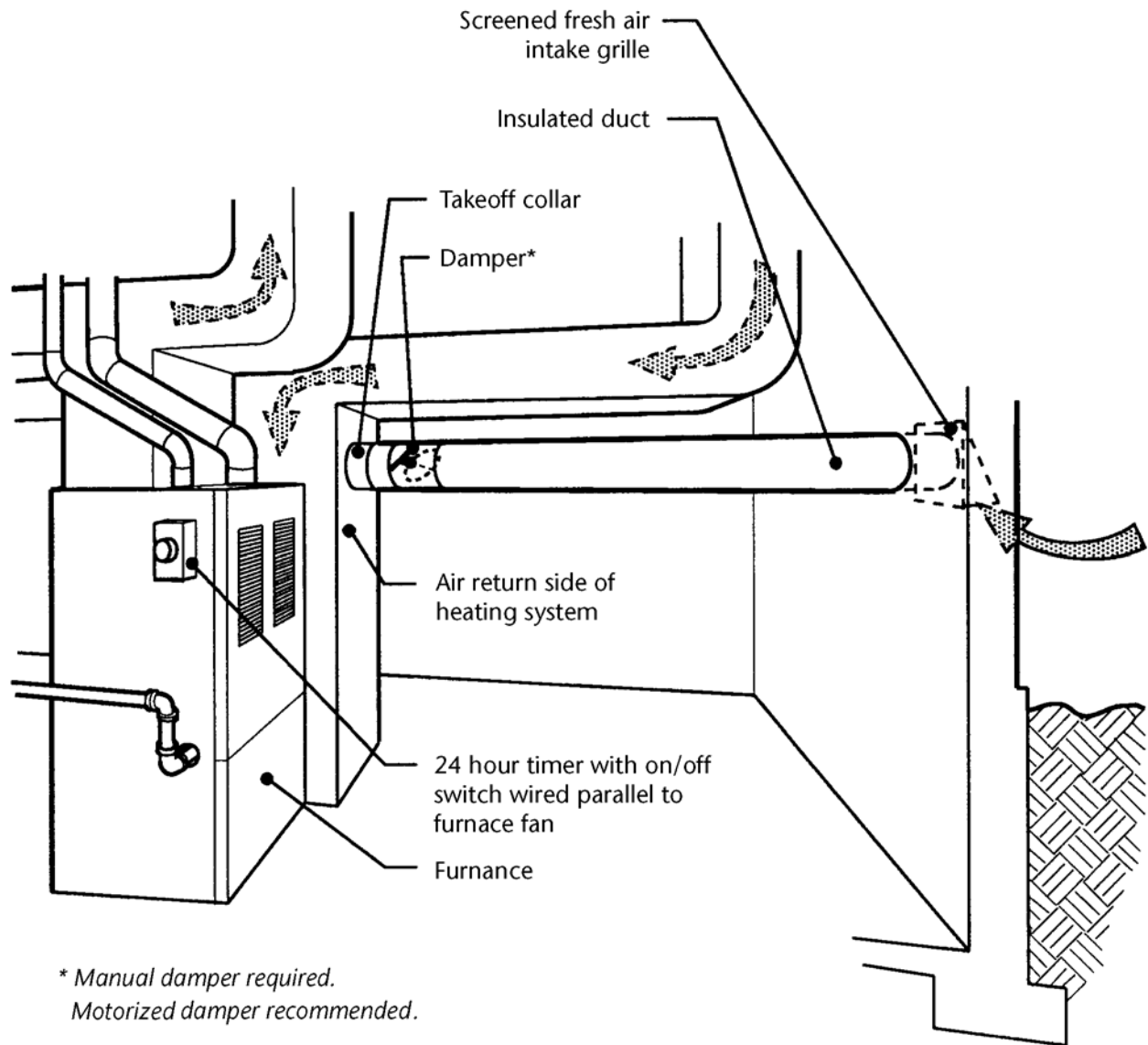


Figure 8-6

Prescriptive Integrated Forced Air Supply Duct Sizing

Required Flow (CFM) Per Table 3-2	Minimum Smooth Duct Diameter	Minimum Flexible Duct Diameter	Maximum Length ¹	Maximum Number of Elbows ²
50-80	6 inches	7 inches	20 feet	3
80-125	7 inches	8 inches	20 feet	3
115-175	8 inches	10 inches	20 feet	3
170-240	9 inches	11 inches	20 feet	3

1. For lengths over 20 feet, increase duct diameter 1 inch.
 2. For elbows numbering more than 3, increase duct diameter 1 inch.

[V303.4.2.1]

The Code requires that the fresh air duct be connected to a terminal element outside the building and run to the return plenum within 4 feet of the air handler (see Figure 8-7). Terminal elements must be screened and sized to be greater or equal to the net free area of the duct.

Terminal Element

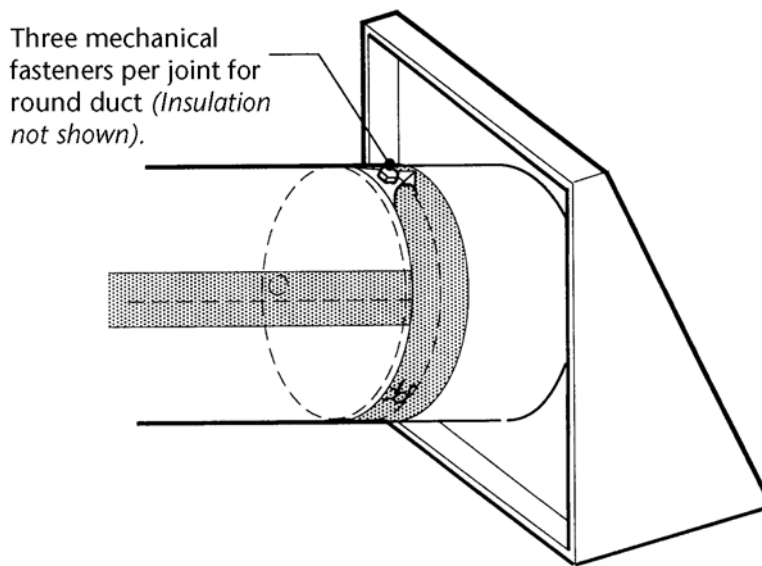


Figure 8-7

[V303.4.2.1]

The duct must also be equipped with a damper and three choices are given:

- A motorized damper connected to the automatic ventilation control (see Figure 8-8).
- A manual damper installed and set to meet measured flow rates in VIAQ Table 3-2.
- Or an automatic or flow-regulated device.

Motorized Damper. When this damper is used, no testing of ventilation flow rates is required, as long as the prescriptive duct sizing VIAQ Table 3-5 requirements are met. Operation should be described in the required instruction manual.

Damper Meeting VIAQ Table 3-2 Flow Rates. This is a manual or volume type damper set to a certain CFM at the site. This system must either be tested or installed according to manufacturer's installation instructions based on site conditions. Operation should be described in the required instruction manual.

Automatic or Flow-Regulated Device. This type of damper refers to a constant airflow regulator, which limits airflow to a specified CFM. This device may be used when it is demonstrated, by field testing or calculation, that there is at least .07" water gauge negative pressure at the connection of the outside air duct and the return air plenum must be the same size as the connecting duct work or 8 inches in diameter, whichever is larger (see Figure 8-8).

Types of Dampers

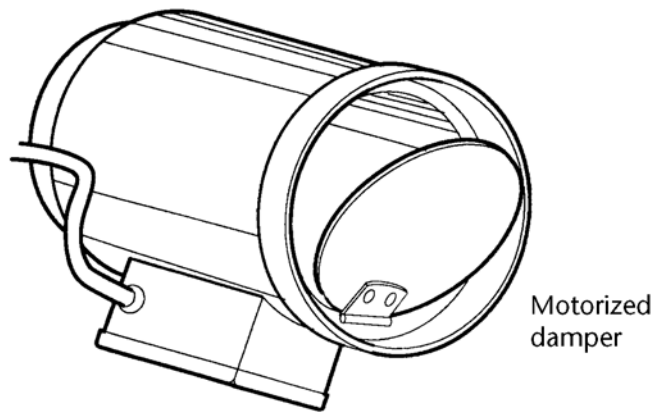
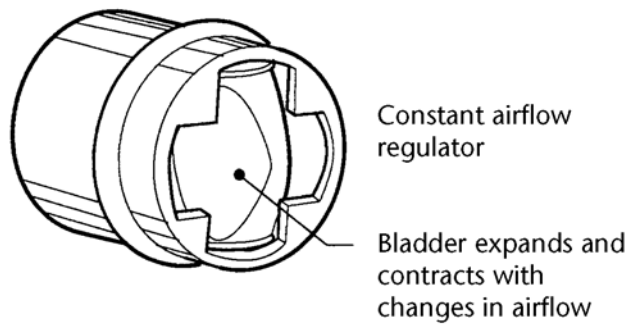
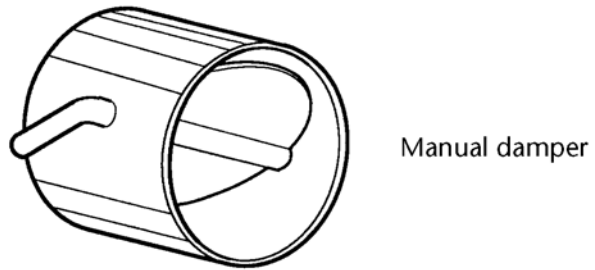


Figure 8-8

[V303.4.3]

Prescriptive Requirements for Ventilation Using a Supply Fan

[V303.4.3.1]

This option provides fresh air to all habitable spaces through the use of a dedicated supply fan. This system can be installed in conjunction with a forced air heating system, or as a stand alone supply air system. In both cases, duct runs are required to each habitable room.

This system provides fresh air with a smaller and quieter fan than systems integrated with forced air heating/cooling fan. This reduces ventilation energy cost.

A Ventilation System Using a Supply Fan includes:

- A Dedicated Supply Fan.
- A fresh air duct, connected to the furnace supply plenum or a dedicated whole house ventilation duct. The duct shall be sized according to VIAQ Table 3-6.
- A clock timer set to operate only the dedicated supply fan for appropriate ventilation periods.
- A filter located in fresh air supply duct, fan housing or in the case of connection to the return duct, in the furnace.

VIAQ Table 3-6

Prescriptive Supply Fan Duct Sizing

Supply Fan Tested CFM at 0.40" WG		
Specified Volume from Table 3-2	Minimum Smooth Duct Diameter	Minimum Flexible Duct Diameter
50 – 90 CFM	4 inch	5 inch
90 - 150 CFM	5 inch	6 inch
150 - 250 CFM	6 inch	7 inch
250 - 400 CFM	7 inch	8 inch

The supply duct must also be equipped with a damper and three choices are given:

- A motorized damper connected to the automatic ventilation control (see Figure 8-8).
- A manual damper installed and set to meet measured flow rates in VIAQ Table 3-2. (see Figure 8-8).
- An automatic or flow-regulated device. (see Figure 8-8).

Motorized Damper. When this damper is used, no testing of ventilation flow rates is required, as long as the prescriptive duct sizing VIAQ Table 3-5 requirements are met. Operation should be described in the required instruction manual.

Damper Meeting VIAQ Table 3-2 Flow Rates. This is a manual or volume type damper set to a certain CFM at the site. This system must either be tested or installed according to manufacturer's installation instructions based on site conditions. Operation of this system is required as described in the instruction manual.

Automatic or Flow-Regulated Device. This type of damper refers to a constant airflow regulator, which limits airflow to a specified CFM. This device may be used when it is demonstrated, by field testing or calculation, that there is at least .07" water gauge negative pressure at the connection of the outside air duct and the return air plenum must be sized using VIAQ Table 3-6. Manufacturer's instructions should be part of the required instruction manual.

Example of Ventilation Using a Supply Fan

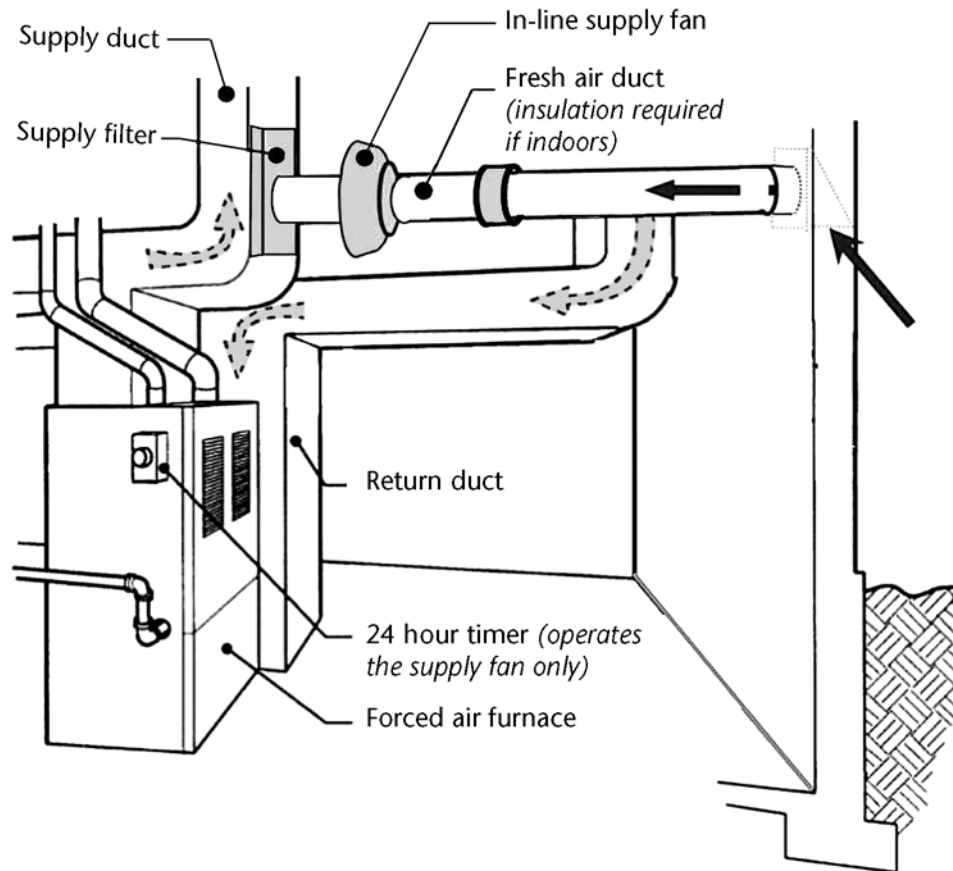


Figure 8-9

Heat Recovery Ventilation

[V303.4.4]

Heat recovery systems are exempt from maximum flow rates and sound rating requirements. Either air-to-air heat exchangers or exhaust air heat pumps may be used.

Air-to-air heat exchangers must meet the following requirements:

- Minimum 6 inch ducts.
- Balancing dampers on the inlet and exhaust ducts.
- Flow grids installed on both supply and return ducts (for balancing).

Chapter 9: Fireplaces and Wood Stoves

[V402.1] To ensure indoor air quality and reduce heat loss, the Washington State Ventilation and Indoor Air Quality (VIAQ) Code places installation requirements on all solid fuel combustion appliances including:

- All wood stoves, including cook stoves.
- Pellet stoves.
- Fireplaces.
- Masonry heaters (must have Washington State Department of Ecology approval).

Combustion Air

In order to prevent backdrafting, an adequate supply of combustion air must be supplied to each solid fuel combustion appliance (see Figure 9-1).

[V402.2b1] Combustion air must:

- Come from outside the building structure.
- Originate from a point below the firebox.
- Enter through a minimum 4-inch diameter duct (minimally 6 square inches for fireplaces) less than 20 feet in length.
- Be directly connected to the appliance (see Figure 9-1).

Exceptions: Combustion air may be supplied to the room in which the solid fuel combustion appliance is located rather than directly to the appliance when either:

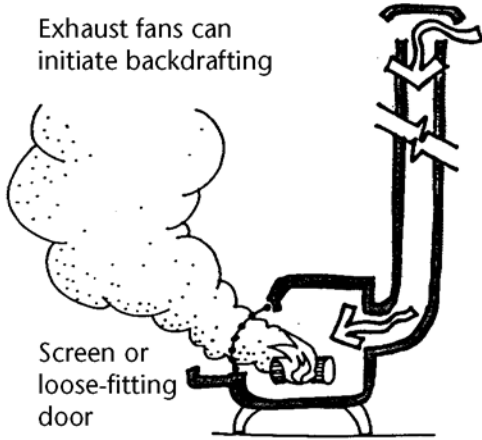
- The appliance is part of a central heating system installed in an unconditioned space in accordance with the International Mechanical Code (IMC).
- Or the appliance is installed in existing construction directly on a concrete floor or surrounded by masonry as in a fireplace.

Backdrafting

Caused by reduced air pressure relative to outside

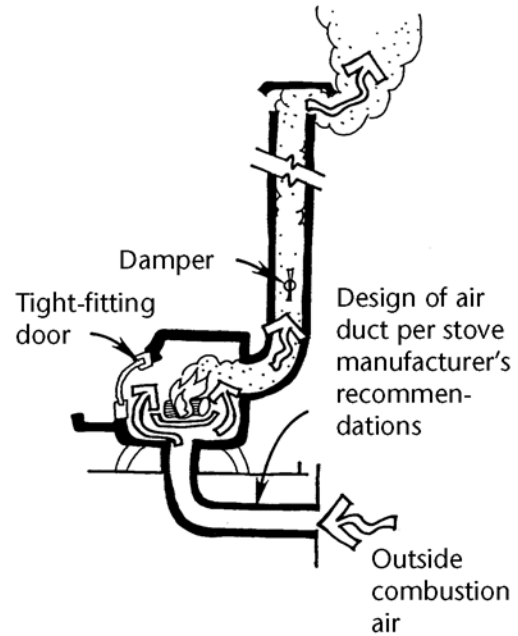
Wind can initiate backdrafting

Exhaust fans can initiate backdrafting



Screen or loose-fitting door

Correctly Operating Stove with Outside Combustion Air



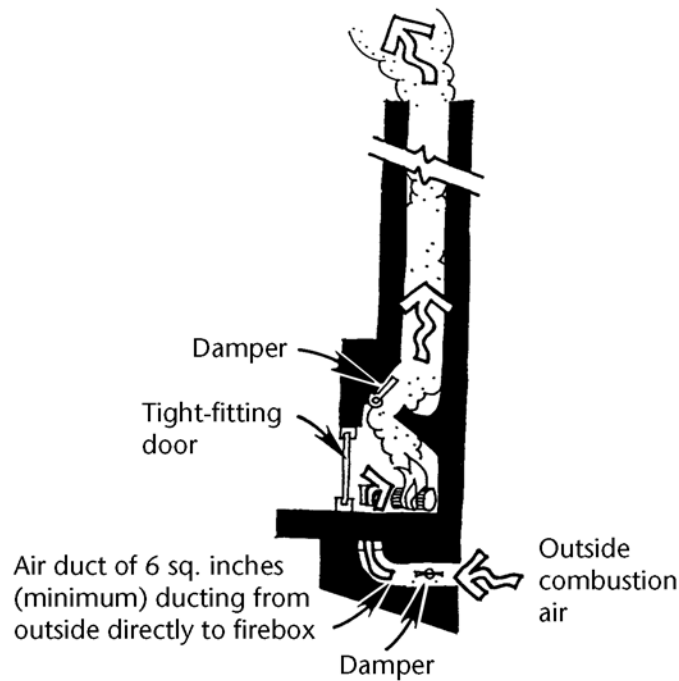
Damper

Tight-fitting door

Design of air duct per stove manufacturer's recommendations

Outside combustion air

Correctly Operating Fireplace with Outside Combustion Air



Damper

Tight-fitting door

Air duct of 6 sq. inches (minimum) ducting from outside directly to firebox

Outside combustion air

Damper

Figure 9-1

Site-built fireplaces may use a flue draft induction fan instead of doors.

In addition: Alternative methods of providing combustion air (using manufacturer's specifications) are allowed if the unit and combustion air supply have been certified. They must have passed a test specified by the VIAQ (see VIAQ 504.2.2) and the test must have been done by an independent lab.

Tight-Fitting Doors

[V402.2a,3c,
402.4b]

All solid fuel burning appliances, fireplaces, and masonry heaters must have tight-fitting ceramic glass or metal doors.

Exception: Site-built fireplaces may use a flue draft induction fan instead of doors.

Note: Although a flue draft induction fan will minimize potential backdrafting glass doors are also recommended to prevent heat loss when the fireplace is not in use.

Flue Dampers

[V402.3a]

Fireplaces must have a tight-fitting flue damper.

Exception: Fireplaces with gas logs must be installed in accordance with IMC.

Chapter 10

Default Heat Loss Coefficients

Building component heat loss coefficients are used extensively when complying with either the **Component Performance** or **System Analysis Approach**. The **Prescriptive Approach** only utilizes heat loss coefficients for doors, windows and skylights.

WSEC Chapter 10 lists default heat loss coefficients for hundreds of building assemblies. Heat loss coefficients are listed as default **F-factors** for slabs and default **U-factors** for most other components.

The WSEC Chapter 10 default heat loss coefficients for **windows, skylights** and **doors** should only be used when the product manufacturer or dealer cannot provide you with National Fenestration Rating Council (NFRC) tested U-factors. In most cases it will be to your advantage to contact the manufacturer to obtain NFRC tested U-factors before submitting your application for a building permit.

Component Descriptions

To assure you select the correct heat loss coefficient, it is important to read the description of the component that precedes each table. The heat loss coefficient will vary based on the construction method. Examples of construction details that will change the heat loss coefficient include framing style, siding type, slope of attic, insulation type and insulation location. The illustrations used in earlier chapters of this guide will help you visualize the written descriptions.

What to do if a building system is not listed in WSEC Chapter 10

[104]

WSEC requires that plans and specifications be submitted to the building official with all the needed supporting data.

This could include detailed U-factor calculation for building systems not detailed in the Chapter 10 default heat loss coefficients. Heat loss coefficients should be calculated

using the methods detailed in the *ASHRAE Handbook of Fundamentals*.

Manufacturers of pre-fabricated building assemblies may have engineering staff available that will provide the required calculations.

Links to WSEC Chapter 10 Default Heat Loss Coefficients

Table 10-1: Default Wall U-Factors and Slab F-Factors for Basements

Table 10-2: Default F-Factors for On-Grade Slabs

Table 10-3: Default U-Factors for Floors Over Vented Crawlspace or Unheated Basement

Table 10-4: Default U-Factors for Floors Over Heated Plenum Crawlspaces

Table 10-4A: Default U-Factors for Exposed Floors

Table 10-5: Default U-Factors for Above-Grade Walls

- 2 x 4 Single Wood Stud: R-11 Batt
- 2 x 4 Single Wood Stud: R-13 Batt
- 2 x 4 Single Wood Stud: R-15 Batt
- 2 x 6 Single Wood Stud: R-19 Batt
- 2 x 6 Single Wood Stud: R-21 Batt
- 2 x 6 Single Wood Stud: R-22 Batt
- 2 x 6 Single Wood Stud: Two R-11 Batts
- 2 x 8 Single Stud: R-25 Batt
- 2 x 6: Strap Wall
- 2 x 6 + 2 x 4: Double Wood Stud
- 2 x 4 + 2 x 4: Double Wood Stud
- Log Walls
- Stress Skin Panel

Table 10-5A: Default U-Factors for Overall Assembly Metal Stud Walls

Table 10-5B: Default U-Factors for Concrete and Masonry Walls

- 12" Concrete Masonry
- 8" Clay Brick
- 6" Concrete Poured Or Precast

Table 10-6: Other Than Group R Occupancy: Default U-Factors for Vertical Glazing, Overhead Glazing and Opaque Doors

- Vertical Glazing
- Overhead Glazing
- Opaque Doors

Table 10-6A: Group R Occupancy: Default U-Factors for Vertical Glazing

Table 10-6B: Group R Occupancy: Default U-Factors for Vertical Glazing for Small Businesses

Table 10-6C: Group R Occupancy: Default U-Factors for Doors

- Revolving Doors (Rough Opening: 82 in. x 84 in.)
- Sectional Overhead Doors (Nominal: 10 ft. x 10 ft.)

Table 10-6D: Group R Occupancy: Default U-Factors for Glazed Doors

Table 10-6E: Group R Occupancy: Default U-Factors for Overhead Glazing

Table 10-7: Default U-Factors for Ceilings

Table 10-8: Assumed Effective Air Changes Per Hour

Table 10-8A: Default Heat Capacity/Density Product for Air

Table 10-9: Heat Capacity

Table 10-10: Default Mass Values

Supplement A

Improving Forced Air Heating Systems

The Challenge

Recent research and testing of new homes in the Pacific Northwest and across the United States shows the importance of a properly installed HVAC system. Interactions between system components, the house envelope, and other equipment can seriously affect:

- Occupant health and safety;
- Occupant comfort;
- Equipment and structural durability; and
- Energy efficiency.

The Washington State Energy Code (WSEC) provides specifications for duct sealing, duct insulation, equipment sizing, equipment efficiency, and controls that provide a basis for a safe, efficient system. In forced air heating and cooling systems, attention to detail in duct installation is very important. Ductwork that is undersized, unbalanced, or leaky can cause serious problems. Understanding these problems helps you build a better, safer home for your client that meets the intent, as well as the letter, of the Code.

Health and Safety

Leaky ducts can compromise health and safety. Because the air handler fan drives air into the ductwork, even small leaks can have a large impact. When duct leaks are connected to areas outside of the conditioned space, the leakage induces pressure changes across the envelope of the house. Supply leaks depressurize the house. Return leaks pressurize the house (see Figure A-1.) Depressurization can cause combustion appliances to backdraft. Backdrafting allows flue gases to enter the living space and can

Supply and Return Leakage

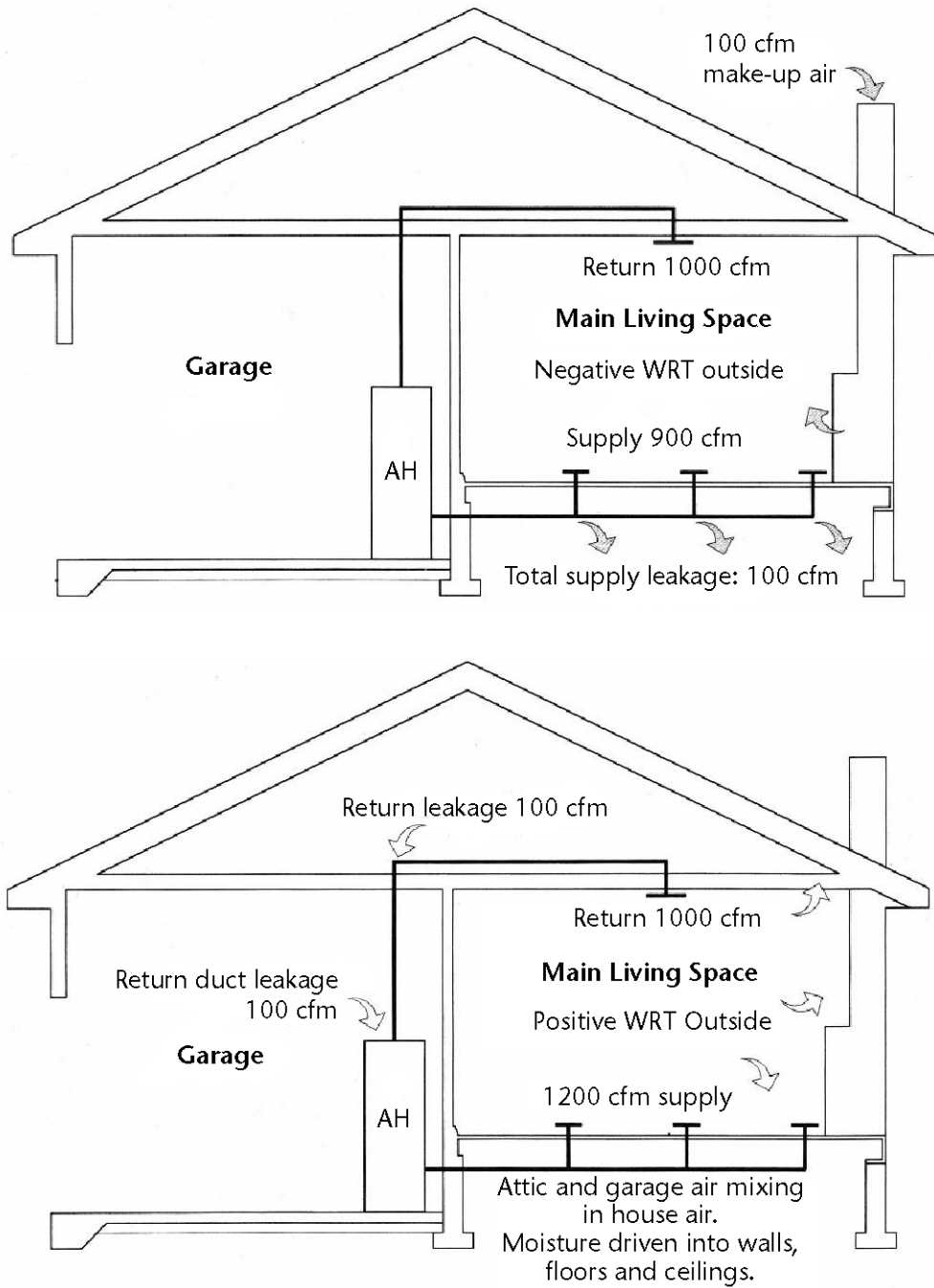


Figure A-1

Unbalanced Duct System

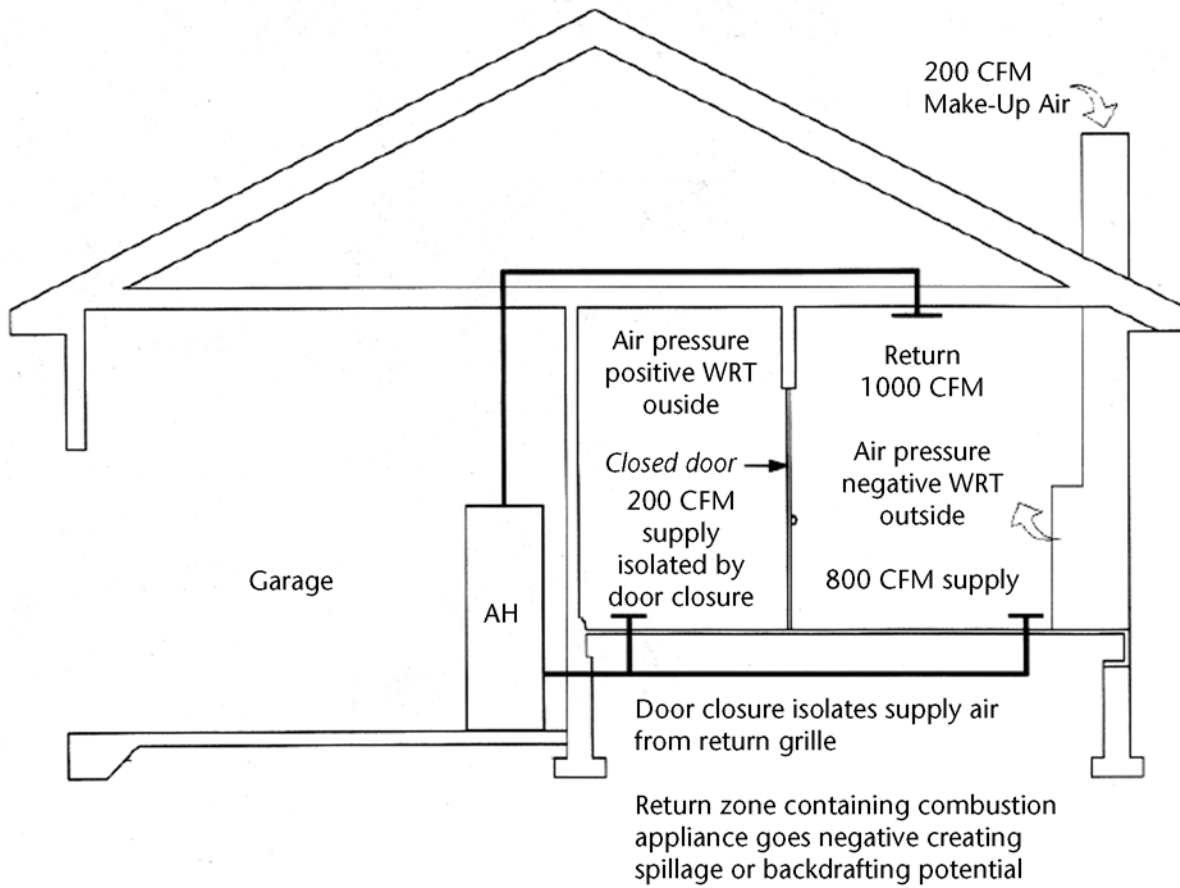


Figure A-2

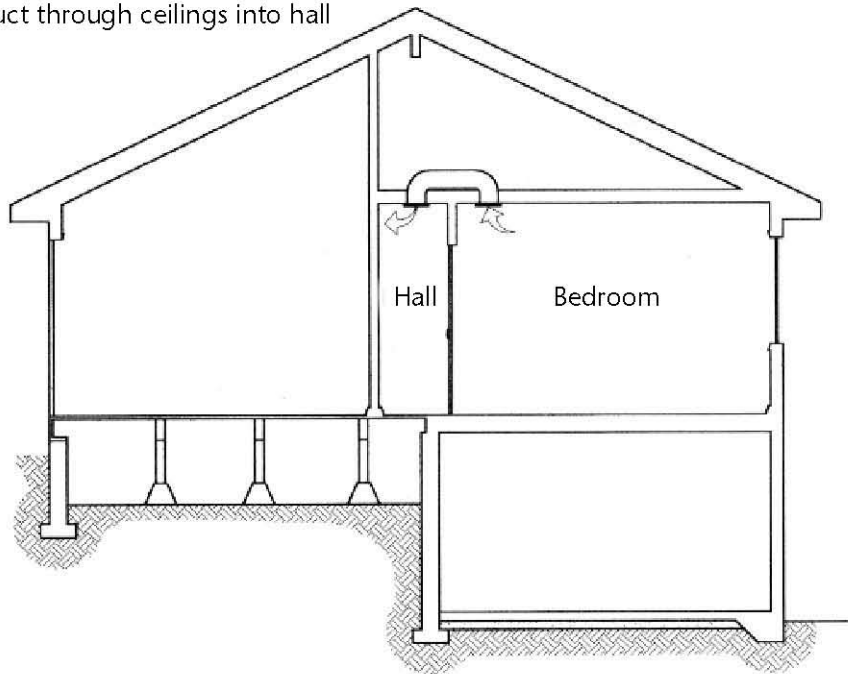
be very serious, potentially leading to death from carbon monoxide exposure. Return leaks in a confined area such as a utility room or basement can also induce depressurization. This can backdraft an adjacent gas-fired water heater, or suck soil gases (such as radon) into a basement. Return leaks in a garage, crawlspace, or attic can potentially introduce pollutants into a house, adversely affecting indoor air quality.

Unbalanced duct systems also cause pressure problems. In systems with central returns (very common in newer homes) supply registers and return grilles are often isolated when bedroom doors are closed. With the door closed, the zone with the return depressurizes, again creating potential backdrafts (see Figure A-2).

Testing in new homes shows that approximately 1 square inch of unobstructed return air pathway is required for each CFM of supply air delivered to a zone. This may be accomplished with ducted returns in each zone, undercut doors, transfer grilles, or some combination of the above (see Figure A-3).

Unobstructed Return Air Options

Duct through ceilings into hall



Through-wall transfer grille to hallway

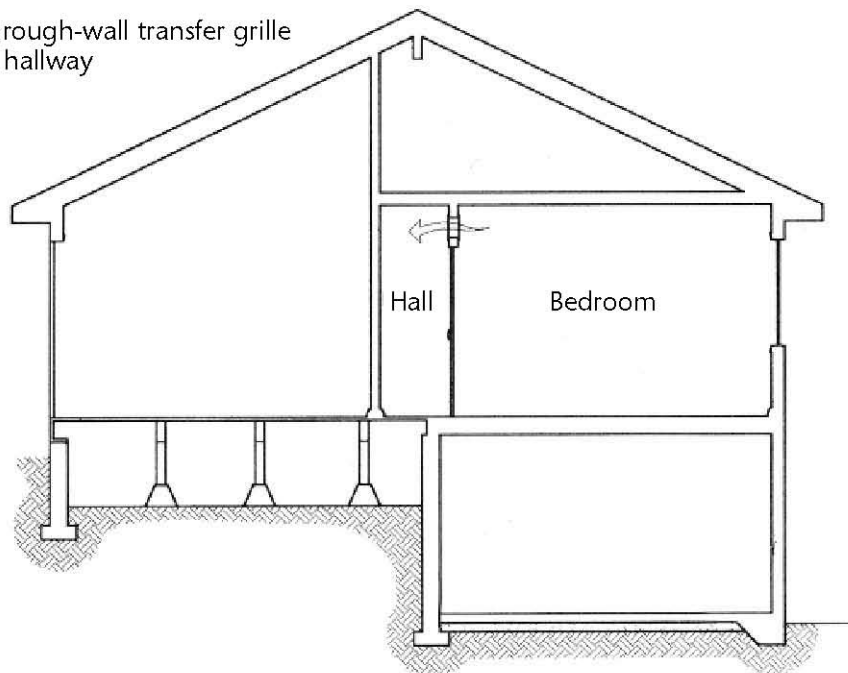


Figure A-3

Moisture Damage Resulting from Return Duct Leakage



Improper duct design and sizing can cause heating and cooling equipment to operate out of manufacturer's specifications for temperature rise, pressure drop, or air flow. This impacts efficiency and equipment lifetime. Airflow through the system is especially important for air conditioning and heat pump equipment. Inadequate airflow is a major cause of premature compressor failure. Follow manufacturer's specifications, but generally look for 400-425 cfm of airflow per ton of installed capacity.

Figure A-4

Comfort

Leaky ducts can also cause comfort problems. When supply ducts leak, the air delivery to different parts of the home may not match heating and cooling loads. If the ducts are well sealed, the register dampers can be adjusted to distribute conditioned air where it is needed. If the ducts leak, this control option is lost.

Return leaks connected to the outside can change the return air temperature, adversely impacting system performance.

Example: A large return leak in an attic in the summer time may draw 150°F air into the system rather than 75-80°F house air. The higher return temperature can overwhelm the system capacity and make it impossible to cool the home.

Duct leakage may also change the air infiltration rate of the home leading to excessive dryness during the heating season and high humidity levels during the cooling season. Both are common comfort complaints.

Improperly sized ductwork and poor register placement often contribute to comfort problems. Inadequate or excessive airflow may result from poor design. Heat pump systems with lower delivery temperatures are especially vulnerable to comfort complaints because of the higher volumes of air that must be moved.

Durability

Leaky return ducts connected to the outside pressurize a home. Unbalanced systems also induce pressurization in zones where supply air does not have an adequate return pathway (see Figure A-1). Pressurized zones in homes in heating climates may adversely affect structural durability. During the heating season, positive pressure in the home causes warm moist air to flow into building cavities. As the air reaches colder exterior surfaces, the moisture condenses and wets the building materials.

Example: The picture in Figure A-4 shows moisture damage to the exterior siding on a new home caused by a return

System with Fully Ducted Returns

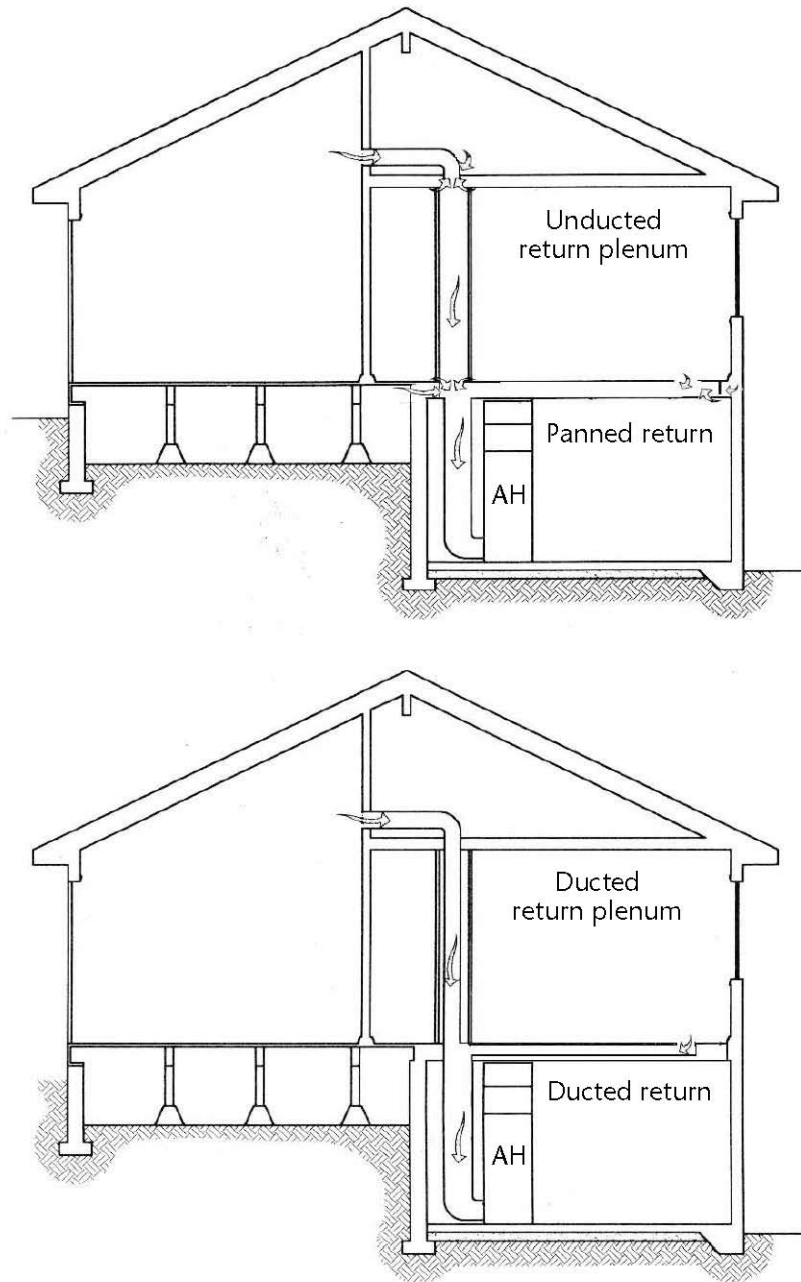


Figure A-5

duct leak, which pressurized the house and drove moisture into the exterior wall. The area of most severe damage is the exterior wall for an upstairs bathroom. The use of air cleaning systems with continuous run times exaggerates this problem, making proper sealing and balancing even more important.

Energy Efficiency

The problems that impact health and safety, comfort, and durability can also adversely affect energy efficiency. Leaky ducts can deliver conditioned air to unconditioned spaces. Pressure differentials created by leaky ducts or unbalanced systems increase whole house air leakage rates. To put this in perspective, studies have shown that, even in new homes, many systems perform below their expected efficiency (losses of 20-30% are not uncommon.)

Ductwork and its interaction with the house has a significant impact on overall system effectiveness. When system components operate outside of manufacturer's specifications for temperature rise, pressure drop, or air flow, efficiency is often lost.

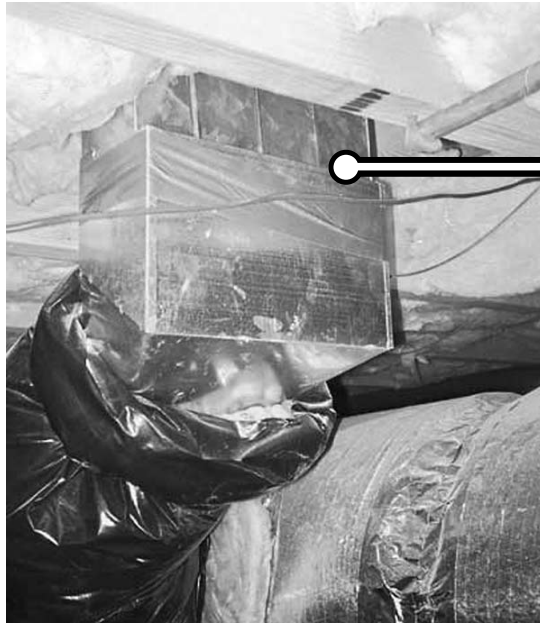
The Solutions

Duct Sealing

To achieve optimum duct sealing performance, the following practices are recommended:

- Don't use building cavities as ductwork. Testing in Northwest homes has shown that return ducts leak far more often than supply ducts. This is associated with the use of panned floor joists and building cavities used as part of the return system. Making a tight well-sealed duct out of a building cavity is often very difficult. For a quality system, it may be less expensive (in the long run) to install a fully ducted return (see Figure A-5).

Poor Duct Fittings Can Not be Well Sealed



Tight fittings and assembly are required to control duct leaks over the long term.

Figure A-6

Tight fittings and Mastic Make the Best Seal

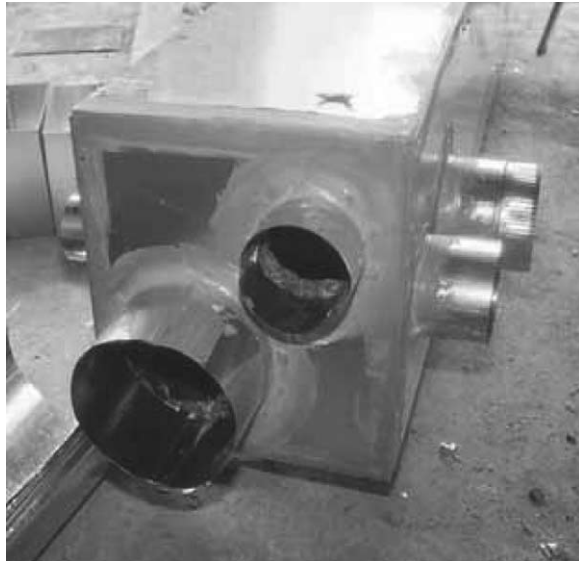


Figure A-7

- Select fittings that don't leave large gaps in the system. Many ducts are assembled with large gaps between fittings. Even if they are well sealed when first installed, this practice will eventually lead to sealing failure. Duct sealing materials simply are not designed to seal large holes for long periods of time. Tight fittings and assembly are required to control duct leaks over the long term (see Figure A-6).
- Don't use "duct tape" – instead, use durable sealing materials. Advanced aging tests conducted on commonly used duct sealing materials by Lawrence Berkeley National Laboratory concluded that duct tape is a poor performer. Cloth or vinyl backed duct tapes with rubber adhesives failed very quickly and are not recommended for duct sealing. The metal-backed tapes with acrylic adhesive worked better. Mastics were by far the most durable (see Figure A-7).
- Select sealing materials that are compatible with duct system components. Duct sealing materials need to be installed according to manufacturers' instructions. Many tapes require that the ducts be clean and oil free before installation. Using sealants rated under the UL 181 standard assures compatibility with duct board and flexible duct systems.
- Use performance testing methods to assure a tight seal. Contractors should consider duct tightness testing. While this may not be practical on every job, it is a valuable learning experience. Duct tightness testing will provide feedback on problem areas and sharpen a crew's ability to provide quality installations. Testing can also alert contractors to potential liabilities associated with combustion appliance back-drafting, as well as durability

issues. Tests are required to obtain Energy Efficient Mortgages and the Energy Star® Homes five star rating. Make sure the ducts are fully insulated. The code requires R-8 insulation for ducts outside the conditioned space (R-5 in slabs or the ground.) The Super Good Cents® energy efficiency standard suggests that insulating ducts up to R-11 is cost-effective in electrically heated homes. See Chapter 7 of the *Builder's Field Guide* for more detail.

Move the Ductwork Inside

Rather than placing the air handler and duct work in the garage, crawlspace or attic, consider moving it inside. By bringing the components inside the insulation and air barrier of the home, significant energy savings can be achieved. By keeping the system completely indoors, the chance of bringing poor quality air in from the garage or attic space is eliminated. An additional benefit is that ducts installed in the heated space do not require insulation.

Studies conducted in the Northwest indicate that forced air heating systems located completely indoors will reduce energy use by about 30%. This can be accomplished at no additional cost. When the builder provides a space indoors for the equipment and ducts, it reduces the HVAC contractors' cost. The HVAC contractor will use less ductwork, will not need to insulate the ducts, and will be able to work in better conditions. The HVAC contractor will also be able to specify smaller equipment, reducing cost further. The builder will need to provide an indoor space for the ducts. This may add to the cost of framing and drywall. Per project, the HVAC contractor and builder cost will usually offset each other.

Moving the heating system indoors is most easily accomplished in two-story homes. The duct work can be placed in the space between the floors. Much of the system can be placed in existing floor cavities (see Figure A-8).

Ducts Placed Within the Floor Joists



Figure A-8

Where transitions must be made between floor cavities, drop soffits are traditionally used (see Figure A-9).

Drop Soffit Conceals Ducts



Figure A-9

The increasing use of engineered floor trusses provide additional opportunities for moving ducts easily between floors. Most composite wood trusses can be cut to accommodate large transitions across the floor joist. Web trusses provide the greatest opportunity. Steel webs with wood cords provide areas large enough to incorporate substantial duct systems (see Figure A-10).

Engineers Trusses Provide Space for Ducts Between Floors

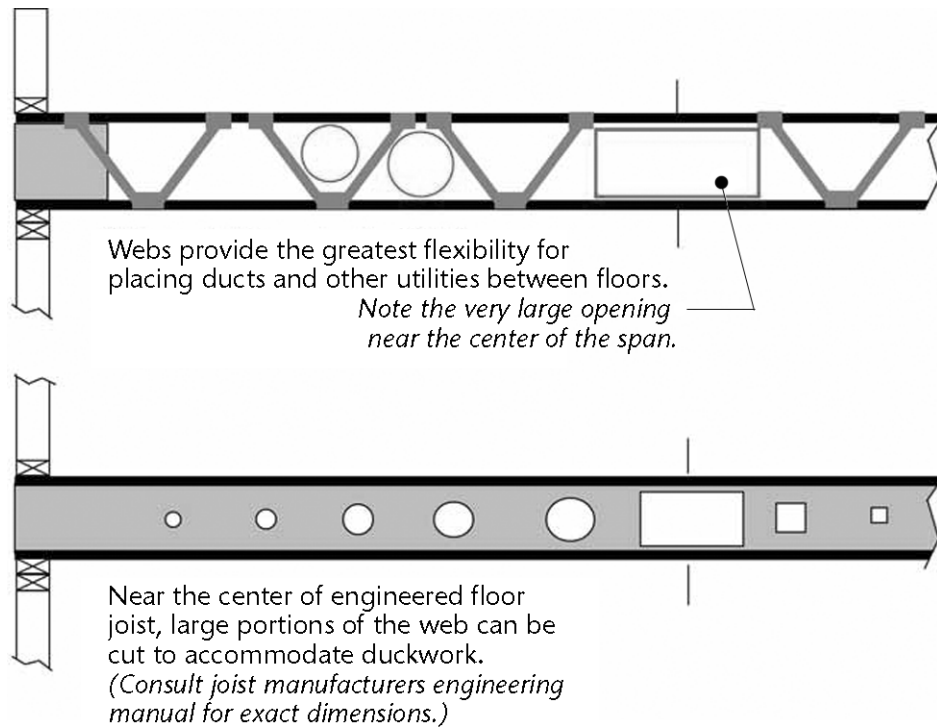


Figure A-10

Bringing combustion furnaces inside the envelope requires care in meeting combustion air and venting requirements. Direct vent and sealed vent equipment are likely the best solutions.

Heating System Design and Installation

Heating systems do not perform to promised specifications when the ducts are not the correct size. Ducts supplying air to individual rooms need to be sized to provide air flow that matches the heating requirement of the room. The entire system must be designed so that it allows the correct air flow through the heating and cooling equipment. In many cases, these two criteria are not met. This leads to comfort problems, and loss of equipment efficiency.

To correctly size duct systems, use recognized engineering principles and calculated loads. The most widely used methods are *ACCA* Manual J* heat loss method and *ACCA Manual D* duct sizing method.

The home designer needs to provide space for the ductwork. Forced air heating systems need to be included in the home planning process. Too often systems fail because the home designer has not provided space for equipment and ductwork. Home designers should consult the HVAC contractor early in the design process.

* Air Conditioning Contractors of America Association, Inc.

Recommended Practice

Follow these suggestions to build quality HVAC systems:

- Meet or exceed Code requirements. Codes affecting HVAC installations are set up to establish minimum safety and efficiency standards. It's a good place to start.
- Size and design duct systems using recognized engineering principles and calculated loads.
Examples: ACCA Manual D and ACCA Manual J.
- Install equipment according to manufacturer's instructions.
- Test and adjust the equipment and the distribution system.
- When combustion appliances are present, provide for combustion safety. Vent properly, provide combustion air, minimize negative pressures, test for CO (carbon monoxide) production and backdrafting, install CO alarms, and educate the homeowner about combustion safety.
- Where possible, install ducts in the heated space.
- Seal ducts.
- Insulate ducts not installed in the heated space.
- Use a systems approach to assure health and safety, comfort, durability and energy efficiency.

Supplement B

Taking Credit for Reduced Air Leakage in Residential Buildings

In recent years, a growing number of Washington State Energy code (WSEC) submittals have attempted to take credit for energy savings that result from air sealing of homes. In many cases these submittals do not include accurate energy simulations and are not performing tests to confirm that they meet the proposed infiltration levels. This supplement will discuss the code language, documentation, and field inspection as it applies to air leakage control in residential buildings.

Chapter 4 of the WSEC allows applicants to take credit for building practices that reduce energy using the systems analysis approach. This approach allows applicants to take credit for improved heating system efficiency, impacts of glazing type and orientation, and other features not covered by the component trade off or prescriptive compliance methods. Software capable of evaluating building performance is used to demonstrate compliance with the code.

Systems analysis is by far the most complex code compliance approach, and both the applicant and code official need to know how to handle these complexities. When evaluating a systems analysis submittal, code enforcement personnel need to establish early on if the software is capable performing needed calculations and whether the proposed measures can be verified during inspection.

What Does the Code Say About Air Leakage Control Credits?

WSEC language is very specific when it comes to the air leakage rate to be used in systems analysis calculations:

[402.1.5]

Infiltration levels used shall be set at 0.35 air changes per hour for thermal calculation purposes only.

As written, the code does not implement a method for taking credit for reduced air leakage in homes. The Code requires that 0.35 ACH be used for both the proposed and target building calculations. In addition, the code does not specify how to calculate the energy impacts of required mechanical ventilation.

The history of this code language dates back to the original adoption of the WSEC in 1990. The code enforcement community did not want to administer additional inspections needed to verify reduced air leakage in homes.

Because of the limitations placed in the code, credit for reduced infiltration must be submitted as an alternative method. The applicant must submit documentation that includes the proper methodology for calculating and inspecting a home with reduced air leakage. Because this is an alternative method, the building department has the latitude to accept or reject the proposed alternative for technical or administrated reasons as stated in WSEC Section 103.

What About Mechanical Ventilation?

In a home with average air leakage area, mechanical ventilation will add about 50% of the fan flow to the natural air change rate. In a home with very little air leakage area, mechanical ventilation will add nearly 100% of the fan flow to the natural air change rate. This occurs because it is more difficult for the fan to overcome the natural stack effect in homes with more air leakage area. Balanced mechanical ventilation systems with equivalent supply and exhaust flows will always add 100% of the fan flow to the natural air change rate. Given the code requirements

for mechanical ventilation, the net annual air change rate in homes will rarely drop below 0.25 per hour.¹

Also at issue is the size of the ventilation fan. Some heat recovery ventilators have a much higher capacity than the minimum ventilation rate specified in the code. If the code requires a 100 CFM exhaust fan and the builder installs a 300 CFM HRV, there won't be any energy savings. As noted below, the software chosen to document savings from reduced air leakage needs to include the capability of analyzing the impacts of the mechanical ventilation system.

What are the Software Capabilities?

The two most popular programs used for energy analysis in Washington, WATTSUN and SUNDAY, are capable documenting the energy savings achieved through reduced air leakage in homes. However, they don't account for required mechanical ventilation. Without including mechanical ventilation in the analysis, the simulation will overestimate the savings of reduced air leakage.

A DOE-2 based program called Energy Gauge does a acceptable job of analyzing this variable.

What are the Recommended Inspections and Tests?

Systems analysis is a whole building approach. Air leakage involves all of the systems in the building. A builder might do a fine job of air sealing the building envelope, but if the back-draft dampers aren't in place on the kitchen exhaust, the building won't perform to the levels promised in the submittal. A blower door test is needed to confirm that the proposed air leakage rate has been achieved as part of the inspections process. There are a number of methods for testing and calculating the results. For simplicity, we recommend a single point blower door test (see next page for details.)

¹ John Heller, *Residential Construction Demonstration Project: Cycle III. Analysis of Innovative Ventilation Systems in Multifamily Buildings*, Bonneville Power Administration, Portland, 1998, p. 4.

What are the qualifications for blower door test professionals? Should code enforcement personnel observe the test? This is not established in the code. The applicant and the jurisdiction will have to agree on qualifications and procedure as part of the permit application. We strongly recommend an independent third party testing agency.

What Happens if the Applicant Fails the Blower Door Test?

This is a sticky issue. Because the test occurs at or near the completion of the home, failure puts both the applicant and code enforcement personnel in a difficult position. If there is one large hole in the building, it is fairly easy to identify the air leakage path and plug it. In most cases, the additional leakage is the result of a series of very small failures in air sealing. Finding and fixing these failures can be difficult – particularly in very tight homes.

The best approach is to avoid failure during submittal by limiting proposed air leakage rates to reasonable levels. For example, if compliance requires passing a blower door test with results of 0.25 ACH, don't submit documentation that places the target at 0.10 ACH.

Summary

1. WSEC Chapter 4 does not allow credit for reduced air leakage in the home. Proposals must be submitted as an alternative method. The code officials can reject proposals for technical or administrative reasons.
2. The target value for home air leakage in the WSEC is 0.35 ACH.
3. Software selected needs to be capable of performing the needed calculations to account for building air sealing and mechanical ventilation.
4. Blower door tests should be used to document compliance.

Single Point Blower Door Test



Figure B-1

The blower door test does not measure air leakage. It is a measurement of the size of all the holes in the home. This is converted to an estimate of average annual air leakage by applying some math to the blower door test results. The final result is called ACH Natural.

To determine the air leakage rate of a home, a blower door test is performed. A specialized fan is placed in an exterior door of the home. The fan exhausts air from the home, creating a negative pressure in the home with respect to outdoors. The target test pressure used for single point test is 50 Pascals (0.205 inches of water). The blower door fan speed is adjusted until the target test pressure is achieved; then the flow through the fan is recorded. The fan flow is noted on the report as CFM50 (cubic feet per minute at 50 Pascals pressure difference). Set up for the test is important. The following notes should be used:

- Testing shall occur after everything is roughed-in/ installed that will penetrate the building envelope (plumbing, electrical, HVAC, ventilation, combustion appliances, etc.) and the air barrier has been

installed. Testing should NOT be conducted when wind gusts exceed 15 mph.

- All windows and doors shall be properly closed, including pass-through wood-box doors and pet doors. All interior doors shall be left open.
- All exhaust fan openings, vent openings, and intake-air vents with backdraft dampers (e.g., dryer vents and kitchen, bathroom, utility room, whole-house, range vents, etc.) shall **NOT** be sealed. Exterior vent openings without backdraft dampers (e.g., some continuous ventilation systems) shall be temporarily sealed for the test. Heat recovery ventilator supply openings shall be sealed. Heat recovery ventilator exhaust openings should have backdraft dampers and shall not be sealed.

Single Point Blower Door Test Math

Step 1:

Convert the blower door test value from CFM50 to ACH50 (air change per hour at 50 Pascals pressure difference)

$$\text{ACH50} = \text{CFM50} \times 60 / \text{Building Volume (cubic feet)}$$

Step 2:

Convert the ACH50 to ACH Natural

$$\text{ACH natural} = \text{ACH50} / 20$$

Example:

House Volume = 15000 cubic feet

Blower door test results = 1600 CFM50

$$\text{Step 1: } \text{ACH50} = (1600 \times 60) / 15000 = 6.4$$

$$\text{Step 2: } \text{ACH natural} = 6.4 / 20 = 0.32 \text{ ACH}$$

Supplement C

Thermal Performance of Common Insulation Materials

Below are listed nominal R-values for typical insulation materials. In some cases a range of R-values is listed to indicate variation in the materials. This will get you started. Specific insulation R-values should be obtained from the product manufacturer.

Use only nominal steady state R-values obtained using test methods approved by the Federal Trade Commission. Nominal R-value labeling is required for all insulation materials. At a minimum this is required to be on the packaging.¹

Batt, board and blanket insulation is labeled with the R-value. Washington State Energy Code (WSEC) requires that these labels be visible for inspection.

Loose or spray applied insulation must be applied at the manufacturers specified thickness and density to provide the tested R-value. This is documented by providing calculations of the volume of insulation installed per square foot of component area. For example, a count of the number of bags of cellulose insulation installed in a 1200 square foot attic can be used to determine the density of the product. An inspection of the depth of the insulation is also required.

The following list has been compiled from a number of sources. This includes the latest edition of the *ASHRAE Handbook of Fundamentals*.² Data obtained by other sources is referenced in the footnotes. For some assemblies we have developed tables that provide insulation values for a filled cavity as they would apply to the prescriptive application of the energy code.

¹ Title 16 – Commercial Practices Chapter 1 – Federal Trade Commission Part 460 – Labeling and Advertising of Home Insulation

² 2005 ASHRAE Handbook Fundamentals, American Society of Heating, Refrigeration and Air-Conditioning Engineers, Inc.

Table C-1

Thermal Performance of Common Insulation Materials

Fiberglass						
Type	Density	R /inch	2X4	2X6	2X10	2X12/Flat Ceiling
Batts LD	0.4-2.0	3.0-3.2	11	19		30 (10.0")
Batts MD	0.4-2.0	3.3-3.6	13			
Batts HD	1.2-1.6	3.6	15	21	30	38 (10.25")
BIBs HD	2.0	4.2	15	23	40	38 (9.0")
Loose fill	0.5-1.0	2.2-2.7				38 (17.0")

Cellulose <i>R-values obtained from the Cellulose Insulation Manufacturers Association</i>						
Type	Density	R /inch	2X4	2X6	2X10	2X12/Flat Ceiling
Loose fill	1.5 – 2.0	3.2 – 3.8				38 (12")
Wet Spray	3.5 - 4.0	2.94 – 3.0	10	17	28	36(12")
Dense Pack	5.5 – 6.0	3.3-3.45	12	19	33	41(12")

Rigid Board			
Type	Density	R /inch	
Extruded Polystyrene (XPS)	1.8 – 3.5	5.0	
Expanded Polystyrene (EPS)	1.0 – 2.0	3.85 – 4.36	
Polyisocyanurate	1.5 – 2.0	5.56 – 7.04	
Fiberglass, cellular glass	8.0	3.03	

Spray Applied Foam			
Type	Density	R /inch	
Polyurethane, closed cell	1.5 – 2.5	5.6 – 7.3	
Polyurethane, open cell	.5	3.7	

Duct Board & Duct liner			
Type	Density	R /inch	
Glass Duct Board	4.0 – 9.0	4.0	
Duct liner	1.75 – 3.0	3.7 - 4.2	

Supplement D

Insulated Concrete Form Systems

Thermal Characteristics

Insulated Concrete Form (ICF) systems use a prefabricated form made of foam insulation that is assembled into walls at the building site and filled with concrete. Systems vary, but generally they are composed of a layer of foam insulation, either expanded polystyrene (EPS) or extruded polystyrene (XPS), on the outside, a concrete layer in the middle and a layer of EPS or XPS foam on the inside.

Examples of Foam Forms

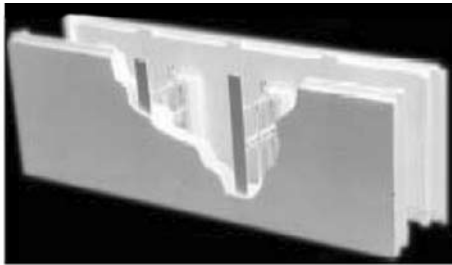
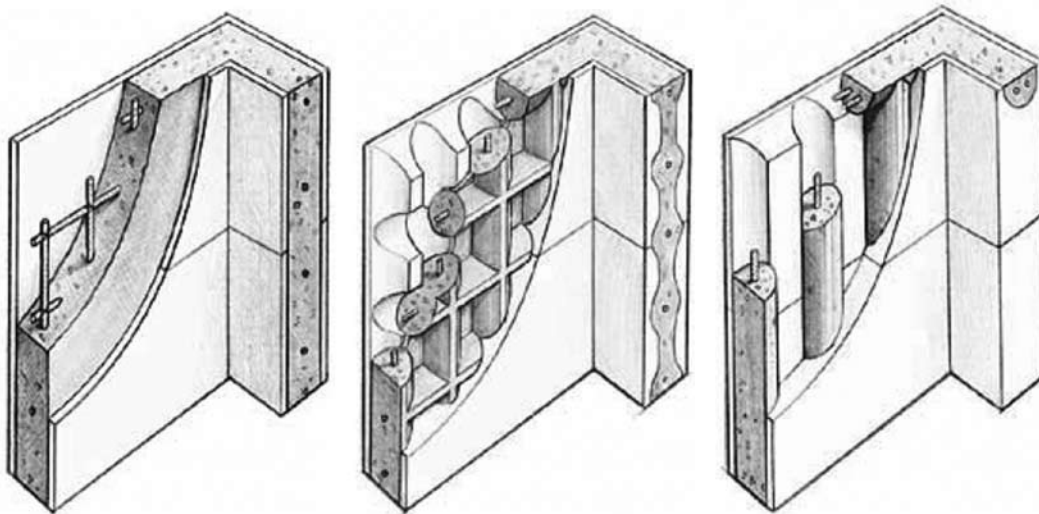


Figure D-1

Conventional finishes are applied to suit the building. ICF systems are differentiated by the type of insulation, the shape of the cavity and the method of connecting the insulation layers. The basic cavity shapes of the concrete blocks are flat, grid and post-and-beam. Many, but not all, ICF systems meet the thermal requirements of the Washington State Energy Code (WSEC), see WSEC Tables 6-1 and 6-2.

Examples of Various Conventional Finishes



Flat Wall

Grid Wall

Post & Beam Wall

Figure D-2

Why Do Some ICF Perform Better Than Others?

Not all ICF systems are constructed the same. The primary variables are the type of material used for the form, the ratio of concrete to form materials, and the type of ties. For example, an ICF with steel cross ties will have greater heat loss than one with plastic ties. Forms with more insulation and less concrete will have less heat loss than forms with high ratios of concrete to insulation.

Prescriptive Application of U-Factors

Strictly speaking, the prescriptive requirements in the WSEC do not allow the use of wall U-factors. But the use of U-factors as a demonstration of compliance with prescriptive values is an acceptable alternative method. For above grade and below grade walls, the following prescriptive U-factors may be utilized (see Tables 6-1 and 6-2).

Table 6-1

Zone 1 Prescriptive Requirements

	R-Value Required	Acceptable U-Factor
Above Grade Wall, option I only	15	0.081
Above Grade Wall, other options	21	0.060
Below Grade, exterior, continuous	10	0.056
Below Grade, interior, in stud cavity	21	0.037

Table 6-2

Zone 2 Prescriptive Requirements

	R-Value Required	Acceptable U-Factor
Above Grade Wall, options I , VI , VII	21 Int.	0.054
Above Grade Wall, option V	19 + 5	0.044
Below Grade, exterior, continuous	10	0.050
Below Grade, interior, in stud cavity	21	0.037

Thermal Storage (Mass Value)

Thermal storage may improve overall building performance. Adding mass in ICF systems has been shown to improve annual performance of a building in certain conditions. Although thermal mass may have a benefit in its ability to store heat, prescriptive path R-values do not take thermal mass into account. R-values used to demonstrate code compliance is the tested “steady state” R-value without any increases for the potential benefit from thermal mass. “Effective” R-values commonly provided by manufacturers or vendors may not be used to demonstrate code compliance.

Moisture Control

The WSEC requires a one-perm or less vapor retarder in all walls. Although extruded polystyrene products typically meet this requirement, ICF construction does not guarantee compliance. Check manufacturer or vendor information to see if applying a one-perm vapor retarder, on the warm side (in winter), is needed.

How to Handle Non-Compliant Walls

If a building cannot meet the prescriptive requirements of the WSEC, the Component Performance approach may allow one element of the structure to be less efficient than what the code requires if the deficiency is compensated for in another area of the building. A home that has ICF walls with U-factors greater than allowed by the Prescriptive Path may comply with code using the Component Performance Approach worksheets. This web site link lets the user download the worksheets:

www.energy.wsu.edu/code/

Default U-Values

The following table (see Figure B-3) lists tested U-factors for common ICF products. Use “Total U-factor” values when using the Component Performance Approach for qualifying an ICF house. Total U-factor values include the effect of air films, wood exterior siding and half inch drywall sheathing.

Figure D-3

Common ICF Products*

Brand Name	Manufacturer	Wall Thickness	Insulation Type ¹	R-Value ²	U-Factor ³
Blue Maxx	AFM Building Corp.	11.25"	EPS	R-21	.043
Diamond SnapForm	AFM Corp.	8"	EPS	R-19	.048
Durisol	Durisol Bldg Systems	12"	No foam inserts	R-9.13	.109
Durisol	Durisol Bldg Systems	12"	3.5" foam inserts	R-21	.048
Feather Lite	Feather Lite, Inc.	Varies	--	R-22	.042
Fold-Form	Lite Form, Inc.	8"	EPS	R-19	.048
GreenBlock	Greenblock Worldwide	9.87"	EPS	R-18	.049
Ice Block	Foam Block	9.25"	EPS	R-12	.070
Lite Form	Lite Form, Inc.	8"	XPS	R-21	.043
Polysteel Form	American Polysteel Forms	9.25"	EPS	R-12	.070
Quad-Lock	Quad Lock Bldg Systems	8.125"	EPS	R-21	.044
R-Forms	R-Forms	8"	XPS	R-21	.043
Rastra	Rastra	8"	EXP	R-8	.1134
Rastra	Rastra	12"	EPS	R-15	.0654
Rastra	Rastra	14"	EXP	R-18	.0524
Reddi-Form	Reddi-Form	9.625"	EPS	R-21	.047
Reward Wall	Reward Wall	9.25"	EPS	R-19	.048
ThermoFormed	ThermoFormed Block Corp.	8"	EPS	R-16	.055
Therm-O-Wall	Therm-O-Wall	9.125"	EPS	R-15	.058

*This list may not include all ICF products available. Refer to manufacturers tested R-values and U-factors for compliance with code requirements. Information courtesy Oregon Department of Energy Pamphlet #20.

¹ EPS Expanded Polystyrene; XPS Extruded Polystyrene.

² R-values are for ICF only – not total wall assembly.

³ U-factors are for total wall assembly.

⁴ Assumes stucco finish exterior and interior.

Supplement E

Permeance Values for Common Building Materials*

Materials	Permeance
Polyethylene (4 mil)	0.08
Latex Primer/Sealer	6.28 (1 coat = 0.0012")
Vapor Retarder Paint	0.45 (1 coat = 0.0031")
<hr/>	
Polyvinyl Acetate Latex (PVA)	5.5 (3 coatings – 4 oz/sf)
Vinyl Acrylic Primer Latex	8.62 (1 coat = 0.0016")
Kraft Paper (Asphalt Impregnated)	0.03
15 lb Asphalt Felt Paper	1.0
<hr/>	
Gypsum Wall Board (3/8")	50
Plywood (1/4" w/exterior glue)	0.7

The Washington State Energy Code requires vapor retarders have a permeance rating (dry cup) of 1.0 or less. Section 502.1.6.1

*2005 ASHRAE Fundamentals Handbook. See Section 25.17, Table 9 for more details.

Materials must be applied in accordance with manufacturer's instructions to achieve specified permeance ratings.

This table permits comparisons of materials: but in the selection of vapor retarder materials, exact values for permeance or permeability should be obtained from the manufacturer or from laboratory tests.

Supplement F

Common Duct Insulation Materials

We have received questions through the WSEC Hotline about different types and thicknesses of duct insulation and there appears to be some confusion about Table 5-11 of the Washington State Energy Code which lists the minimum densities, out-of-packages thickness and R-values for different types of duct insulation. The above table shows what the R-values are for varying thicknesses and types of duct insulation in a better layout than Table 5-11. The table also lists the ASTM and UL.

Table F-1

R-Values for Common Duct Insulation Materials

Installed R-Value ¹ (h.oF ft ²)/Btu	Typical Material meeting or exceeding the given R-value ²
1.9	1/2 in. Mineral fiber duct liner per ASTM C 1071, Type I
	1 in. Mineral fiber duct wrap per ASTM C 1290
3.5	1 in. Mineral fiber duct liner per ASTM C 1071, Types I & II
	1 in. Mineral fiber board per ASTM C 612, Types I & IB
	1 in. Mineral fiber duct board per UL 181
	1 1/2 in. Mineral fiber duct wrap per ASTM C 1290
	1 in. Insulated flex duct per UL 181
6.0	1 1/2 in. Mineral fiber duct liner per ASTM C 1071
	1 1/2 in. Mineral fiber duct board per UL 181
	1 1/2 in. Mineral fiber board per ASTM C 612, Types IA & IB
	2 in., 2 lb/ft ³ Mineral fiber duct wrap per ASTM C 1290
	2 1/2 in., .6 to 1 lb/ft ³ Mineral fiber duct wrap per ASTM C 1290
	2 1/2 in. Insulated flex duct per UL 181
8.0	2 in Mineral fiber duct liner per ASTM C 1071, Types I & II
	2 in. Mineral fiber Duct board per UL 181
	2 in. Mineral fiber board per ASTM C 612, Types 612, Types II & IB
	3 in. 3/4 lb/ft ³ Mineral fiber duct wrap insulation per ASTM C 1290
	3 in. Insulated flex duct per UL 181
10.0	2 1/2 in. Mineral fiber board per ASTM C 612, Types IA & IB

¹ Listed R-values are for the insulation only as determined in accordance with ASTM C 518 at a mean temperature of 75oF at the installed thickness and do not include air film resistance.

² Consult with manufacturers for other materials or combinations of insulation thickness or density meeting the required R-value¹.

• This table is from the User's Manual for ANSI/ASHRAE/IESNA Standard 90.1-2004, p 6-29.2

Duct Insulation Requirements

The Washington State Energy Code requires residential ducts be insulated per Table 5-11 Chapter 5, page 26.

Table F-2

Duct Insulation
(Table 5-11 WSEC Chapter 5)

Duct Location	Climate Zone	Group R Occupancy Heating or Cooling Ducts
On roof or on exterior of building	1	E and W
	2	D and W
Attic, garage, crawl space, in walls ¹ , in floor/ceiling ¹	1	E
	2	E
Within the conditioned space or in heated basements		None Required
In cement slab or in ground		B

Note: Where ducts are used for both heating and cooling, the minimum insulation shall be as required for the most restrictive condition.

¹ Insulation may be omitted on that portion of a duct which is located within a wall or floor/ceiling space where both sides of this space are exposed to conditioned air and where this space is not ventilated or otherwise exposed to unconditioned air.

² Vapor barriers shall be installed on conditioned air supply ducts in geographic areas where the average of the July, August and September mean dewpoint temperature exceeds 60°F.

INSULATION TYPES: Minimum densities and out-of-package thickness.

- A. 0.5-inch 1.5 to 2 lb/cu. ft. duct liner, mineral or glass fiber blanket or equivalent to provide an installed total thermal resistance of at least R-2.
- B. 2-inch 0.60 lb/cu. ft. mineral or glass fiber blanket, 1.5-inch 1.5 to 2 lb/cu. ft. duct liner, mineral or glass fiber blanket. 1.5-inch 3 to 7 lb/cu. ft. mineral or glass fiber board or equivalent to provide an installed total thermal resistance of at least R-5.
- C. 3-inch 0.60 lb/cu. ft. mineral or glass fiber blanket, 2-inch 1.5 to 2 lb/cu. ft. duct liner, mineral or glass fiber blanket. 2-inch 3 to 7 lb/cu. ft. mineral or glass fiber board or equivalent to provide an installed total thermal resistance of at least R-7.
- D. 4-inch 0.60 lb/cu. ft. mineral or glass fiber blanket, 3-inch 1.5 to 2 lb/cu. ft. duct liner, mineral or glass fiber blanket. 3-inch 3 to 7 lb/cu. ft. mineral or glass fiber board or equivalent to provide an installed total thermal resistance of at least R-10.
- E. 3.5-inch 0.60 lb/cu. ft. mineral or glass fiber blanket, 2.5-inch 1.5 to 2 lb/cu. ft. duct liner, mineral or glass fiber board or equivalent to provide an installed total thermal resistance of at least R-8.
- V. Vapor barrier, with perm rating not greater than 0.5 perm, all joints sealed.
- W. Approved weatherproof barrier.

Supplement G

Inspecting Attic Insulation

There are several factors to consider when inspecting loose fill, blown-in attic insulation. These include the type, depth and density of the insulation.

Types of blown-in insulation

The two commonly used types of blown-in attic insulation are cellulose and fiberglass. Blown-in rock wool insulation is also available but its use in the Pacific Northwest is not common.

Cellulose is a natural wood product and is made primarily from recycled newspaper.

A fire retardant chemical is added to meet flame-spread and smoke-development requirements of today's building codes. Fiberglass insulation is the same type of material that is in batts or rolls of fiberglass insulation except it is chopped or cubed so that it can be installed with an insulation blowing machine. Fiber glass insulation typically contains 20% to 30% recycled glass¹.

The R-value of loose fill cellulose is R-3.2 to 3.8 per inch². Loose fill fiberglass has an R-value of R-2.2 to 2.7 per inch³. Achieving the desired R-value depends on both the depth of the insulation and its density.

Insulation depth

Depending on your climate, energy codes require varying R-values for ceiling insulation. Code requirements may also vary for attics and single rafter or joist vaulted roof assemblies. The Washington State Energy Code (WSEC) requires that all attics be insulated to R-38 in both Climate Zones 1 and 2. Using the known R-values per inch of each type of insulation, we know that to install R-38 you need

¹ Percentages of recycled content from USDOE, EERE

² R-values obtained from Cellulose Insulation Manufacturers Association

³ Loose fill fiberglass R-values from USDOE, EERE

from 10" to 12" of cellulose and 14" to 17" of fiberglass. For an accurate depth for a given type of insulation there is a chart on the insulation bag noting the required depths for various R-values.

To assist an inspector and the installer in verifying the depth of the insulation, the WSEC requires that depth markers (see Figure G-1) be placed in the attic space. The depth markers must be installed for every three hundred square feet of attic area and must face toward the attic access.

Insulation density

Checking the depth of the insulation is essential but the density of the insulation is equally important. Blown-in insulation can be "fluffed up" when installed so that it appears to meet the depth requirement without achieving the desired R-value. Over time the insulation may settle, resulting in a lower R-value.

The easiest way to document the amount and R-value of installed blown-in insulation is to install an attic card. These are usually stapled to the truss or rafter near the attic access. The card should contain the following information cited by the Federal Trade Commission.

If you are an installer, you must give your customers a contract or receipt for the insulation you install. For loose-fill, the receipt must show the coverage area, initial installed thickness, minimum settled thickness, R-value, and the number of bags used.⁴

The following table (Table G-1) is a chart for Owens Corning ThermaCube Plus® blown-in fiberglass insulation.



*Figure G-1
Insulation depth marker*

⁴ Code of Federal Regulations (CFR) 460.17

Table G-1

Attic/Ceiling Guidelines

R-Value	Minimum Bags/1,000 Sq. Ft	Maximum coverage/Bag (Net Sq. Ft.)	Minimum Weight/Sq.Ft. (lbs)	Minimum thickness (inches)
R-49	25.0	40	0.878	19.50
R-44	22.2	45	0.786	17.75
R-38	19.2	52	0.676	15.50
R-30	15.2	66	0.531	12.25
R-26	13.2	76	0.459	10.75
R-22	11.1	90	0.388	9.25
R-19	9.5	105	0.334	8.00
R-11	5.5	182	0.193	4.75

Manufacturers provide similar charts on their insulation bags. The chart states the minimum number of bags that need to be installed per 1000 square feet of area to obtain a specific R-value. For example, to install R-38 in an attic with 3200 square feet of area use the following formula:

$$3200 \text{ ft}^2 \div 1000 = 3.2$$

$$19.2 \text{ (bags per } 1000 \text{ ft}^2 \text{ for R-38)} \times 3.2 = 61.4 \text{ bags}$$

Building inspectors typically check the insulation depth to verify compliance with local codes. Making sure the correct amount of insulation is installed requires a bag count, or a comparison with the recommendations on an attic card.

